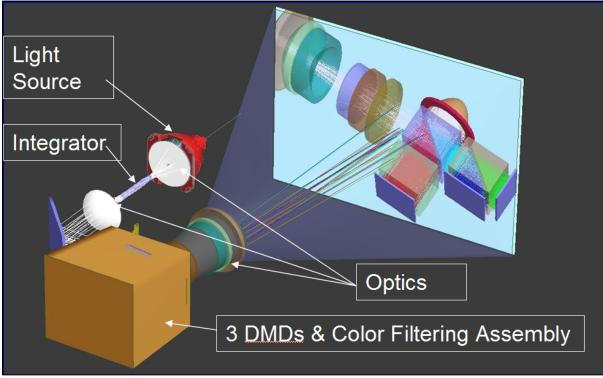
FRED User Manual



Revision 6.100 September 14, 2007

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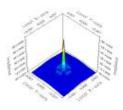
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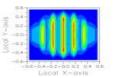
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Chapter 1 – Introduction

Introduction to the FRED Reference Manual

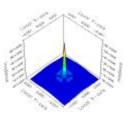


If you are like many computer users, you have opened this reference manual as a last resort and under duress. You don't have the time or the inclination to read an entire manual before you see results. We have made an effort to organize this manual to mediate gratification while being both complete



provide immediate gratification while being both complete and informative.

What is FRED?



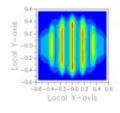
FRED is an optical engineering software package designed to analyze optical systems including mechanical structures using nonsequential, sequential, and coherent raytracing. FRED has a point and click graphical user interface for building geometry and performing analysis that is both powerful and intuitive. FRED can analyze a wide range of optical phenomena including straylight, scatter, illumination, imaging quality, coherent propagation, irradiance, intensity,

polarization, and much more. FRED also has excellent graphics that facilitates visualizing the optical system.



How do you get started?

One of the best ways to learn how to use FRED is to go through the tutorials There are several tutorials offered on different topics. We recommend that new users start with the Test Flight document and then work through the 7 step by step tutorial in the hyper-text help in FRED under the Help Menu.



This help file is still under construction. In addition, not all of the commands have been documented. If you are not able to find what you need in the help files, please **call or email** us regarding any questions or problems you have.



Additional Information

Though optical technology is discussed in general terms, this manual is not a primer in optical technology. A list of **excellent books and papers on various optical topics is provided** in the reference section in this manual.

Help Manual Overview

This help file has been organized into 31 chapters.

The quality of this help manual will be enhanced with feedback from users. We would like to hear or read any suggestions you have for content, organization, or style. Please email support@photonengr.com with suggestions.

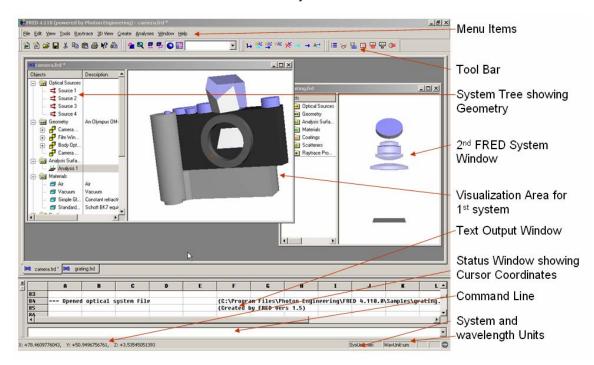
Document View Architecture

The **FRED** graphical user interface (GUI) is very similar to most Windows programs, but it has been tailored to the needs of optical design and analysis. A **FRED** document can be considered as a stand-alone optical system consisting of at least one or more of the following seven major object types:

- **Optical sources** Objects that describe the wavelengths, positions, angles, wavelength apodization (weighting), position apodization, angle apodization, coherence, and flux of rays to be created. Note that sources are NOT rays, they are only the definitions of the ray starting points and directions.
- **Geometry** Objects that describe elements that are made of surfaces and curves. This includes optical as well as mechanical geometry.
- Analysis surfaces Objects that allow the analysis of ray positions, directions, irradiance, and intensity. These can be placed on any surface in the optical system.
- **Materials** Objects that are assigned to surfaces to describe the complex refractive index (n-ik) properties of the surfaces using the geometry and coatings.
- **Coatings** Objects that are assigned to surfaces to describe the reflection, transmission, and absorption characteristics of the surfaces. These can be entered as coefficients or as thin film coating layers. The coatings allow **FRED** to maintain correct radiometry through a raytrace.
- **Scatterers** Objects that are assigned to surfaces to describe the scatter properties of a surface.
- **Raytrace Properties** Objects that are assigned to surfaces to describe whether reflected and/or transmitted rays are traced from the surface. These objects also control how many ray splits are allowed (children) for a given parent ray.

The **FRED** user interface comes complete with menus, toolbars, system tree, visualization view, text output window, status line, and command line. The user interface has standard Windows Menu items at the top of the **FRED** document interface that features drop down lists when selected. This Menu list includes all of **FRED's** functionality with the Tools, Raytrace, 3D View, Create, and Analyses menus.

The Toolbar features many standard Windows icon buttons to open documents, cut-andpaste folder operations, undo/redo functions, and more. The toolbar is customizable and, besides including many standard **FRED** functions for raytrace, analyses and viewing, can be customized to add or delete icons for almost every **FRED** menu item.



The visualization area is the main viewing area to verify geometry generation. This area can be set to view two-axis profiles, X-Y, X-Z, Y-Z or any combination of these two axes, or arbitrary views from any 3D direction. It is also possible to use the trackball to manipulate any view or directly input viewing coordinates into the Tools \rightarrow Preference \rightarrow Visualization menu dialog.

The text output area can be selected to be either spreadsheet-like with cells containing output information, or similar in functionality to a notepad where output results are simply shown in text format. The preference for spreadsheet or notepad-like is set in the View \rightarrow Output Window \rightarrow Cells menu.

The status window is menu-specific and can show everything from cursor coordinates detailing where the cursor is on the visualization window when active to showing the function selected when using menu or tool bar items. The status window also shows the system and wavelength units in the bottom right hand corner. Finally the command line can be used to directly enter enhanced **FRED** basic script commands.

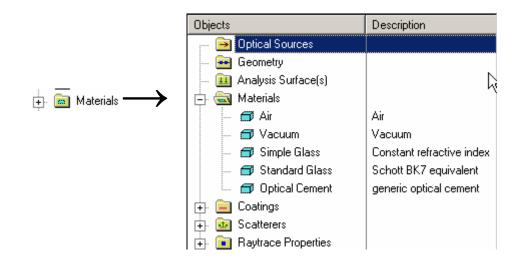
Each **FRED** document has a system tree which provides a hierarchal organization of the **FRED** document and contains the 7 folders of information specific to each document: Geometry, Analysis surfaces, Materials, Coatings, Scatterers, and Raytrace Properties. A node in the system tree view refers to one of these folders and consists of an icon, title, and a description as shown below.

🕅 FRED1 *	
Objects	Description
🖻 Optic Sources	
🚘 Geometry	
🏨 Analysis Surface(s)	
🕂 🛅 Materials	
🕂 🧮 Coatings	
🕂 🚾 Scatterers	
🕂 间 Raytrace Properties	
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Defining Objects

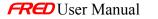
To define or enter objects, such as a lens or mirror, in **FRED**, you **right** click on the appropriate node in the system tree. This will bring up a menu of actions; choosing to enter a new object will then bring up a dialog box in which you enter the parameters for the object to be entered. As you enter the parameters, you can click Apply to see how the object is being created before you enter other parameters. You click on OK to finalize the entering of the object.

When an object is entered into a **FRED** document, it is listed under the appropriate node. A node with objects can be expanded to show the objects or collapsed to hide the objects, similar to the Windows Explorer. A collapsed node has a \textcircled symbol in front of the node and an expanded node has a \boxdot symbol in front of the node. To expand or collapse a node, **left** mouse click on the \textcircled or \boxdot symbols respectively. For example, expanding the Materials node will show all the materials currently in the document. The materials shown below are in all **FRED** documents by default.



To create a lens element is a simple process. First, right mouse click on the Geometry Folder in the system tree to have the geometry creation menu appear. Then select the "Create News Lens" menu option to have the "Create a New Lens Dialogue" appear. Accept the default lens information by Left mouse clicking on the OK button to create the lens as shown in Y-Z profile below. Notice that if you click on the + sign in front of the lens node, the system shows that the lens is comprised of three surfaces, the front, back and edge of the lens. So a lens primitive in FRED creates a solid with all three surfaces automatically created to define a complete solid bounded object.

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Surface 2	Avially Symmetric Conicoid Surface							
- JEdge	Bilaterally Symmetric Tubular Surface							
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Objects (curves, surfaces, lens, prisms, mirrors, custom elements, and subassemblies) in **FRED** are located by default at the global origin in the Y-Z plane. After making a surface, custom element, lens, mirror, prism or subassembly you can move this object by right mouse clicking on the object in the geometry folder, and then selecting the option to position the object. Objects can be positioned in global space, or in reference to any other positioned object. This is particularly useful if you only know the distance of this object in reference to another object which is often the case in optical designs. Most objects often have a specific tab on the Edit dialogue which allows them to be defined directly or can be modified directly in their creation dialogue. Please note that it is best to group curves and surfaces together into custom elements and subassemblies and position all of these objects at one time by defining the correct position on the custom element or subassembly. Shown below is the lens creation dialogue showing the many reference coordinates available to position a lens.

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Name:	Lens 1	Close
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	Reference Coordinate Action Parameters (right mouse-click for popup menu)	
0	Starting Coordinate System Geometry ()	
	Global coordinate system Self System (System) Optical Sources () Geometry () Geometry.Lens 1.Surface 1 (Axially Symmetric Conicoid Surface) Geometry.Lens 1.Surface 2 (Axially Symmetric Conicoid Surface) Geometry.Lens 1.Edge (Bilaterally Symmetric Tubular Surface) Analysis Surface(s) ()	
		▶
	Properties (computed from the basic parameters entered above) 51.11234085744 Front Prin: -5.804953172{ Wavlen(um): 0.5875618 Back Prin: -5.804953172{ YEdge Thick: 1 Update	

After selecting the reference coordinate system you can then right mouse click on the 0 reference coordinate and append a change to the position by selecting the append modification, selecting the reference coordinated action and the shift, rotation or change to the position of the object as shown below.

Parent:	Geometry	OK
Name:	Lens 1	Cancel
Description	on:	Apply
		Help
Paramet Radii	arameters eter Type: Front Radius: Back Radius: Thick 3 3 1 perture Specification i-ape: Y Semi-ape: Catalog: 1 Standard Glass Current Advanced Settings	ness: Select: Glass
Location	n of the Lens (at front surface vertex) (right mouse-click for pop-up menu) Reference Coordinate Action Parameters (right mouse-clic	
	Reference Coordinate Action Parameters (right mouse-clic Starting Coordinate System	k for popup menu)
0	Global coordinate system	▼
	X Y Z	Cut
1	Global coordinate syst Shift 0 0 5	Сору
		Paste Delete
		Insert
1		
	Properties (computed from the basic parameters entered above) 51.11234085744 Front Prin: -5.804953172{ Wavlen(um): 0.5875618	T
1 1		
Bend: 0	0 Back Prin: 5.804953172{ YEdge Thick: 1	Update

The hierarchy of the geometry building in *FRED* works as follows:

The Geometry Folder can contain:

Subassemblies

Elements

Lens – Dynamic, know how to create and maintain themselves

 $\ensuremath{\mathsf{Mirror}}$ – Dynamic, know how to create and maintain themselves

Prism – Dynamic, know how to create and maintain themselves

Custom Element – static they defined by the user, contain user defined surfaces and curves

A Subassembly can also contain:

Other Subassemblies

Elements (Mirrors, Lenses, Prisms or Custom types)

An Element can contain:

Surfaces – created directly or used as trimming surfaces (implicit surfaces)

Curves – used to create explicit surfaces by extrusion, revolution or ruling, or to be used as a trimming curve

A Surface can contain:

Curves – used to create explicit surfaces by extrusion, revolution or ruling, or to be used as a trimming curve

The figure below is an excellent example of the geometry hierarchy with subassemblies, elements, surfaces and curves called out under the geometry folder.

jects	Description	
🔁 Optical Sources		
Geometry		Maksutov Subassembly
B maksutov A corrector		
- front	Sth order aspheric	Corrector Custom Element
- d back	an order asphenic solvedcal	
Edge	Blaterally Symmetric Tubular Surface	Static Surfaces
Bevel 1	Planar Surface	Princers Demonstral and Element
primary	1.0.0 00.000	Primary Dynamic Lens Element
- B Reflecting Surfac	e 🚽 Auchy Symmetric Contestid Surface	Dynamic Mirror Surfaces
- A Back Surface	Avially Symmetric Conicoid Surface	
- S Edge	Blaterally Symmetric Tubular Surface	Secondary Dynamic Mirror Element
- & Hole	Blaterally Symmetric Tubular Surface	
Isecondary		Baffles Custom Element
e baffes		
- 🧳 telescope tube in	side 🚄	Static Baffle Surfaces
- 🦨 telescope tube	and shall be a second	
- 🧳 primary baffle	b t	Structure Subassembly
🚽 🥒 secondary baffie		
🖻 🗗 structure		Primary Mount Custom Element
Primary mount		X-Section Curve
- C x section		A-Section Curve
- 🧳 revolved 🚽		Revolved Surface
 Prism mount Prism mount 		Revolved Surface
- Prem mourt		Prism 1 Dynamic Prism Element
- 2 prism mount		
- prism mount		Secondary Strut Custom Elemen
C knob 1	-	
focus knob	2	Sputter Subassembly
- A focus knob		
knob 2		Eyepiece Subassembly
Prism 1		
💿 🔐 secondary moun		
spotter		



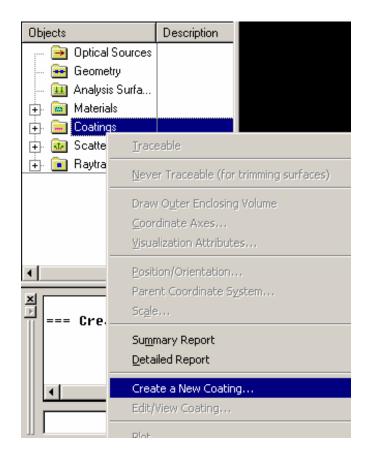
All of the commands in *FRED* are available through a <u>left</u> mouse button click on the appropriate menu item,

Eile Edit View Tools Raytrace 3D View Create Analyses Window Help

a left mouse click on the appropriate toolbar item,

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]] 1→ 🕮 🎬 🏁 🔀 → → #ł At 🕂 🕂 📗 🖪 🕐 🗙 ● 🔮	- ● 15 15 16 入入入入入入入入入入
🗀 😸 🤮 🖓 📟 🜚 ൙ 🗶 🍬 🖻 🎾 🎨 🕅 🖄 🙏 🕫 🐙	ऽ द द! । ऽ ⊾ ₽ ₽ ₽ ₽ व व थ ः ऽ ि ₩

or a *right* mouse click on the appropriate node in the system tree view.



Generally, if you want to perform an action with the information in a **FRED** document, you do so with either a menu item or toolbar item. If you want to add or change an object in the **FRED** document, then **right** click on the appropriate node of the system tree and make a selection in the pop-up menu.

The Output Window and the Command Line

The results of actions taken with the information in a *FRED* document are listed in the output window. For example, if a raytrace is performed then the results of the raytrace are listed in the output window (as shown below). In addition, the coordinates of the cursor in the visualization window are shown below the output window and command line.

RAYTRACE SUMMARY:	(cassegrain)
243	Num rays at start
243	Num rays at end
176	Num rays traced
724	Num ray-surface intersections
8.1 msec	Elapsed ray trace time
70	Num rays halted due to no more intersections found
•	-

The output window is actually a spreadsheet. The view of the output window can be toggled between a plain text format (Notepad-like) or a spreadsheet format with cells similar to Excel in the View menu (View \rightarrow Output Window \rightarrow Cells).

	<u>F</u> ile <u>E</u> dit	<u>V</u> iew	<u>T</u> ools	<u>R</u> aytrace	<u>3</u> D	Vie	w	⊆rea	te	<u>A</u> nal	yses	Y	<u>V</u> inc
I	16 16 -	I	oolbars	;		5	!?	9	۵. آ	b 🕑	r	6	
H			įtatus B	lar		Ĕ.	•-	- 10	-		· [].	1	
I	1→ ³⁶ ×	g	2utput V	Window	≯	~	⊻ie	w				- 3	P.
Î	:= I	Q	alculat	or			⊆e	lls					Ť
ļ] -		s nu	9	1		Cļe	ear O	onte	ents		1	Δ.

	A B	C D E F
47	RAYTRACE SUMMARY	<u>':</u> (cassegrai
48		
49	243	Num rays at start
50	243	Num rays at end
51	176	Num rays traced
52	724	Num ray-surface intersections
53	8.1 msec	Elapsed ray trace time
 1000 		

Show or hide the output window grid cells

Commands can be typed in manually on the command line. Presently, any of the enhanced BASIC scripting commands can be entered into the command line; multiple commands on the same line are separated by colons.

You can change the color of text, numbers, and formulae in the output window in the format page of the preferences dialog (Tools \rightarrow Preferences \rightarrow Format). This format page handles both the output window and the script editor so you need to select the output window as the category before you can change the output window colors.

🔆 Preferences	×
Warnings Miscellaneous Output Window Visualizatio	Miscellaneous 2 File Locations n Format Units of Measurement
Category: Script Editor Window Text Output Window	Eont: <u>S</u> ize: Fixedsys ♥ 9 ♥ Colors Text Language Keywords Comments Built-In Functions Identifiers
<u>R</u> eset <u>Reset All</u> <u>Script Editor Window</u> Iab size 4	Foreground Color:
 Keep Tabs Insert Space 	Sample AaBbCcXxYyZz
	OK Cancel Help

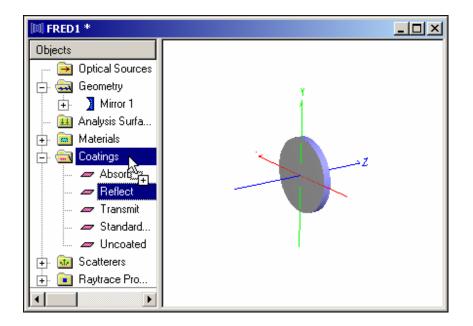
Copy-and-Paste

Most objects in FRED including geometry objects, materials, coatings, and optical sources can be copied and pasted using the copy command, (Ctrl+C) and paste command, (Ctrl+V). The exception to this is the output window, which is actually a spreadsheet. For operations inside the output window, use the output window commands, which are print, cut (Shift+Ctrl+X), copy (Shift+Ctrl+C), and paste (Shift+Ctrl+V) respectively. If you want to copy a raytrace result from the output window into a dialog box text window, then you use , (Shift+Ctrl+C), to copy out of the output window spreadsheet and (Ctrl+V), to paste into the dialog box text window.





A quicker alternative to copy-and-paste is drag-and-drop. All **FRED** geometry objects, materials, coatings, and sources can be dragged and dropped to make copies. To make copies with drag-and-drop, simply **left** mouse click on the object to be copied and while pressing the Ctrl key and holding the left mouse button down, drag the object to another node in the same section of the system tree and release the mouse key and then the Ctrl key. When you press the Ctrl key, you will get a "+" next to the cursor, indicating a copy is being made.



To move an object with drag-and-drop, *left* mouse click on the object to be moved and drag the object to another location in the same section of the system tree.

In the case of materials and coatings, they can be dragged and dropped onto geometry objects to apply them to geometry objects. You do not need to hold down keys to apply a material or coating using the drag-and-drop method.

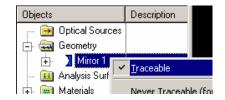
Visualization

The visualization window can be zoomed, translated, rotated, etc., using the visualization window toolbar controls.



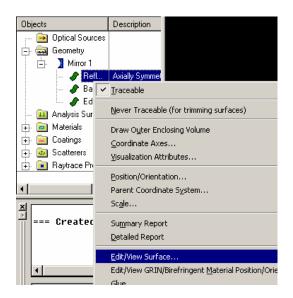
The trackball option, \bigcirc , allows the user to spin the objects about a fixed point. The default fixed point is the global origin. The fixed point can be changed to any surface in the *FRED* document by placing the cursor over the object, pressing the Ctrl key, and left mouse clicking on the object. You may have to turn off other objects to get a clear view of the object you wish to make the center of the rotation.

If you want something to be visible in the visualization window (and raytraced), then the object must have the Traceable toggle switch turned on. This option is available in the right mouse click pop-up menu. When entering a new item in the geometry, the default is to be traceable.



When you left mouse click on a geometry or source object in the **FRED** tree view, then a bounding box around that object is traced out in **RED** in the visualization view. This helps you verify the proper item is selected.

The color, transparency, and surface drawing mode of an individual surface can be changed in the visualization page of the surface edit dialog. To display this dialog page, *right* mouse click on the surface you would like to edit, and choose "Edit/View Surface...".



From there, click on the Visualization tab, shown on the next page.

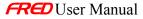


(FRED1 *) Crea	te a New Surface	as Child of: "Elem	1"		
SURFACE	· · · · · · · · · · · · · · · · · · ·	Location/Orientation	Materials	Coating/RayControl	OK
Scatter	Visualization	Glue	Grating	Auxiliary Data	Cancel
- Drawing Mode					
	h flat shading		wire frame		Apply
C Surface wit	h smooth shading	C Irregular	point sampling		Help
- Color Attributes				Tesselation(0=default)	
		Color scheme	Predefined List	Size Scale	
Wire Frame:	Amb	ient:	Default Sur 💌	X: 0 1	
Shine (0>128)	: 28 🛨 Diff	use:	< Assign	Y: 0 1	
Opacity (0>1.): 1 Spec	ular:		Z: 0 1	
– Coordinate Axe	s			Drawing Items	
Origin	Neg axis length	Pos axis length	Axis color	Draw coord axes	
X: 0	1.2	1.2			
Y: 0	1.2	1.2		🗖 Draw local trim	
7.0	1.2	1.2		•	
<u> </u>				Draw global trim	
 Absolute or Relative ori 	-	- protaction raise	es are expressed		
	yırı 🤨 Helative ler	igin jas nacion on	anning volume		

There are times when the rendering of an object is poor or non-existent because the object is fairly small compared to the Outer Trimming Volume. If an object is not rendering properly in the visualization window (and it is set as Traceable) then reducing the tessellation in the visualization page of the surface edit dialog will likely fix the problem (see the right hand side of the Visualization page).

The color, transparency, and surface drawing mode can be changed for all the objects highlighted in the tree with the Color Attributes dialog available in the pop-up menu from a *right* mouse click on any geometry node. When selecting a color for an object, be sure to click the Assign box before clicking OK.

(FRED1) Visualization /	Attributes	
Drawing Mode	C Flat shading C Irregular wire frame Smooth shading C Irregular point samplir	
Color Attributes ✓ Reset Color Wire Frame: Shine (0>128): 128	Color scheme Predefined Li Ambient: Default Sur	st
Copy Color Attributes		-
Randomize Color ☐ Randomize Color Tessellation Scale ☑ Scale tessellation by [(Typ. 0.1> 10.0)	0pacity (Translucency)))
OK Cance	el Apply Help	



FRED will allow multiple independent documents to be open at the same time. This makes it easy to compare and contrast systems and to copy-and-paste from one document to another. It should be noted that the objects and system raytrace information in any given open **FRED** document is independent of any other open **FRED** documents.

Both the drag-and-drop option and the copy-and-paste option can be done inside of one document or between multiple documents. If you apply a material or coating from one document to another document via a drag-and-drop, the material or coating is automatically added to the materials or coating node respectively and will be available inside the destination document for future use.

The GUI interface is discussed in more detail in the user interface section of the help files.



Chapter 2 - FRED Document Views

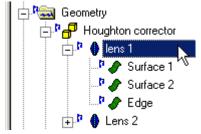
Topics and Examples

This section has examples and topics that explain the FRED document views including the **Tree View** and the **Visualization Window**.

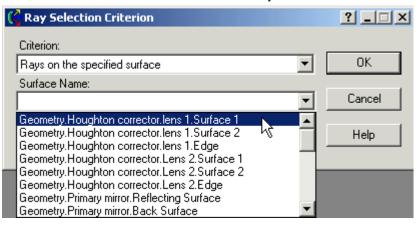
Hierarchy Naming Convention

Hierarchy Naming Convention

The graphical representation of FRED <u>document</u> data hierarchy is shown in the <u>Tree</u> <u>View</u>. The graphical nature of the Tree View makes the organization of the data clear. In the example below, Surface 1, Surface 2, and the Edge are child <u>nodes</u> of <u>element</u> Lens 1. The <u>subassembly</u> called Houghton Corrector is the parent node of elements Lens 1 and Lens 2. And the Geometry node is the parent node of the Houghton Corrector.



The textual representation of the data hierarchy is also easy to understand but not quite as transparent. Parent child node relationships are denoted with a ".", for example see how Surface 1 of element Lens 1 is denoted in the Ray Selection Criterion dialog example below.





Chapter 3 – Creating and Editing Simple Sources

Create Simplified Source...

Description - Create Simplified Source...

There are two options for creating new sources from scratch in FRED: the Create Detailed Source... dialog and the Create Simplified Source... dialog. The Create Detailed Source... dialog provides all the available source options and the Create Simplified Source... dialog provides simpler user interface for generating commonly used sources. A source created with the Create Simplified Source... dialog can edited with either the Edit / View Simplified Source... dialog or the Edit / View Detailed Source... dialog. If a source created with the Create Simplified Source... dialog is edited with the Edit / View Detailed Source... dialog, it may no longer be possible to edit it with the Edit / View Simplified Source... dialog depending on what source attributes that were changed in the Edit / View Detailed Source... dialog.

As stated above, the Create Simplified Source... dialog allows the user to quickly create common source types with a relatively small number of user inputs. The following sources can be created with the Create Simplified Source... dialog:

- <u>Detailed Optical Source (arbitrary user defined source)</u> Note that Detailed Optical Source ray locations and directions cannot be edited with the Simplified Optical Source dialog.
- <u>Collimated Source (Plane wave)</u>
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

The Create Simplified Source... command will then set all the detailed source attributes to generate the selected source type.

How Do I Get There? - Create Simplified Source...

Right click on the Optical Sources and select Create New Simplified Optical Source... in the right click pop-up menu,



Objects	
👘 🧰 🖻 Optical S	ources
🕂 📻 Geometri	✓ <u>I</u> raceable
🏛 Analysis	
🕂 🧰 Materials	Never Traceable (for trimming surfaces)
🕂 🧰 Coatings	Draw Outer Enclosing Volume
🕂 🔬 Scatterei	Coordinate Axes
🕂 💼 Raytrace	– Visualization Attributes
	Position/Orientation
	Parent Coordinate System
	Sc <u>a</u> le
	Summary Report
	Detailed Report
X F	
볼 === Creat	Create New Simplified Optical Source
	Create New Detailed Optical Source
	Edit/View GRIN/Birefringent Material Position

Dialog Box and Controls -Create Simplified Source...

🔆 (FRED	01) Crea	te a New Source				? _ 🗆 X
Logical f	Parent:	Optical Sources				OK
Name:		Source 1				Cancel
Descript	ion:					Apply
						Help
)				
Туре:	Collima	ted source (plane way	/e)	•	Power: 1	
	Value	Description		_	Coherence and P	olarization
Xinum	11	Number of ray	s across th	e full X aperture	Coherent	
Ynum	11	Number of ray	s across th	e full Y aperture		
X semi	0.5	X semi-apertur	e of the col	limated beam		
Y semi	0.5	Y semi-apertur	re of the col	limated beam	Polarized	
Shape	Elliptical	Cross section	shape of th	e beam	0 <ellipticity<1< td=""><td>: 0</td></ellipticity<1<>	: 0
X dir	0	X-axis compor	ient of the p	ropagation direction —	Angle (deg):	90
Y dir	0	Y-axis compor	nent of the p	propagation direction 🚽	Hingio (dog).	100
_ ⊢Locati	on/Orien	tation			-Wavelength List-	
	Refe	rence Coordinate	Action	Parameters (rig	Wavien	s (um) Weigt
	Starti	ng Coordinate System	n		1 0.58756	18 🖵 1
0		al Sources ()			2	- 1
				F		

See Also - Create Simplified Source...

There are four source types available in the pull down menu in the Create Simplified Source... dialog. The four options are discussed separately.

Detailed Optical Source (arbitrary user defined source)

Collimated Source (Plane wave)

Point Source (Spherical wave)

Laser Beam (Gaussian 00 mode)

Diode Laser Beam (Astigmatic Gaussian)

Edit / View Simplified Source...

Description - Edit / View Simplified Source...

The Edit / View Simplified Source... dialog allows the user to quickly edit Simple Source types with a relatively small number of user inputs. Simple Sources are sources setup to model commonly used sources.

The following sources are options in the Edit / View Simplified Source... dialog:

- Detailed Optical Source (arbitrary user defined source)
- <u>Collimated Source (Plane wave)</u>
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

The Edit / View Simplified Source... command will then set all the detailed source attributes to generate the selected source type.

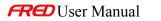
A Simple Source created with the Create Simplified Source... dialog can edited with either the Edit / View Simplified Source... dialog or the Edit / View Detailed Source... dialog. If a source created with the Create Simplified Source... dialog is edited with the Edit / View Detailed Source... dialog, it may no longer be possible to edit it with the Edit / View Simplified Source... dialog depending on what source attributes that were changed in the Edit / View Detailed Source... dialog.

How Do I Get There? - Edit / View Simplified Source...

Right click on the Optical Sources and select Edit / View New Simplified Optical Source... in the right click pop-up menu.

Objects	Description	
🖃 🔄 Optical Sourc	es	
💷 🚅 Source T 🕂 🧰 Geometry	✓ <u>T</u> raceable	
🛄 Analysis Surf	Never Traceable (for trimming surfaces)	
 ← Coatings ← Coatings ← Scatterers ← Coatings 	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes,	
	<u>P</u> osition/Orientation Parent Coordinate S <u>v</u> stem Sc <u>a</u> le	
	 ✗ Cut 健 Copy 健 Paste Delete (all highlighted items) 	Ctrl+X Ctrl+C Ctrl+V Del
	Summary Report Detailed Report	Dei
	Edit/View Simplified Optical Source	
	Edit/View GRIN/Birefringent Material Position/Orient	ation
	Edit/View Array Parameters Delete Array Parameters	

Dialog Box and Controls - Edit / View Simplified Source...



候 (newp	ort.frd) Edit Source					? <u> </u>
Logical F	Parent:	Optical Sources					OK
Name:		Source 1					Cancel
Descripti	on:						Apply
							Help
T	Calling	ted source (plane way)		_	Power: 1	
Туре:		d source (piane way d source (arbitrary use	<u> </u>	rcej	<u> </u>		Delecter
	Collima	ted source (plane way	e)	areej		Coherence and	Polarization
Xinum	Point se	ource (spherical wave)			Coherent	
Ynum		leam (Gaussian 00 mo					
X semi	LaserL	iode Beam (Astigmation)	e or the con	mateu peam			
Y semi	5	Y semi-apertu	re of the coll	imated beam		Polarized	
Shape	Elliptical	Cross section	shape of the	e beam		0 <ellipticity<< td=""><td>1: 0</td></ellipticity<<>	1: 0
X dir	0	X-axis compor	ent of the p	ropagation direction		Angle (deg):	90
Y dir	0	Y-axis compor	hent of the p	ropagation direction		Angie (deg).	100
_ Locatio	on/Orien	Itation				ength List	
	Refe	rence Coordinate	Action	Parameters (rig		Wavlens (um)	Veights Ray Co
	Start	ing Coordinate Syster	n		1	0.5875618 💌	1
0		al Sources ()			2		1
				Z			
1	Optic	al Sources () 🔻	Shift in Z c				
				•			

There are four source types available in the pull down menu in the **Edit / View Simplified Source...** dialog. The four options are discussed separately.

- Detailed Optical Source (arbitrary user defined source)
- <u>Collimated Source (Plane wave)</u>
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

See Also... Edit / View Simplified Source...

- Detailed Optical Source (arbitrary user defined source)
- <u>Collimated Source (Plane wave)</u>
- Point Source (Spherical wave)
- Laser Beam (Gaussian 00 mode)
- Diode Laser Beam (Astigmatic Gaussian)

Collimated Source (Plane Wave)

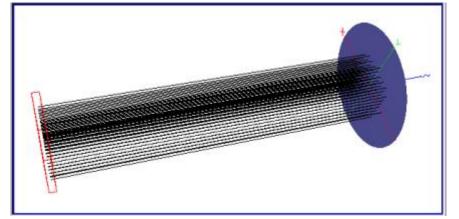
Description How Do I Get There? Dialog box and Controls See Also...

Description Collimated Source (Plane Wave)

The **Create Simplified Source...** dialog provides simple user interface for generating commonly used sources types. The **Collimated Source (Plane Wave)** option generates a grid of collimated rays.

	-			-			-	
	82	(0)	50		53	80		
22		ų.			33	2 0	34	611 • 12
3	32	3	58	3	22	t2	3	13
24	13	8	80		10	£5	8	80
S	5	3	53	63	32	53	8	33
23	23	55	53		33	(0)	9 7)	10
24	32	3	33	(\mathbf{x})	25	¥11	4	83
1	:	2	83		33	53	3	8
	$\mathbf{\hat{c}}$	24	63		23	$\overline{\mathbf{H}}$	ί÷.	

The figure above shows a grid of rays for a collimated source.



The grid of rays above traced to a plane.

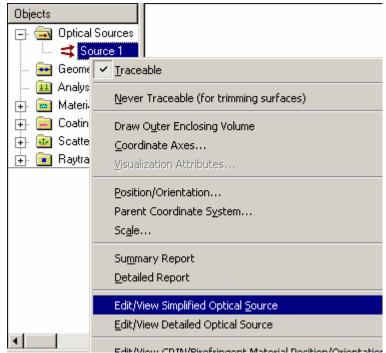
<u>How Do I Get There?</u> Collimated Source (Plane Wave)

There are two different ways to execute this command:

1. Right click on the **Optical Sources** and select **Create New Simplified Optical Source...** in the right click pop-up menu,

Objects	burces
Geometry Geometry Analysis Geometry Materials Geometry Geometry	✓ <u>T</u> raceable
	Never Traceable (for trimming surfaces)
	Draw O <u>u</u> ter Enclosing Volume Coordinate Axes
🕂 💼 Raytrace	Visualization Attributes
	Position/Orientation
	Parent Coordinate System Scale
×	Summary Report
	Detailed Report
=== Creat	Create New Simplified Optical Source
	Create New Simplified Optical Source Create New Detailed Optical Source Edit/View GRIN/Birefringent Material Positic

2. Right click on a **Sources** and select **Edit/View Simplified Optical Source...** in the right click pop-up menu,



In the Create New Simplified Optical Source... dialog, select the Collimated Source (Plane Wave) option.

Collimated source (plane wave)	oherence and Polarization -
Collimated source (plane wave)	
X semi Point source (spherical wave) X semi Laser Beam (Gaussian 00 mode) Laser Diode Beam (Astigmatic Gaussian) □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □	Coherent

Dialog Box and Controls Collimated Source (Plane Wave)

(houg	hton.frd) C	reate a New So	ource			? <u>- </u> ×
Logical Parent: Optical Sources					OK	
Name:	Sou	urce 1				Cancel
Descript	ion:					Apply
						Help
Туре:	Collimated s	ource (plane way	re)		Power: 1	
	Value	Description		<u> </u>		anzation
X semi	0.5	X semi-apertur			Coherent	
Y semi	0.5	Y semi-apertur				
Xinum	11			e full X aperture		
Ynum	11 515-451		Number of rays across the full Y aperture Cross section shape of the beam			<u> </u>
Shape X dir	Elliptical 📘		X-axis component of the propagation direction			0
∧ uir Ydir	0			ropagation direction	Angle (deg):	90
- Locati	on/Orientatio	n			Wavelength List	
Reference Coordinate Action Parameters (rig Wavlens (um) Weigt Starting Coordinate System 1 0.5875618 1 Optical Sources () 1 1 1 1						



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Parent:	Logical Parent for the Source listed here.	Optical Sources				
Name:	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source #				
Description:	A user description of the Source can be entered here.	blank				
Туре:	Type of the Simplified Source can be selected from this pull down menu.	Collimated Source				
X semi	X axis semi-aperture of the grid of rays in the collimated beam.	0.5				
Y semi	Y axis semi-aperture of the grid of rays in the collimated beam.	0.5				
X num	Number of rays across the full aperture of the collimated beam in the X direction.	11				
Y num	Number of rays across the full aperture of the collimated beam in the Y direction.	11				
Shape	Cross section of the beam.	Elliptical				
X dir	X direction cosine α.	0				
Y dir	Y direction cosine β.	0				
Z dir	Z direction cosine γ .	1				
Location/Orientation	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Sources				
Power	Total power of the Source.	1				
Coherence and Polarization						
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked				
Polarization	If checked, polarization data for the rays is maintained and stored.	Unchecked				
Ellipticity	Sets the ellipticity of the polarization state, 0 represents linear polarization and 1 represents circular.	0				
Angle	Sets the angle of the polarization relative to the X axis.	90				
Wavelength List						

Table	The wavelengths, weights, and rendered ray colors are set in this section.	0.5875618
ОК	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also...</u> Collimated Source (Plane Wave)

> Detailed Optical Source (arbitrary user defined source) Point Source (Spherical wave) Laser Beam (Gaussian 00 mode) Diode Laser Beam (Astigmatic Gaussian) Coherent Source Introduction

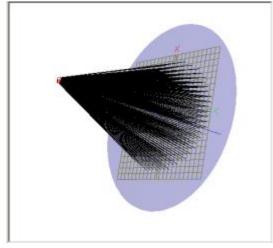
Diode Laser Beam (Astigmatic Gaussian)

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

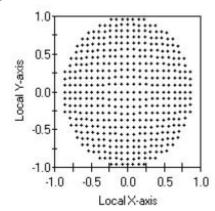
Description Diode Laser Beam (Astigmatic Gaussian)

The Create Simplified Source dialog provides simple user interface for generating commonly used sources types. The Diode Laser Beam (Astigmatic Gaussian) option generates a diverging set of rays that emanate from separate X & Y focii along the z-axis. The diverging set of rays is apodized so that the irradiance profile of the beam is gaussian.

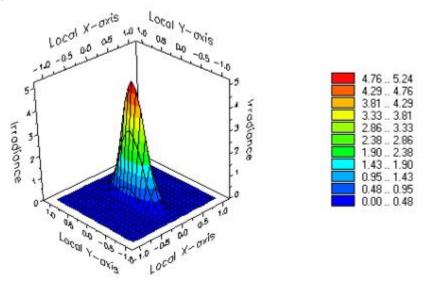


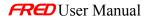


The Position Spot Diagram for this grid of rays looks much like a regular grid of diverging rays.



The Irradiance Spread Function however has a Gaussian profile with a different divergence angle in the X and Y directions. The Position Spot Diagram above and the Irradiance Spread Function below have the same extent in the X and Y.



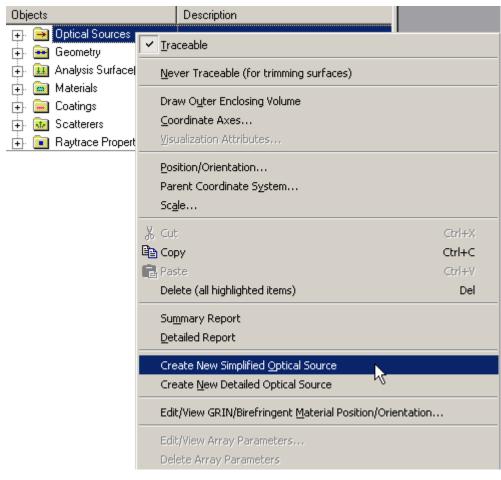


—

How Do I Get There? Diode Laser Beam (Astigmatic Gaussian)

Create a new Simplified Source by:

1. Right clicking on the Optical Sources and select Create New Simplified Optical Source.....



2.

Create Analyses Window	Help
New Simplified Source	Ctrl+Alt+I
New Detailed Source	K Ctrl+Alt+D
New Lens	Ctrl+Alt+L
New Mirror	Ctrl+Alt+M

3. Use the Accelerator Key - Ctrl+Alt+I

Dialog Box and Controls

Diode Laser Beam (Astigmatic Gaussian)

(CALCERTER (CALCERTER))))))))))	reate a N	New Source	? _ 🗆 🗙
Logical Parer	nt: Optica	al Sources	ОК
Name:	Sourc	xe 1	Cancel
Description:	i –		Applu
Description.			Apply
			Help
Type: Las	er Diode B	eam (Astigmatic Gaussian)	1
	Value		e and Polarization
Ang X	10	X divergence angle of full cone (degrees)	rent
Ang Y	10	Y divergence angle of full cone (degrees)	
Focii	0.01	Axial separation of the astigmatic focii (in system units)	zed
Create	0.2	Z-axis location for ray creation	0 < Ellipticity < 1
Wavelength	1	▼ Wavelength (micron) for computing Gaussian Beam param	
X samp Pts	11	# of beam sample points in X direction	Angle (deg)
	11		asured from local X axis)
Location/0	ientation –		
			nts Ray Color
	Starting Coordinate System		
	ptical Sou	rces ()	
		_	
Control	,	Inputs	Dofaulto
<u>Control</u>		<u>Inputs</u>	<u>Defaults</u>
			Optical
Logical Pa	arent:	Logical Parent for the Source is listed here.	÷
			Sources
		Name of the Source is listed here. The name	
Name:		can be of any alphanumeric text length.	Source <i>n</i>
D		User description of the Source can be typed	11 1
Descripti	on:	here.	

FRED User Manual

Type:

Ang X Ang Y Type of the Simplified Source can be selected

from this pull down menu. Choose **Laser**

Divergence full cone angle in the X and Y

Diode.

direction in degrees.

Collimated

Source

10

Focii	Axial separation between focii in the X- and the Y- directions.	10
Create	Plane in which the beam is synthesized from the grid of rays (see <u>App Notes</u> below for more detail).	0.2
X Sample Pts Y Sample Pts	Number of sample points in the X and Y directions across the beam.	11
Location/Orientation:	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Source
Power:	Total power of the Source.	1
	Coherence and Polarization	
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, then polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state; 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the local source X axis.	90
	Wavelength List	
Table	Wavelengths, weights, and rendered ray colors are set in this section.	0.5875618, 1, black
ОК	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

Application Note Diode Laser Beam (Astigmatic Gaussian)

• For coherent sources, FRED synthesizes the LD wavefront on a plane located at the 'Create' z-location using the number of rays specified in

"X/Y samp Pts". These "X & Y samp Pts" can be thought of as defining the angular sampling of the source. Tracing <u>does not</u> begin at the 'Create' plane. The beamlets associated with each ray are propagated back to the current origin of the source before tracing begins.

- For incoherent sources, FRED sets the pathlengths and powers of this Astigmatic Laser Diode beam on a plane located at the 'Create' z-location using the rays selected in X/Y Samp Pts. Tracing does not begin at the 'Create' plane. Each ray is propagated back to the current origin of the source before tracing begins.
- For both coherent and incoherent versions of the Laser Diode source, the 'Create' plane should be in the far-field, i.e., z_{create} >> Z_{Rayleigh}= (_____ In general, choose the Create plane to correspond to the position at which the beam first encounters optical elements.
- A Simplified Source can be viewed or edited as a Detailed Source. The complete set of parameters used to construct the Diode Laser Beam Simplified Source are shown when editing/viewing the source in a Detailed Source dialog. Such parameters include the location of the X & Y focii and the beamwaist sizes computed from the divergence angle.

<u>See Also....</u> Diode Laser Beam (Astigmatic Gaussian)

> Detailed Optical Source (arbitrary user defined source) Collimated Source (Plane wave) Point Source (Spherical wave) Laser Beam (Gaussian 00 mode) Coherent Source Introduction

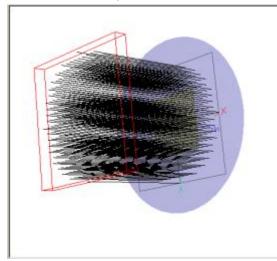


Laser Beam (Gaussian 00 mode)

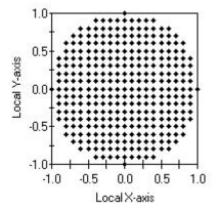
Description How Do I Get There? Dialog box and Controls Application Notes Examples See Also...

Description Laser Beam (Gaussian 00 mode)

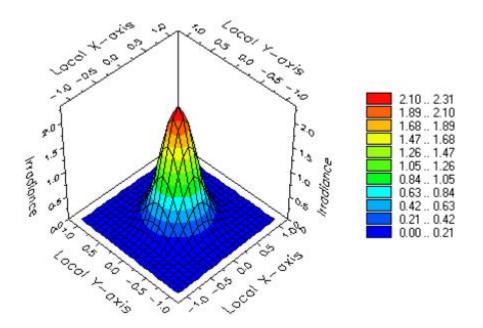
The **Create Simplified Source...** dialog provides simple user interface for generating commonly used sources types. The **Laser Beam (Gaussian 00 mode)** option generates collimated grid of rays that has been apodized in position so that the irradiance profile of the beam has a Gaussian profile.



The **Position Spot Diagram** for this grid of rays looks like a regular grid of rays.



The Irradiance Spread Function however has a Gaussian profile. The Position Spot Diagram above and the Irradiance Spread Function below have the same extent in the X and Y.



How Do I Get There? Laser Beam (Gaussian 00 mode)

There are two different ways to execute this command:

1. Right click on the **Optical Sources** and select **Create New Simplified Optical Source...** in the right click pop-up menu,



Objects	Description	
 ⊕ Optical Sources ⊕	✓ <u>I</u> raceable	
🕂 🛄 Analysis Surfacel	Never Traceable (for trimming surfaces)	
🕂 💼 Materials 🕂 🧮 Coatings	Draw O <u>u</u> ter Enclosing Volume	
🕂 🚾 Scatterers	Coordinate Axes	
🕂 直 Raytrace Propert	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	B Copy	Ctrl+C
	R Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Create New Simplified Optical Source	
	Create New Detailed Optical Source	
	Edit/View GRIN/Birefringent Material Position/Orient	ation
	Edit/View Array Parameters	
	Delete Array Parameters	

2. Right click on a **Source** and select **Edit/View Simplified Optical Source...** in the right click pop-up menu,



Objects			Description	
	Optical S			
	- A	✓ Traceable		
🕂 🔁	Geometry			
🕂 🛄	Analysis	<u>N</u> ever Trace	able (for trimming surfaces)	
🕂 📠	Materials	Drow Outor	Enclosing Volume	
÷ 📃	Coatings	_		
÷	Scatterer	<u>C</u> oordinate		
+ 📃	Raytrace	Visualization	Attributes	
		Position/Ori	entation	
		Parent Coor	rdinate S <u>v</u> stem	
		Sc <u>a</u> le		
		👗 Cut		Ctrl+X
		🖹 Сору		Ctrl+C
		R Paste		Ctrl+∀
			ighlighted items)	Del
		Su <u>m</u> mary Re	eport	
		Detailed Rej		
		e duduran ex		
			mplified Optical Source	
		Edit/view De	etailed Optical Source	
		Edit/View G	RIN/Birefringent Material Position/Orientation	
		Edit/View Ar	ray Parameters	
		Delete Arra	y Parameters	

In the Create New Simplified Optical Source... dialog, select the Laser Beam (Gaussian 00 mode) option.

		Help
Type:	Collimated source (plane wave)	Power: 1
2	Detailed source (arbitrary user defined source)	Coherence and Polarization
Xsemi	Collimated source (plane wave) Point source (spherical wave)	Coherent
	Laser Beam (Gaussian 00 mode)	Consistix
X num	Laser Diode Beam (Astigmatic Gaussian)	
Voum	11 Number of rave across the full V anerture	Polarized

Dialog Box and Controls Laser Beam (Gaussian 00 mode)

FRED User Manual

	C. C. C. C.	a New Sourc			? -0
arent:	Optical Sources				OK
ame:	Source 1				Cancel
escription:					Apply
					Help
ype:	ser Beam (l	Gaussian 00 m	iode)	▼ Power: 1	
	Value	Descript	ion	Coherence an	d Polarization
earn Size	0.5		ni-aperture	Coherent	
rid Size	1	Semi-ape	rture of the sample plane at th	e wais	
•1				Polarized O <ellipticit (deg<="" angle="" th=""><th>S</th></ellipticit>	S
	Drientation -			Wavelength L	ist
Location/C		4	Parameters	10/20	
	Parent	Туре	rarantecers	YYdy	lens (um) Weigt
F					92938 1 1

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Parent:	Logical Parent for the Source is listed here.	Optical Sources
Name:	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source <i>n</i>
Description:	User description of the Source can be typed here.	blank
Туре:	Type of the Simplified Source can be selected from this pull down menu. Choose Laser Beam .	Collimated Source
Beam Size	Gaussian beam waist semi-aperture measured at the $1/e^2$ points. The Gaussian beam waist is set with the position apodization in the Create and Edit/View Detailed Source dialogs.	0.5
Grid Size	Semi-aperture of the grid of rays in the Gaussian beam.	1

Sample Pts	Number of sample points (in X and Y) across the Gaussian beam profile.	21
Location/Orientation:	Location/Orientation Parent and any required translations and rotations to correctly position the Source.	Optical Source
Power:	Total power of the Source.	1
	Coherence and Polarization	
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked
Polarization	If checked, then polarization data for the rays is maintained and stored.	Unchecked
Ellipticity	Sets the ellipticity of the polarization state, 0 represents linear polarization and 1 represents circular.	0
Angle	Sets the angle of the polarization relative to the X axis.	90
	Wavelength List	
Table	Wavelengths, weights, and rendered ray colors are set in this section.	0.5892938
ОК	Create a new Optical Source and close dialog box.	
Cancel	Discard new Optical Source and close dialog box.	
Apply	Accept new Optical Source changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also...</u> Laser Beam (Gaussian 00 mode)

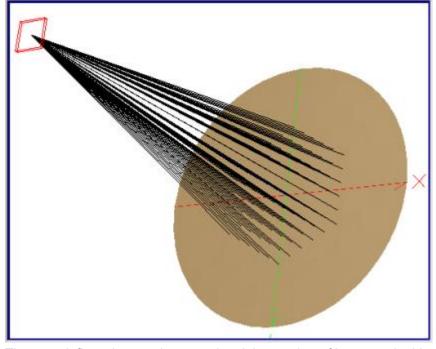
> Detailed Optical Source (arbitrary user defined source) Collimated Source (Plane wave) Point Source (Spherical wave) Diode Laser Beam (Astigmatic Gaussian) Coherent Source Introduction

Point Source

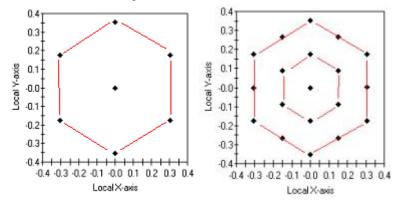
Description How Do I Get There? Dialog box and Controls See Also...

Description Point Source

The Create Simplified Source... dialog provides simple user interface for generating commonly used sources types. The Point Source option generates a point source of rays. The rays go from a single point towards a grid of hexagonal points in a plane.



The user defines the angular spread and the number of hexagonal grid zones to use to cover that angular range. One zone, or the first zone, is simply a hexagon with the array at the center. A second zone adds a ring to the outside of the single zone hexagon. A third zone adds an another ring to the outside of the two zones, and so on.

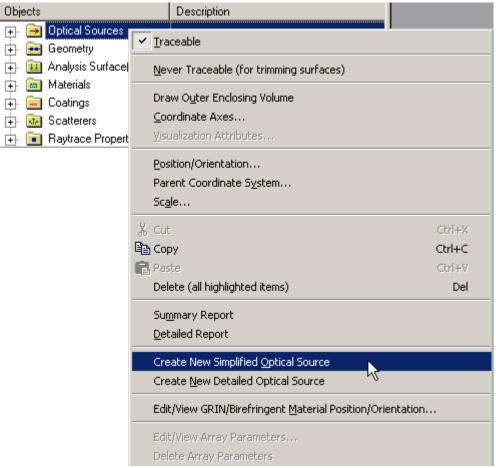




How Do I Get There? Point Source

There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Simplified Optical Source... in the right click pop-up menu,



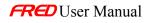
2. Right click on a Sources and select Edit/View Simplified Optical Source... in the right click pop-up menu,

Objects			Description	
	Optical S			
	volu			
🕂 🔁	Geometry	✓ <u>T</u> raceable		
🕂 🔁	Analysis	<u>N</u> ever Trac	eable (for trimming surfaces)	
÷ 💼	Materials			
÷ 🧰	Coatings		r Enclosing Volume	
÷ 💁	Scatterer	<u>C</u> oordinate		
÷• 主	Raytrace	⊻isualization	h Attributes	
		Position/Ori	entation	
			rdinate S <u>v</u> stem	
		Sc <u>a</u> le		
		👗 Cut		Ctrl+X
		🖹 Copy		Ctrl+C
		📳 Paste		Ctrl+V
		Delete (all h	nighlighted items)	Del
		Su <u>m</u> mary Report		
		 Detailed Re		
			mplified Optical Source	
		Edit/View D	etailed Optical Source	
		Edit/View G	RIN/Birefringent Material Position/Orientation	
		Edit/View A	rray Parameters	
		Delete Arra	y Parameters	

Once the Create New Simplified Optical Source... dialog appears, select the Point Source option.

Detailed source (arbitrary user defined source) Collimated source (plane wave) K semi Point source (spherical wave) Coherent			and a second sec
			Coherence and Polarization
	X semi	Point source (spherical wave)	Coherent
	X num		
Y semi Laser Beam (Gaussian 00 mode)	Y semi X num	Laser Diode Beam (Astigmatic Gaussian)	

Dialog Box and Controls Point Source



	ynton 2.frt) Create a New Source	? _□	
arent:	Optic	al Sources	OK	
ame:	Source	e 1	Cancel	
escrip	tion:		Apply	
			Help	
pe:	Point sour	ce (spherical wave)	Power: 1	
-	Value	Description	Coherence and Polarization	
ngle	10	Angular spread cone semi-angle (deg) (0 <angle<=:< td=""><td>Coherent</td></angle<=:<>	Coherent	
ones	5	Number of angular zones over the angular spread		
1			Polarized 0 <ellipticity<1: 0<br="">Angle (deg): 30</ellipticity<1:>	
Locat	tion/Orientati	on]	- Wavelength List	
	Parent	Type Parameters	Wavlens (um) Weigl	
1	Optical	So 💌 Make coin 💌	1 0.5892938 • 1 2 • 1	
2				

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Parent	Logical Parent for the Source is listed here.	Optical Sources
Name	Name of the Source is listed here. The name can be of any alphanumeric text length.	Source #
Description User description of the Source can be typed here.		
Туре	Type of the Simplified Source can be selected from this pull down menu. Choose Point Source .	Collimated Source
Angle	Half angle of the ray bundle from the source.	10

Zones	Number of hexagonal zones used to fill the angular spread of the ray bundle. One zone is simply a hexagon with one ray in the center generating 7 rays total. Two zones adds a ring around the hexagon generating 19 rays. A third rings adds another ring which generates 35 rays. And so on.			
Location/Orientation	Location/Orientation Parent and any required translations and rotations to correctly position the Source	Optical Source		
Power	Total power of the Source.	1		
	Coherence and Polarization			
Coherent	If checked, rays are treated as Gaussian Beamlets and coherently propagated.	Unchecked		
Polarization	Polarization If checked, then polarization data for the rays is maintained and stored.			
Ellipticity	0			
Angle	ngle Sets the angle of the polarization relative to the X axis.			
	Wavelength List			
Table	Table Wavelengths, weights, and rendered ray colors are set in this section.			
ОК	Create a new Optical Source and close dialog box.			
Cancel	Discard new Optical Source and close dialog box.			
Apply	Accept new Optical Source changes and keep dialog box open.			
Help	Access this Help page.			

See Also.... Point Source

Detailed Optical Source (arbitrary user defined source) Collimated Source (Plane wave) Laser Beam (Gaussian 00 mode) Diode Laser Beam (Astigmatic Gaussian)

Chapter 4 – How to Create and Edit Detailed Sources

Create and Edit Detailed Source

<u>Description - Source (Create New and Edit/View Detailed Source...)</u>

The Source page of the Create New and Edit/View Detailed Source... dialogs is the opening page of the dialog where the user can name the Source, describe the Source, and establish the initial starting conditions of the Source rays.

How Do I Get There? - Source (Create New and Edit/View Detailed Source...)

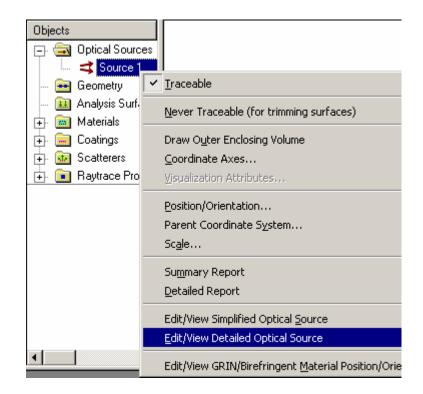
There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,

Objects	
🚽 🖻 🔁 🖂	urces
- 📻 Geometry	✓ <u>T</u> raceable
🔲 🏛 Analysis S	Never Traceable (for trimming surfaces)
🕂 🦲 Coatings	Draw Outer Enclosing Volume
🕂 🚾 Scatterers	<u>C</u> oordinate Axes
🕂 间 Raytrace	Visualization Attributes
	<u>P</u> osition/Orientation Parent Coordinate S <u>y</u> stem Sc <u>a</u> le
	Su <u>m</u> mary Report Detailed Report
	Create New Simplified Optical Source
	Create New Detailed Optical Source
	Edit/View GRIM/Birefringent Material Position/Orienta

2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu,





Dialog Box and Controls - Source (Create New and Edit/View Detailed Source...)

🚰 (FRED1) Create a New Optical Source: "Optical Sources"	<u>- </u>
Polarization Wavelengths Visualization Source Positions/Directions Location/Orientation Power Coherence Logical Parent: Optical Sources Name: Source 1 Description:	OK Cancel Apply Help
Immersion Material Additional Phase to Add to the Source Name: Catalog: Select Air Current Select Phase: 0 waves (Ex. 0.25 = quarter wave, 0.5 = half wave, etc.) Post-Creation Ray Propagation Specification • Propagate To Point:	

<u>Control</u>	<u>Defaults</u>					
Logical Parent	Optical Sources					
Name	Alphanumeric name of any length maybe typed here.	Source <i>n</i>				
Description	Alphanumeric description of any length maybe typed here.	Blank				
	Immersion Material					
Name	Name of material in which rays are immersed.	Air				
Catalog	Specifies the catalog containing the immersion material currently in use.	Current				
Select	Opens a dialog for changing the immersion material.					
	Additional Phase to Add to the Source					
Phase	Phase Add phase (in waves) to the rays prior to tracing .					
I	Post-Creation Ray Propagation Specification					
No Extra Propagation (do nothing)	This selection is made if no propagation is required. Default.	Selected				
Propagate by:	Not Selected					
Propagate to:	Not Selected					
Propagate to optical path length:	Not Selected					
Propagate to Point:	Not Selected					

Propagate to sphere:	Rays are propagated along their trajectory to their closest approach to the surface of the specified sphere. Select negative or positive direction.	Not Selected
OK	Create a new Source and close the dialog box.	
Cancel	Discard Source changes and close the dialog box.	
Apply	Apply Source changes and keep dialog box open.	
Help	Access this Help page.	

See Also - Source (Create New and Edit/View Detailed Source...)

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength Visualization



Description - Coherence (Create New and Edit/View Detailed Source...)

FRED performs diffraction and interference calculations using a technique called coherent beam superposition. The coherent beam superposition technique works by modeling arbitrary optical fields with the coherent summation of smaller fundamental beams. In FRED, these smaller fundamental beams are generally astigmatic Gaussian beamlets. It was been demonstrated by <u>J. Arnaud</u> that Gaussian beams could be represented and propagated with real rays. Those real rays can be traced through an optical system while maintaining the Gaussian beam representation. The near and far field diffraction patterns can be calculated coherently summing the Gaussian beams, which are represented by real rays traced through the system.

If the Source is set as coherent on the Coherence page, then each of the ray positions defined in the source becomes a Gaussian beamlet that is represented by two, four, or eight secondary real rays. In addition to choosing the number of secondary rays, the overlap of the adjacent beam overlap factor, and the secondary beam scaling can be set on the Coherence page.

How Do I Get There? - Coherence (Create New and Edit/View Detailed Source...)

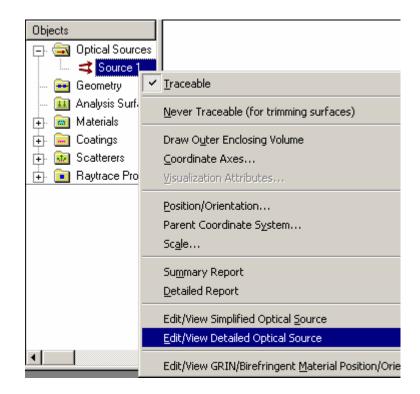
Objects Optical Sources 📻 Geometry 🖌 <u>Traceable</u> 💷 Analysis S Never Traceable (for trimming surfaces) 🕂 💼 Materials 🕂 🥃 Coatings Draw Outer Enclosing Volume ∔ 🚺 Scatterers Coordinate Axes... 🕩 间 Raytrace Visualization Attributes... Position/Orientation... Parent Coordinate System... Scale... Summary Report Detailed Report Create New Simplified Optical Source Create New Detailed Optical Source Edit/View GRIN/Birefringent Material Position/Orienta

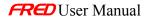
There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,

2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu,







Dialog Box and Controls - Coherence (Create New and Edit/View Detailed Source...)

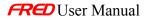
((FRED1) Create a New Optical Source:	"Optical Sources"	_ 🗆 🗙
Polarization Source Positions/Directions	Wavelengths Visualization Location/Orientation Power Coherence	
Coherent O Not Coherent		Cancel Apply
Gaussian Beam Properties (for coherent on Adjacent Beams Overlap Factor:		Help
1.5	< The fractional overlap of the waists of adjacent Gaussian beams when created in a grid. Typically this has a value between 1.4 and 1.6.	
Number of Secondary Rays:	< The number of secondary rays associated with each Gaussian beam. Typically this has the value 4 or 8.	
Secondary Ray Scale Factor:	< Advanced feature. Typically this has the value 1.0. Changing this value is not recommended.	
Number of Sample Points For Coherent Sou	urce Power Scaling	
49 49	< The number of sample points in X and Y for sampling the field for setting the source power. Typically, these values are 49.	

<u>Control</u>	Inputs	<u>Defaults</u>
Coherent/Not CoherentIf the coherent option is selected, then the ray positions defined in the source become Gaussian beamlets represented with 2, 4, or 8 secondary real rays.		Not Coherent
	Gaussian Beam Properties	
Adjacent Beams Overlap FactorThe fractional overlap of adjacent Gaussian beamlets. This factor changes the waist diameter of the Gaussian beamlets. Typical value between 		1.5
Number of Secondary Rays	umber of Pull down menu of available options for the number of secondary real rays representing the	
Secondary Ray Scale FactorThis is an advanced feature that scales the secondary rays representing the Gaussian beamlets.		1

Number of Sample Points for Coherent Source Power Scaling				
X,Y	X,Y Sampling resolution used only for setting source power.			
ОК	Create a new Optical Source and close dialog box.			
Cancel	ancel Discard new Optical Source and close dialog box.			
Apply	Accept new Optical Source changes and keep dialog box open.			
Help	Access this Help page.			

See Also... - Coherence (Create New and Edit/View Detailed Source...)

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength Visualization



Create Detailed Source - Location / Orientation

<u>Description - Location / Orientation (Create New and Edit/View Detailed</u> <u>Source...)</u>

The Location / Orientation page of the Create New and Edit/View Detailed Source... dialogs two functions.

- Establish the Location Parent Coordinate System for the source or object. The source or object is placed at the origin of the Location Parent Coordinate System.
- Locate and orient the source or object relative to the Location Parent Coordinate System or any other coordinate system.

The Location Parent Coordinate System should not be confused with the Logical Parent Node in the Tree View though they are cab be and are often chosen to be the same. The Location Parent Coordinate System should also not be confused with the Reference Coordinate System for a particular location or orientation transformation. The Location Parent Coordinate System will default to the Logical Parent Node but it can be changed to any other coordinate system in the FRED document. All of the nodes listed in the Geometry and Source sections of the Tree View represent available coordinate systems in the FRED document.

The Reference Coordinate System for the first location and orientation action will default to the Location Parent Coordinate System. For subsequent location and orientation actions, Reference Coordinate System will revert to the Reference Coordinate System on the previous action, i.e. the line above.

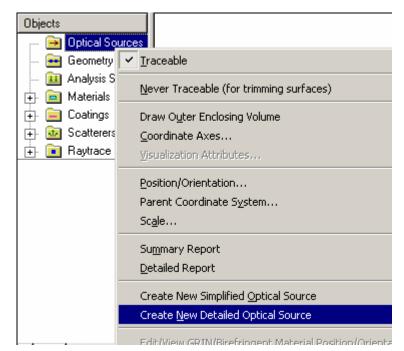
Note: The source or object is placed at the origin of the Location Parent Coordinate System. From there, the source or object can be moved using the Location/Orientation dialog or this tab of the Detailed Source Dialog.

How Do I Get There? - Location / Orientation (Create New and Edit/View Detailed Source...)

There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,





2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu,

Objects	
🕞 🧟 Optical Sourc	es
Source 1	
- 🔤 Geometry	✓ <u>I</u> raceable
🔤 🏛 Analysis Surf	Never Traceable (for trimming surfaces)
🕂 💼 Materials	
🕂 🧮 Coatings	Draw O <u>u</u> ter Enclosing Volume
🕂 🐱 Scatterers	<u>C</u> oordinate Axes
🕂 间 Raytrace Pro	⊻isualization Attributes,
	Position/Orientation
	Parent Coordinate System
	Scale
	Su <u>m</u> mary Report
	Detailed Report
	Edit/View Simplified Optical Source
	Edit/View Detailed Optical Source
•	Edit/View GRIN/Birefringent Material Position/Orie



Dialog Box and Controls - Location/Orientation (Create New and Edit/View Detailed Source...)

Ç	(FRED1) Create a New Optical	Source: "Opti	cal Sources"			<u> </u>
		Polarization		elengths	Visual		ОК
	Source			cation/Orientation	Power	Coherence	Cancel
		Reference Coordinate		Parameters (right			Apply
	0	Starting Coordinate Syste Global coordinate system				-	Help
	•		-			F	
_							

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Reference Coordinate SystemPull down menu of all the coordinates systems in FRED. The nodes listed in the Geometry and So sections of the Tree View represent all of the ava coordinate systems in the FRED document.		Coordinate system of Parent
ActionPull down menu listing of all possible location and orientation actions relative to the reference coord system.		Shift
Parameters	Parameters Spatial coordinates, angles or direction cosines.	
ОК	Accept Location/Orientation changes and close dialog box.	
Cancel Discard Location/Orientation changes and close dialog box.		
Apply	Apply Location/Orientation changes and keep dialog box open.	

Help	Access this Help page.	

<u>See Also... - Location / Orientation (Create New and Edit/View Detailed</u> <u>Source...)</u>

Source	
Positions / Directions	
Location / Orientation	
Power	
Coherence	
Polarization	
<u>Wavelength</u>	
Visualization	

Create Detailed Source - Polarization

<u>Description - Polarization (Create New and Edit/View Detailed Source...)</u>

The polarization state of the rays is by default not tracked or stored for the rays. The rays can be polarized by selecting the Polarized option on the Polarization page of the Create New and Edit Detailed Optical Source... dialogs. In addition, if unpolarized rays hit a polarizer coating then they are changed from unpolarized rays to polarized rays.

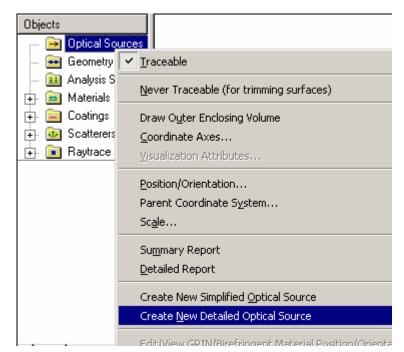
The Polarization page has three sections for defining the polarization state Ellipticity, handedness, and the angle of the polarization ellipse relative to the local X axis.

<u>How Do I Get There? - Polarization (Create New and Edit/View Detailed</u> <u>Source...)</u>

There are two ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,





2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu

Objects	
📄 🗟 Optical Source	es
🔤 🚅 Source 1	
- 🔤 Geometry	✓ <u>T</u> raceable
📖 🏛 Analysis Surf	Never Traceable (for trimming surfaces)
🕂 💼 Materials	House Hacobbe (for annual granacos)
🕂 🧰 Coatings	Draw Outer Enclosing Volume
🕂 🔂 Scatterers	<u>C</u> oordinate Axes
🕂 间 Raytrace Pro	Visualization Attributes
	Position/Orientation
	Parent Coordinate System
	Scale
	Su <u>m</u> mary Report
	Detailed Report
	Edit/View Simplified Optical Source
	Edit/View Detailed Optical Source
•	Edit/View GRIN/Birefringent Material Position/Orie

Once the dialog appears, click on the Polarization tab.

—

Dialog Box and Controls - Polarization (Create New and Edit/View Detailed Source...)

🚰 (FRED1) Create a New Optical Source: "Optical Sources"	_
Source Positions/Directions Location/Drientation Power Coherence Polarization Wavelengths Visualization Polarized No Polarization Defined (unpolarized)	OK Cancel
Polarization Properties	Apply Help
Image: Construction of Linear Image: Construction of Constructin of Construction of Construction of Constructin of Constructino	
Handedness C Left Hand C Randomize Handedness viewed as the ray propagates toward the observer. Left hand = counterclockwise, right hand = clockwise.	
Angle of Polarization ellipse Image: Exact: 90 Angle (in degrees) of major axis of the polarization ellipse with respect to the local X axis.	
X: 1 Y: 0 Z: 0 Local X axis direction vector.	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>	
Polarized / No Polarization Defined	If the Polarized option is selected, then polarization state information of the rays is maintained and stored for each ray.	No Polarization Defined	
	Polarization Properties		
Ellipticity	Sets Ellipticity of the polarization state. Linear and circular can be selected directly or an arbitrary ellipticity ($0 \le e \le 1$) may be entered. There is also the option to randomize the ellipticity.	Linear	
Handedness	Sets the handedness of the polarization state. Options are right handed, left handed, or randomly chosen handedness.	Right Hand	
	Angle of Polarization Ellipse		
Angle of major axis	The angle of the polarization ellipse relative to the local X axis.	Exact 90	

X, Y, Z	The direction cosine vector of the local X axis used for the angle of the polarization ellipse. Note that this does NOT change the local X axis of the source itself.	1, 0, 0
ОК	Create a new Optical Source and close dialog box.	
Cancel	Discard Polarization changes and close dialog box.	
Apply	Apply Polarization changes and keep dialog box open.	
Help	Access this Help page.	

Create Detailed Source - Positions/Directions

<u>Description - Positions/Directions (Create New and Edit/View Detailed</u> <u>Source...)</u>

The first step to defining rays is to establish the starting positions and directions of the rays. Not surprisingly, this task is done on the Positions / Directions page of the Create New and Edit/View Detailed Source... dialogs. The Positions / Directions page has been split into these two related but separate operations:

- Positions of the rays in the Source
- Directions of the rays in the Source

There are different options available in pull down menus for how to define the rays starting positions and directions.



i olar	ization		Wavelengths Visualization) OK
Source	Positions/D	irections	Location/Orientation Power Coherence	
Ray Position:	e			
Туре:		ctangular array	of points arranged on a plane)	Apply
Parameters:		Parameter	Description	- Help
		11	Number of rays across X	-
	Y Num Rays		Number of rays across Y	
	X Semi-Ape	5	X Semi-aperture	
	Y Semi-Ape	5	Y Semi-aperture	
		Elliptical 🗖	The aperture shape	
D D <i>i i</i>	•			<u>.</u>
Ray Directior Type:		on (plane wave		
-		on (plane wave Parameter	2)	
Туре:		Parameter	2)	
Туре:	Single Direction	Parameter 0	e) Description	
Туре:	Single Direction	Parameter 0 0	e) Description X component of ray direction	

There are different options available in a pull down menu for how the ray Positions are defined.

Ray Position	
Туре:	Grid Plane (rectangular array of points arranged on a plane)
Parameters:	Grid Plane (rectangular array of points arranged on a plane) Random Plane (random points arranged on a plane) Random Volume (random points arranged in a volume) Random String (random points arranged in a character or string) User defined rays (manually defined and/or read from ray file) Random Surface (random points on a designated surface) Hexagonal Plane (hexagonal array of points arranged on a plane) Bitmap (points specified by bitmap pixels)
	I I I I I I I I I I I I I I I I I I I

And there are different options available in a pull down menu for how the ray **Directions** are defined.

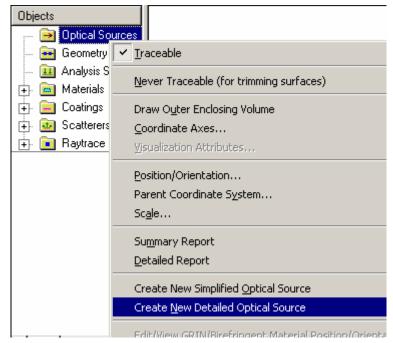
Ray Direction	18
Туре:	Single Direction (plane wave)
Parameters:	Random Directions into an angular range Random directions into a sphere Focus to/from a point Directions to rectilinear grid points Directions to hexagonal grid points in angle space Focus to/from two astigmatic focii Astigmatic Gaussian Beam Multiple source angles (plane waves)

For the most part, the ray positions are independent of the ray directions. But there are some cases where ray directions are set by actions in the ray positions section alone. For example, in the case of user defined rays, the ray positions and directions are defined at the same time in the ray positions section.

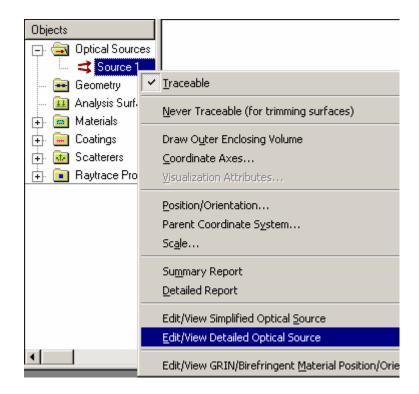
How Do I Get There? - Positions/Directions (Create New and Edit/View Detailed Source...)

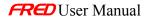
There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,



2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu,





Dialog Box and Controls - Positions/Directions (Create New and Edit/View Detailed Source...)

Polar	rization		Wavelengths	Visualiza	ation	ОК
Source [Positions/D	Virections	Location/Orientation	Power	Coherence) Canc
Ray Position:	s					
Туре:		ctangular array	of points arranged on a plane)		-	Appl
Parameters:	í –	Parameter	Description			Hel
	X Num Rays	1	Number of rays across X			
	YNum Rays	1	Number of rays across Y			
	X Semi-Ape	0.5	X Semi-aperture			
	Y Semi-Ape	0.5	Y Semi-aperture			
	Aperture	Rectangular 💌	The aperture shape			
Ray Direction	าร					
Туре:	Single Directi	on (plane wave)		•	
Parameters:		Parameter	Description			
	X Component	0	X component of ray direction			
	Y Component	0	Y component of ray direction			
	Z Component] 1	Z component of ray direction			

There are six different ways to define the positions of the rays:

- Grid Plane (rectangular array of points arranged on a plane)
- Random Plane (random points arranged in a plane)
- Random Volume (random points arranged in a volume)
- Random String (random points arranged in a character or string)
- User defined rays
- Random Surface (random points on the designated surface)

There are seven different ways to define the directions of the rays:

- Single Direction (plane wave)
- Random directions into an angular range
- Random directions into a sphere
- Focus to/from a point
- Directions to rectilinear grid points
- Directions to hexagonal gird points in angle space
- Focus to/from two astigmatic foci

The different ray position and direction options are discussed separately. Click on the option for help on that option.

See Also... - Positions/Directions (Create New and Edit/View Detailed Source...)

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength

Visualization



Create Detailed Source - Position/Directions - Bitmap

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Bitmap

Create a source from a color bitmap graphic. The spectral content of this source is synthesized from pixel RGB values using discrete wavelengths selected by the user. The Ray Direction type determines the angular distribution. The source shown below was synthesized with 10 wavelengths spanning the visible.



Bitmap

There are three ways to create a Detailed Bitmap source:

1. from the Sources Tree folder drop-down:



Objects	Description	
	✓ Iraceable	
📻 Ge	Never Traceable (for trimming surfaces)	
🕂 🧰 Ma	Duran Outen Deale de Lieburg	
🕂 🦲 Co.	<u>C</u> oordinate Axes	
🕂 🔂 Sc	⊻isualization Attributes	
🕂 直 Ra	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	🛃 Paste	⊂trl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	Detailed Report	
•	Create New Simplified Optical Source	
 ×	Create New Detailed Optical Source	
	Edit/View GRIN/Birefringent <u>M</u> aterial Position/Orientation	on

2) from the Main menu

	<u>Create</u> <u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
Ī	< New Simplified Source	Ctrl+Alt+I
_	💐 New <u>D</u> etailed Source	Ctrl+Alt+D
1	۷۶ New Lens	Ctrl+Alt+L
1	New Mirror	Ctrl+Alt+M
	New Prism	Ctrl+Alt+P
	A New Subassembly	Ctrl+Alt+S
	P New Custom Element	Ctrl+Alt+E
	New Surface	Ctrl+Alt+F
_	C New Curye	Ctrl+Alt+∀
	➡ New A <u>n</u> alysis Surface	Ctrl+Alt+N
	🗇 New Material	Ctrl+Alt+T
	🗢 New <u>C</u> oating	Ctrl+Alt+C
	🞾 New Sc <u>a</u> tter Model	Ctrl+Alt+A
	22 New <u>R</u> aytrace Control	Ctrl+Alt+R

or

3) Key Accelerator Key combination Ctrl+Alt+D.

Dialog Box and Controls Bitmap

Polar	ization	_ I	Wavelengths	Visu	alization	OK
Source	Positions/E)irections	Location/Orientation	Power	Coherence	Cano
Ray Position:						
Туре:		s specified by b	itmap pixels)		•	Арр
Parameters:		Bitmap Sou	rce (press button to sele	ect bitmap file)	,	Hel
	File Name:	Select				
	File Info:					
		Parameter	Des	cription		
	Rays/pixel	1	Number of random rays pe	er pixel		
	Semi-width	0.5	X semi-width of the sourc	e		
	Semi-height	0.5	Y semi-height of the source	e		
	Center X	0	X center of the source			
	Center Y	0	Y center of the source			
	Center Z	0	Z center of the source			
	Wavelengths	Set waveleng	gths in the wavelengths tab			
	•		1		Þ	

Select Bitmap from the Ray Position dialog on the Position/Direction Tab:

<u>Control</u>	Inputs / Description	<u>Defaults</u>					
Type - Bitmap							
File Name	Name of bitmap file: (*.bmp or *.jpg)	blank					
	Parameters						
Rays/pixel	Number of rays per pixel (per wavelength)	1					
Semi-width/height	Set the source size here.	0.5, 0.5					
Center X Y Z	Set where the center of the source is positioned.	0,0,0					
ОК	Accept changes and close dialog box.						
Cancel	Discard changes and close dialog box.						
Apply	Apply changes and keep dialog box open.						
Help	Access this Help page.						

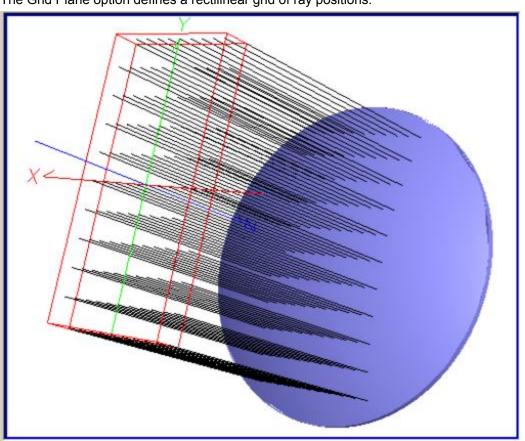
Application Notes Bitmap

- The Ray Direction dialog determines the angular distribution of this • source.
- The RGB value of each pixel is synthesized from entries on the • Wavelength Tab. A ray is created for each wavelength entry.

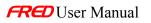
Create Detailed Source - Position/Directions - Grid Plane

Description How Do I Get There? **Dialog box and Controls**

Description Grid Plane (Create New and Edit/View Detailed Source...)



The Grid Plane option defines a rectilinear grid of ray positions.



<u>How Do I Get There?</u> Grid Plane (Create New and Edit/View Detailed Source...)

This is an option in the Positions / Directions page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

remportanta) Edit Optical	Source: Sou				
Polar	ization		Wavelengths	Visual	ization	OK
Source	Positions/D	irections	Location/Orientation	Power	Coherence	
- Ray Position:						Cance
Type:		- I	(-)		Apply
rype.	Jurid Plane (re	ctangular array	of points arranged on a plan	iej		
Parameters:		Parameter	Description			Help
	X Num Rays	11	Number of rays across X			
	Y Num Rays	11	Number of rays across Y			
	X Semi-Ape	5	X Semi-aperture			
	Y Semi-Ape	5	Y Semi-aperture			
	Aperture	Elliptical 📃	The aperture shape			
	•				F	
Ray Direction Type:		on (plane wave	۵ ۱		Ţ	
		un (piane wave	a)			
Parameters:		Parameter	Description			
	X Component	0	X component of ray directio	n		
	Y Component	. 0	Y component of ray directio	Π		
	Z Component	1	Z component of ray directio	Π		
					•	

Dialog Box and Controls

Grid Plane (Create New and Edit/View Detailed Source...)

Ray Positions Type:	Grid Plane (rectangular array of points arranged on a plane)							
Parameters:		Parameter	Description					
	X Num Rays	11	Number of rays across X					
	Y Num Rays		Number of rays across Y					
	X Semi-Ape	5	X Semi-aperture					
	Y Semi-Ape	5	Y Semi-aperture					
	Aperture	Elliptical 📘	The aperture shape					
	1	•••••••••••••••••••••••••••••••••••••••	E E E E E E E E E E E E E E E E E E E					

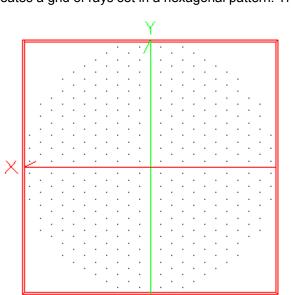
<u>Control</u>	<u>Description</u>	<u>Defaults</u>					
Ray Positions							
Туре	Type Pull down menu for selecting the method for defining the ray positions. Choose Grid Plane .						
	Parameters						
X Num Rays	Number of rays across ray bundle in the X direction.	1					
Y Num Rays	Number of rays across ray bundle in the Y direction.	1					
X Semi-Ape	Ray bundle semi-diameter in the X direction.	0.5					
Y Semi-Ape	Ray bundle semi-diameter in the Y direction.	0.5					
Aperture	Pull down menu with the available ray bundle parameter shapes.	Rectangular					
OK	Create new source and close dialog box.						
Cancel	Discard new source and close dialog box.						
Apply	Apply source changes and close dialog box.						
Help	Access this Help page.						



Create Detailed Source - Position/Directions - Hexagonal Plane

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Hexagonal Plane

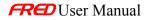


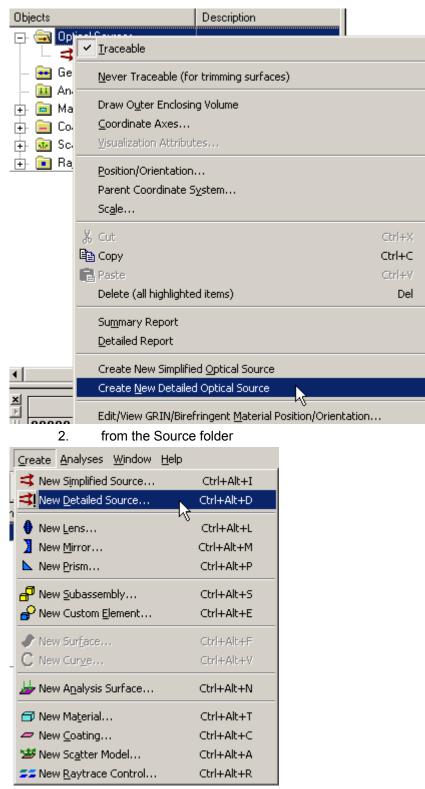
Creates a grid of rays set in a hexagonal pattern. The user sets the ray unit cell size.

How Do I Get There? Hexagonal Plane

There are three different ways to execute this command:

1. from the Main Menu:





3. from the Accelerator key Ctrl+Alt+d

Dialog Box and Controls Hexagonal Plane

Polar	ization		Wavelengths	Visu	alization	0K
Source	Positions/[Directions	Location/Orientation	Power	Coherence	Cance
- Ray Position:	s					
Туре:	Hexagonal P	lane (hexagona	al array of points arranged on	i a plane)	•	Apply
Parameters:		Parameter	Description			Help
	Cell	0.1	The semi-aperture of one	hexagonal cell		<u> </u>
	X Semi-Ape	1	X outer semi-aperture			
	Y Semi-Ape	1	Y outer semi-aperture			
	Aperture	Elliptical 📘	The aperture shape			
	I					
Ray Direction	ns					
Туре:	Single Direct	ion (plane wav	e)		_	
Parameters:		Parameter	Description			
	X Componen	t O	X component of ray direction	on		
	Y Componen	t O	Y component of ray direction	on		
	Z Componen	t 1	Z component of ray direction	on		
					•	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Туре	Hexagonal Plane	Grid Plane
Cell	Hexagonal cell size. One ray per cell.	0.1
XY Semi-Ape	Semi-aperture of grid.	1,1
Aperture	Aperture shape (Elliptical/Rectangular)	Elliptical
ОК	Accept changes and close dialog box.	
Cancel	Discard changes and close dialog box.	
Apply	Apply changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes Hexagonal Plane

• Number of rays is determined by the cell size and aperture.

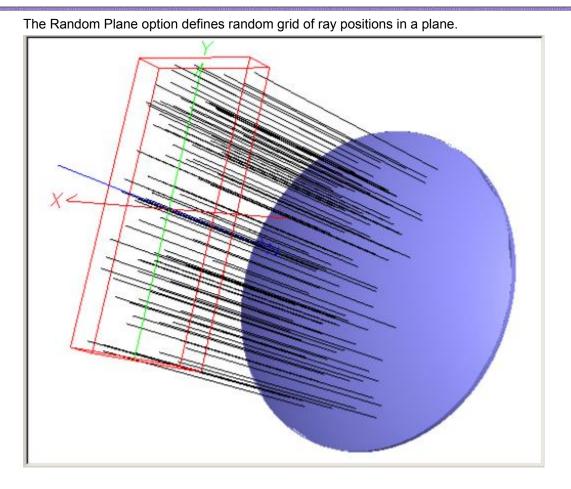
See Also.... Hexagonal Plane



Create Detailed Source - Position/Directions - Random Plane

Description How Do I Get There? Dialog box and Controls

<u>Description</u> Random Plane (Create New and Edit/View Detailed Source...)



<u>How Do I Get There?</u> Random Plane (Create New and Edit/View Detailed Source...)

This is an option in the Positions / Directions page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



Polar	ization	,	Wave	elengths	Visua	lization	ОК
Source	Positions/Di	ections	Loc	ation/Orientation	Power	Coherence	Cance
Ray Position:	s						
Туре:		(random poi	nts arrar	nged on a plane)		•	Apply
Parameters:		Param	eter	Description			Help
	Num Rays	42		Total number of ran	dom ray position	s	<u> </u>
	X Outer Semi-/	Ape 0.5		X outer semi-apertu	re of the plane s	urface	
	Y Outer Semi-	Ape 0.5		Y outer semi-apertu	re of the plane s	urface	
	X Hole Semi-A	pe O		X inner hole semi-ap	perture of the pla	ine surface	
	Y Hole Semi-A	pe O		Y inner hole semi-a	perture of the pla	ane surface	
	Shape	Rectang	gular 💌	The aperture shape	of the plane sur	face	
	•					Þ	
Ray Direction	าร						
Туре:	Single Directio	n (plane wav	e)			•	
Parameters:		Parameter	Descr	iption			
	X Component	0	X com	ponent of ray directio	n		
	Y Component	0	Y com	ponent of ray directio	Π		
	Z Component	1	Z com	ponent of ray directio	Π		

Dialog Box and Controls

Random Plane (Create New and Edit/View Detailed Source...)

Гуре:	Random Plane (random points arranged on a plane)						
^D arameters:		Parameter	Description				
	Num Rays	42	Total number of random ray positions				
	X Outer Semi-Ape	0.5	X outer semi-aperture of the plane surface				
	Y Outer Semi-Ape	0.5	Y outer semi-aperture of the plane surface				
	X Hole Semi-Ape	0	X inner hole semi-aperture of the plane surface				
	Y Hole Semi-Ape	0	Y inner hole semi-aperture of the plane surface				
	Shape	Rectangular 📘	The aperture shape of the plane surface				

<u>Control</u>	Description	<u>Defaults</u>						
	Ray Positions							
Туре	Grid plane							
	Parameters							
Num Rays	The number of rays randomly distributed across the ray bundle in the X and Y directions.	42						
X Outer Semi-Ape	Ray bundle semi-diameter in the X direction.	0.5						
Y Outer Semi-Ape	Ray bundle semi-diameter in the Y direction.	0.5						
X Hole Semi-Ape	Ray bundle hole semi-diameter in the X direction.	0						
Y Hole Semi-Ape	Ray bundle hole semi-diameter in the Y direction.	0						
Aperture	Aperture This is a pull down menu with the available ray bundle parameter shapes.							
ОК	Create new source and close dialog box.							
Cancel	Discard new source and close dialog box.							
Apply	Apply source changes and close dialog box.							
Help	Access this Help page.							



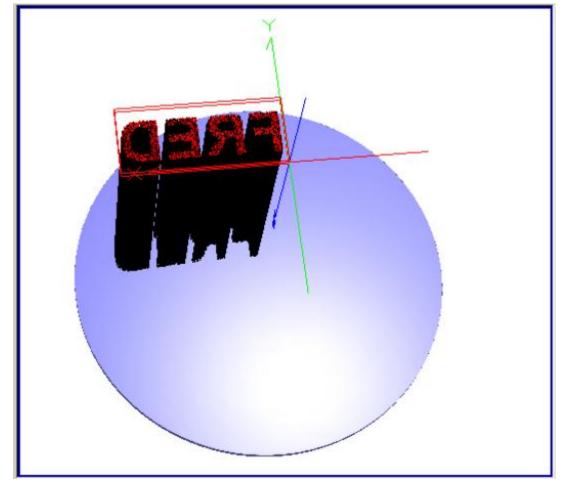
Create Detailed Source - Position/Directions - Random String

Description How Do I Get There? Dialog box and Controls

Description

Random String (Create New and Edit/View Detailed Source...)

The Random String option defines random Ray Positions in a plane in the shape of the user input character string. In the example below, the Single Direction option was selected for the Ray Directions.



<u>How Do I Get There?</u> Random String (Create New and Edit/View Detailed Source...)

This is an option in the Positions / Directions page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



Polar	ization	1	Wavelengths Visualization		OK				
Source	Positions	/Directions		erence	Cance				
- Ray Position:	s								
Туре:	Random String (random points arranged in a character or string)								
Parameters:		Parameter	Description		Help				
	Text	P	Character text string						
	Num Rays	1000	The number of rays per character						
	Height	0.5	Character Height						
	•			▶					
-Ray Direction	ns								
Туре:	Random dir	rections into a	sphere						
Parameters:		Parame	eter Description						
	Num Directi	ons 1	Number of random ray directions per ray position						

Dialog Box and Controls Random String (Create New and Edit/View Detailed Source...)

The Ray Position section of the dialog:

- Ray Positions			
Туре:	Random St	tring (random)	points arranged in a character or string)
Parameters:		Parameter	Description
	Text	Ρ	Character text string
	Num Rays	1000	The number of rays per character
	Height	0.5	Character Height
	•		

<u>Control</u>	Description	<u>Defaults</u>
	Ray Positions	
Туре	Grid plane	
	Parameters	
Text	Text string used to define the position of the rays.	Р
Num Rays	Number of rays randomly distributed per character.	1000
Height	Height of the characters in the string.	0.5
OK	Create new source and close dialog box.	
Cancel	Discard new source and close dialog box.	
Apply	Apply source changes and close dialog box.	
Help	Access this Help page.	



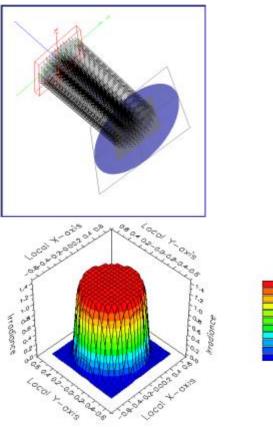
Create Detailed Source - Position/Directions - Uniform Position Apodization

Description How Do I Get There? Dialog box and Controls

Description

Uniform Position Apodization (Create New and Edit/View Detailed Source...)

The Uniform Position Apodization option scales all the rays in the source to have a uniform, equal power as a function of ray positions. This is equivalent to having no position apodization.



<u>How Do I Get There?</u> Uniform Position Apodization (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

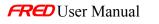
0.89 0.76 0.63 0.51 0.38 0.25

0.51

Objec	ets			Description	
- Ç. 🗧	•	Optical Source	S		
	••••	Source 1 Geometry	✓ <u>T</u> rac	eable	
	11	Analysis Surfac	Nev	er Traceable (for trimming surfaces)	
		Materials Continent	Drav	V Outer Enclosing Volume	
	en l	Coatings Scatterers		dinate Axes	
Er u Fr (Raytrace Prop	_	alization Attributes	
		<u> </u>	Deci	ian Yoyiantakian	
			_	ion/Orientation	
				nt Coordinate S <u>v</u> stem	
			Sc <u>a</u> l	e	
			🔏 Cut		Ctrl+X
			E Cop	/	Ctrl+C
			📳 Past	e	⊂trl+V
			Dele	te (all highlighted items)	Del
			Sum	mary Report	
			Deta	iled Report	
			Edit,	View Simplified Optical Source	
				View Detailed Optical Source	
			Edit,	んぱ View GRIN/Birefringent <u>M</u> aterial Position/Orient	ation
			Edit,	View Array Parameters	
			Dele	te Array Parameters	

Dialog Box and Controls Uniform Position Apodization (Create New and Edit/View Detailed Source...)

The Position Apodization section of the dialog:



🕻 (newport.frd) Edit Optical Sc	urce: "Source 1"		_ 🗆 🗡
Polarization	Wavelengths	Visualization	ОК
Source Positions/Dire	ctions Cocation/Orientation	Power Coherence	Cancel
Position Apodization	Direction Apodia	zation	Apply
Type: Uniform Unit Apodization (equi	valent to no (Valent	podization (equivalent to no 💌	Help
Parameters:	Parameters:		
No Data Required	No Data Requ	M ed	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>					
Total Power:	Total Power:Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.						
Position Apodization							
Туре:	Pull down menu of available position apodization options.	Uniform					
Parameters:							
Direction Apodization							
Туре:	Type:Pull down menu of available direction apodization options.						
Parameters:	There are no parameters for this option.						
ОК	Create new source and close dialog box.						
Cancel	Discard new source and close dialog box.						
Apply	Apply source changes and close dialog box.						
Help	Access this Help page.						

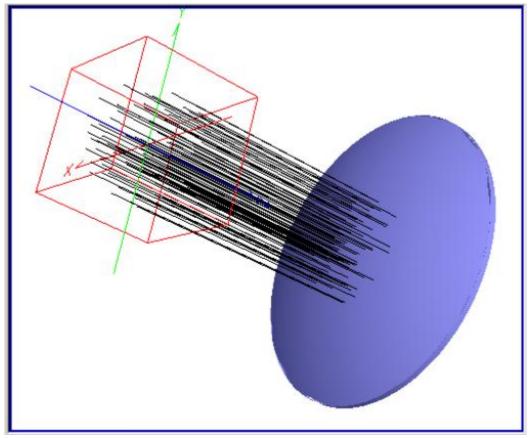


Description How Do I Get There? Dialog box and Controls

Description

Random Volume (Create New and Edit/View Detailed Source...)

The Random Volume option defines random Ray Positions in a volume. In the example below, the default settings for the Random Volume were used and the Single Direction was selected for the Ray Directions.



<u>How Do I Get There?</u> Random Volume (Create New and Edit/View Detailed Source...)

This is an option in the Positions / Directions page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

Polar	ization	,	Wavelengths Visualization	OK
Source	Positions/D	irections	Location/Orientation Power Coherence	
Ray Position:	s			
Туре:	Random Volu	ime (random po	pints arranged in a volume)	Apply Apply
Parameters:		Parameter	Description	Help
	Num Rays	100	Total number of random ray positions	
	X Semi-Ape	0.5	X Semi-aperture of the volume	
	Y Semi-Ape	0.5	Y Semi-aperture of the volume	
	Z Semi-Ape	0.5	Z Semi-aperture of the volume	
	Shape	Spheroid 📃	The shape of the volume	
	•		<u> </u>	
Ray Direction	าร			
Туре:		on (plane wav	e)	
Parameters:		Parameter	Description	
	X Component	0	X component of ray direction	
	Y Component	t O	Y component of ray direction	
	Z Component	1	Z component of ray direction	

Dialog Box and Controls Random Volume (Create New and Edit/View Detailed Source...)

Гуре:	Random Volume (random points arranged in a volume)								
Parameters:		Parameter	Description						
	Num Rays	100	Total number of random ray positions						
	X Semi-Ape	0.5	X Semi-aperture of the volume						
	Y Semi-Ape	0.5	Y Semi-aperture of the volume						
	Z Semi-Ape	0.5	Z Semi-aperture of the volume						
	Shape	Spheroid 💌	The shape of the volume						

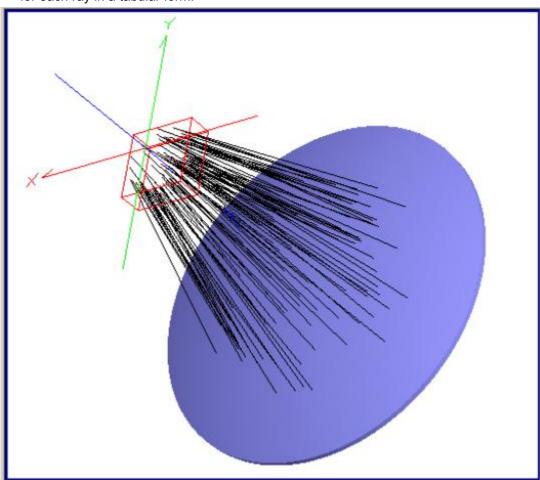
<u>Control</u>	Description	<u>Defaults</u>						
	Ray Positions							
Туре	Pull down menu for selecting the method of defining ray positions. Choose Random Volume.							
Parameters								
Num Rays	Number of rays randomly distributed in the volume.	100						
X Semi-Ape	Ray volume semi-diameter in the X direction.	0.5						
Y Semi-Ape	Ray volume semi-diameter in the Y direction.	0.5						
Z Semi-Ape	Ray volume semi-diameter in the Z direction.	0.5						
Shape	Pull down menu with the available ray bundle parameter shapes.	Spheroid						
OK	Create new source and close dialog box.							
Cancel	Discard new source and close dialog box.							
Apply	Apply source changes and close dialog box.							
Help	Access this Help page.							



Create Detailed Source - Position/Directions - User Defined Rays

Description How Do I Get There? Usage Dialog box and Controls Application Notes

Description User Defined Rays (Create New and Edit/View Detailed Source...)



The User Defined Rays option defines Ray Position, Direction, Power, and Path Length for each ray in a tabular form.

<u>How Do I Get There?</u> User Defined Rays (Create New and Edit/View Detailed Source...)

This is an option in the Positions / Directions page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



newport.frd) Edit Optical	Source: "So	ource 1"					_ 🗆 ×	
Polari		1	Wavele	engths	- L	Visualization		0K	
Source	Positions/D	herence	Cancel						
Ray Positions	;							Apply	
Туре:	User defined r	User defined rays (manually defined and/or read from ray file)							
Parameters:	X	Pos	Y Pos	Z Pos	X Dir	Y Dir		Help	
	0	0		0	0	0	1	<u> </u>	
Ray Direction Type:	s Single Directio	on (plane wav	e)				•		
Parameters:		Parameter	Descrip	tion					
	X Component	0	X compo	nent of ray di	rection				
	Y Component	0	Y compo	onent of ray di	rection				
	Z Component	1	Z compo	nent of ray di	rection				
	•						Þ		

<u>Usage</u>

User Defined Rays (Create New and Edit/View Detailed Source...)

Rays can be inserted by hand if you know the data for the rays. To do this, enter the x, y, and z components of the position, the x, y, and z components of the direction the ray travels, the power, and the path length for one ray in one row. When you enter values, FRED automatically adds another row for more rays.

You can also import user-defined ray data from a file in any of several formats. Right mouse click on the input spreadsheet for the context menu. Select either the "Append Rays From a File..." or "Replace With Rays From a File..." menu item. This will produce a File Open dialog that will allow you to select the ray data type and the file to import. This is a handy way to import ray data files created by the ProSource software of Radiant Imaging. Note that it is important to specify the correct ray file data type in the "File Open" dialog before you attempt to import rays from the file. The wrong data type will result in invalid rays being imported from the file.



Dialog Box and Controls User Defined Rays (Create New and Edit/View Detailed Source...)

The Ray Position section of the dialog:

urce Positio	ns/[Directions	Location/Or	rientation	Power Co	herence	olarization	Waveleng	ths Visua	lization	OK
Ray Position:	-										Can
Туре:	Us	er defined r	ays								Арр
Parameters:	Г	X Pos	Y Pos	Z Pos	X Dir	Y Dir	Z Dir	Power	Path Len		whh
	1	0.228711	0.0908522	-0.256429	0.255418	0.076461	-0.963802	4.830e-6	0		Hel
	2	-0.068696	0.147213	-0.307761	-0.039253	0.178682	-0.983123	6.891e-6	0		
	3	-0.076235	-0.235063	-0.254874	-0.177880	-0.235919	-0.955353	4.482e-6	0	1	
	4	-0.096810	-0.112504	-0.311655	-0.120378	-0.147511	-0.981707	6.890e-6	0		
	5	0.074773	-0.0233854	-0.325073	0.137699	-0.019420	-0.990283	7.460e-6	0	and the second	
	e	0.050200	0.054024	0 324037	0.442022	0.490000	0.075420	4 207 - E	0		

<u>Control</u>	<u>Description</u>	<u>Defaults</u>						
	Ray Positions							
Туре	TypePull down menu for selecting the method for defining the ray positions.							
X Pos	X coordinate of the ray position.	0						
Y Pos	Y coordinate of the ray position.	0						
Z Pos	Z coordinate of the ray position.	0						
X Dir	X component of the ray direction cosines α .	0						
Y Pos	Y component of the ray direction cosines β .	0						
Z Pos	Z component of the ray direction cosines γ .	1						
Power	Power of the ray	1						
Path Len	Path length of the ray at this (X, Y, Z) location.	0						
OK	Create new source and close dialog box.							
Cancel	Discard new source and close dialog box.							
Apply	Apply source changes and close dialog box.							
Help	Access this Help page.							

<u>Application Notes</u> User Defined Rays (Create New and Edit/View Detailed Source...)

• Text file format for entry of user-defined rays is one ray per row with eight columns of data (Xpos, Ypos, Zpos, Xdir, Ydir, Zdir, Power & Pathlength):

🕞 newwrite.dat - Notepad	JN
File Edit Format View Help	
<pre>!FRED optical Engineering Software Ray Text File (www.photonengr.com) -0.5 0 0 0 0 1 0.012345679012346 0 -0.4 -0.3 0 0 0 1 0.012345679012346 0 -0.4 -0.2 0 0 0 1 0.012345679012346 0 -0.4 -0.1 0 0 0 1 0.012345679012346 0 -0.4 0.1 0 0 0 1 0.012345679012346 0 -0.4 0.2 0 0 0 1 0.012345679012346 0 -0.4 0.3 0 0 0 1 0.012345679012346 0 -0.3 -0.4 0 0 0 1 0.012345679012346 0 -0.3 -0.4 0 0 0 1 0.012345679012346 0 -0.3 -0.2 0 0 0 1 0.012345679012346 0 -0.3 -0.2 0 0 0 1 0.012345679012346 0 -0.3 -0.2 0 0 0 1 0.012345679012346 0</pre>	
<u> </u>	



Create Detailed Source - Position/Directions - Read Ray File Dialog

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Dialog name/function

Specify a ray file and select a subsection of the content.

How Do I Get There? Dialog name/function

1. Select User defined rays from the Ray Positions>Type dropdown menu.

Polar	ization		Wavele	naths	1	Visualizat	ion) OK
Source	Positions/Directions Location/Orientation Power Coherence						i ——	
			'					
Ray Positions								Apply
Туре:	User defined r	ays (manual	y defined a	nd/or read from	ray file)			
Parameters:	X	Pos	Y Pos	Z Pos	X Dir	Y Dir		Help
	0	0			0	0	1	
				elete One Row				
			D	elete Highlighte	d Rows			
			A	ppend Rays Fro	om a File			
	Replace With Rays From a File							
Ray Direction	ons Show Last Accessed File Name							
Туре:	Single Directio	n (plane wa		How case Heess	sea i ne name		_	
			-					
Parameters:		Paramete	-					
	X Component		•••••	nent of ray dire				
	Y Component		•••••	nent of ray dire				
	Z Component].]	Z compo	nent of ray dire	CTION			

2. Select an existing ray file.

Open: Ray Da	ta File			<u>? ×</u>
Look in: 🗀	Documents	-	* 🖻	∷
RayData.r	ау			
	2			
	2			
File name:	RayData.ray			Open
Files of type:	FRED Binary Format (*.ray)	•	-	Cancel
	·		_	

Dialog Box and Controls



Dialog name/function

Read Ray	File		×
Name:	C:\Documents	and	<u>ОК</u>
Format:	Text		Cancel
2000		Total number of rays detected in the file	Help
1	*	Start reading rays at this ray	
2000	•	Stop reading rays at this ray	
1	-	Read every n'th ray. (1 for every	y ray)

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Name_	Ray file name	<u>N/A</u>
Format_	Ray file format [binary = *.ray or text = <u>*.txt]</u>	<u>N/A</u>
Total number of rays in file	Total number of rays	<u>N/A</u>
Start/Stop	Beginning/ending ray number	<u>1, max #</u>
Read every n'th ray	Reduces number of rays read by a factor of n	<u>1</u>
<u>OK</u>	Read Ray File and close dialog box.	_
Cancel	Discard Read and close dialog box.	_
Help	Access this Help page.	_

Application Notes Dialog name/function

_

See Also.... Dialog name/function

Description- Detailed Source Wavelength Dialog

This tab of the Source editing dialog allows you to specify the wavelengths along with their associated weights and colors, and wavelength apodization for a given source.

The wavelengths are specified in units of microns. Each wavelength has an associated relative weight in arbitrary units. It also has an associated color that sets the color of the ray trajectory as it is being drawn on the computer screen. The default color is opposite of the background color of the 3D rendering window. A right mouse click context menu item can be used to automatically set ray colors to match the visual color at the associated wavelength.

How Do I Get There? - Detailed Source Wavelength Dialog

Right click on the Optical Sources folder in the tree and choose "Create <u>New Detailed Optical</u> Source". Alternately, right click on an existing source and choose "<u>E</u>dit/View Detailed Optical Source". When the dialog appears, click the Wavelengths tab.

Dialog Box and Controls - Detailed Source Wavelength Dialog

(* (FRED1) Create a New Optical Source: "Optical Sources"	
Polarization Wavelengths Visualization)K
Wavelength List (right mouse-click for rmenu) Wavelength Apodization (optional) Wavelength List (right mouse-click for rmenu) Type:	ncel pply elp

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Wavelength List	Specifies the wavelengths for the source	One wavelength, 0.5875618 um, weight 1
Wavelength Apodization Type	Specifies any apodization applied to the source	Uniform Unit Apodization
Wavelength Apodization Parameters	Specifies the parameters of the apodization	
OK	Dismisses the dialog and applies the changes	
Cancel	Dismisses the dialog and discards the changes	
Apply	Keeps the dialog open and applies the changes	
Help	Displays this help article	

Application Notes - Detailed Source Wavelength Dialog

This tab is part of a modeless, resizable dialog.

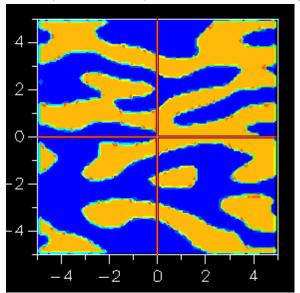
See Also - Detailed Source Wavelength Dialog



Create Detailed Source - Amplitude/Phase Mask from Rectilinear Grid

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Power Apodization - Amplitude/Phase Mask



Source power can be apodized from a rectilinear grid of amplitude/phase data.

How Do I Get There? Power Apodization - Amplitude/Phase Mask

Amplitude/Phams mask apodization can be accessed from the Position Apodization option on the Power Tab of a Detailed Source:

Polari	ization		Wave	elengths	Visu	alization	OK
Source	Positions/E	irections	Loc	ation/Orientation	Power	Coherence	
Tatal David			1				
Total Powe	,-						Appl
Position Apodi: 	zation			Direction Apodiza	ation		
Туре:				Туре:			Help
,	ase Mask on Ri	ectilinear Grid	<u> </u>		odization (equivale	nt to no apoc	
Parameters:				Parameters:			
X across	Cell: (top=p	ower, bot=w	/ave_≜	No Data Requi	red		
Y down	(0) -1	(1) -0.5					
(0)	1	1	1				
-1	0	0	0				
(1)	1	1	1				
-0.5	0	0	0				
(2)	1 0	<u>1</u> 0					
(3)	1	1					
0.5	0	0	<u> </u>				
- ⁷⁴	1	4					

A right-click in the Table area offers the following options:



Polaria	zation	1	Wave	elengths
Source	Positions/	Directions	Loc	ation/Orientation
Total Powe Position Apodiz]	Direction Apodization
Type:		Marine Codel		Type:
Amplitude/Pha	ase Mask on H	ectilinear urid	▼	Uniform Unit Apodiza
Parameters:	Calls (tan			Parameters:
X across Y down	(0) -1	ower, bot=) (1) -0.5		No Data Required
(0) -1 (1) -0.5 (2) 0 (3) 0.5 (4) 1	1 Se 1 Ma 0 Im 1 Im 0 Im	-0.5 t Sampling Arr dify Cell Value port Bitmap to port Bitmap to play as Power play as Power play as Amplit play as Real F play as Wave play as Wave play as Phase play as Ph	es) Cell Tops.) Cell Botto r :ude Part s (degrees) (radians) nary ver olitude I Part ves se (degrees se (degrees se (radians)	ms

Importing amplitude data - Import Bitmap to Cell Tops...

Interpret as Power Amplitude Real Part

Importing Phase data - Import Bitmap to Cell Bottoms.. Interpret as Waves OPL

Phase (deg) Phase (radians) Imaginary

<u>Application Notes</u> Power Apodization - Amplitude/Phase Mask

- The Sampling Array Size should match the X- and Y-Semi-Ape as set on the Source Position/Direction Tab. Take into account the dimensions of the bitmap as well.
- The spatial sampling of a Grid should be consistent with sampling required to accurately reproduce the amplitude/phase mask. In the case of coherent sources, be aware that spatial sampling is limited to about 10 λ due to the paraxial condition imposed on the individual gaussian beamlets ($\theta < 0.01$).

<u>See Also....</u> Power Apodization - Amplitude/Phase Mask

> R^n distance apodization Gaussian apodization Amplitude/Phase Mask Modify Sizing the Amplitude/Phase Mask



Create Detailed Source - Wavelength - Synthesize A Color Dialog

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Synthesize A Color Dialog

Synthesizes a source color over a given wavelength range based upon user-specified Chromaticity coordinates, Tristimulus values, or visual RGB color.

How Do I Get There? Synthesize A Color Dialog

Open a dialog with a wavelength list, then right-click in the list and choose "Synthesize a Color..."

FRED1) Cre	eate a New Optica	al Source: "Optical Sources"	<u>_ ×</u>
Source Pol	Positions/Dire arization	ctions Location/Orientation Power Co Wavelengths Visualizatio	n Cancel
-	h List (right mouse-c /aviens (um)	ick for rmenu) Wavelength Apodization (option Weights Ray Color Type:	
1 0 2	.5875618	1 Uniform Unit Apodization 1 Image: Comparison of the second se	Help
	Insert V Delete V Set War Set CDF Set CdF Set CdF Set C'df	velength /avelength /avelength /elength Range 'Wavelengths 'Wavelengths 'Wavelengths idard Bitmap Wavelengths ize a Color	
<u> </u>	Apply <u>P</u> Apply <u>S</u>	Veights to Unity (1) notopic Weights cotopic Weights (dark adapted) Color From Wavelength	

The Synthesize a Color option as shown on the Create/Edit Detailed Optical Source Dialog

Dialog Box and Controls Synthesize A Color Dialog

(Localized Local

Synthesize A Color	X
Use this dialog to define a set of weighted wavelengths whic given color. Note that the wavelength range and count of w range is not unique. Many different combinations can synthe color. The Color Specification (select one option) Chromaticity Coordinates × 0.3127 y 0.329 Tristimulus Values × 0.3127 Y 0.329 Z 0.3583 Visual Color (RGB)	avelengths in the
Wavelength List (press the Refresh button to refresh) Wavelength Weight	Refresh Wavelength List
	Apply Nonzero to Source Apply All to Source Note: negative weights mean the color can not be synthesized by the current wavelength range and count.

<u>Control</u>	Inputs / Description	<u>Defaults</u>
	The Color Specification	
Chromaticity Coordinates: x, y	Specify color using Chromaticity Coordinates.	Selected (0.3127, 0.329)
Tristimulus Values: X,Y,Z	Specify color using Tristimulus values.	Not selected (0.3127, 0.329, 0.3583)
Visual Color (RGB)	Specify color using RGB.	Not selected



Visual Color Selector	Select color from Windows RGB color palette.	White
	Wavelength Range	
From - To	Range of wavelengths used to synthesize color.	0.46, 0.62
Count	Number of wavelengths in the From-To range.	3
	Wavelength List	
Refresh Wavelength List	List wavelengths and weights.	
Apply Nonzero to Source	Use only nonzero weighted wavelengths in range to construct source.	
Apply All to Source	Use all wavelengths in range to construct source.	
Dismiss	Closes dialog box.	
Help	Access this Help page.	

Application Notes Synthesize A Color Dialog

This dialog is resizable and retains its position when dismissed. It is modal and must be dismissed before other work can be done.

<u>See Also....</u> Synthesize A Color Dialog



Create Detailed Source - Wavelength - Range Dialog

Description How Do I Get There? Dialog Box and Controls Application Notes

Description Wavelength Range Dialog

This dialog adds a range of wavelengths to a Wavelength List.

How Do I Get There? Wavelength Range Dialog

From a wavelength list, right click and choose "Set Wavelength Range...".

(FRED1 *) Create a New Optical Source: "Optical Sources"				
Source Positions/Direc Polarization	Wavelengths	Visu	Coherence	OK Cancel
1 0.46 💌	Weights Ray Color 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	- Wavelength Apodization Type: Uniform Unit Apodization Parameters: No Data		Apply Help

The menu option for the Wavelength Range dialog, as seen from the Wavelengths page of the New Detailed Optical Source dialog

Dialog Box and Controls Wavelength Range Dialog

Wavelength Range	×
Generate wavelengths from 0.486	1327 💌 microns
to 0.656	2725 💌 microns
Number of steps in range: 3	÷
Cancel	Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Generate wavelengths from	The starting wavelength of the range, measured in micrometers.	0.4861327
to	The ending wavelength of the range, measured in micrometers.	0.6562725
Number of steps in range	The number of wavelengths between the start and the end.	3
ОК	Accept Wavelength Range changes and close dialog box.	
Cancel	Discard Wavelength Range changes and close dialog box.	
Help	Access this Help page.	

Application Notes Wavelength Range Dialog

This dialog is modal - that is, it must be closed before any other work can proceed.

Create Detailed Source - Power

<u>Description - Power (Create New and Edit/View Detailed Source...)</u>

The Power page of the Create New and Edit/View Detailed Source... dialogs three functions:

- Set the total Power of the source after the Position Apodization and Direction Apodization have been applied to the rays.
- Set the Position Apodization for the ray positions defined.
- Set the Direction Apodization for the ray directions defined.

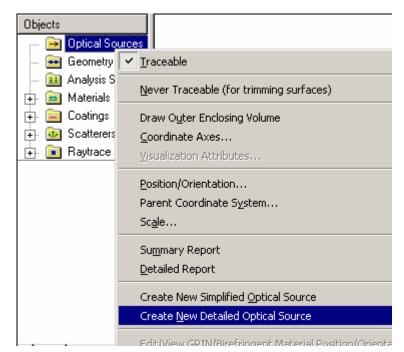
(FRED1) Create a New Optical Source: "Optical Sources"	_ 🗆 🗵
Polarization Wavelengths Visualization	ОК
Source Positions/Directions Location/Orientation Power Coherence	Cancel
Total Power: 1	Apply
Position Apodization	
Туре: Туре:	Help
Uniform Unit Apodization (equivalent to no 💌 Uniform Unit Apodization (equivalent to no 💌	
Parameters: Parameters:	
No Data Required No Data Required	

How Do I Get There? - Power (Create New and Edit/View Detailed Source...)

There are two different ways to execute this command:

1. Right click on the Optical Sources and select Create New Detailed Optical Source... in the right click pop-up menu,





2. Right click on an Source and select Edit/View Detailed Optical Source... in the right click pop-up menu,

Objects	
🕞 🗟 Optical Source	es
🔤 🚅 Source 1	
- 🔤 Geometry	✓ <u>T</u> raceable
🔤 🏛 Analysis Surf	Never Traceable (for trimming surfaces)
🕂 💼 Materials -	Herei Hacobie (for anning sarraces)
🕂 🧰 Coatings	Draw O <u>u</u> ter Enclosing Volume
🕂 亟 Scatterers	<u>C</u> oordinate Axes
🕂 间 Raytrace Pro	Visualization Attributes
	<u>P</u> osition/Orientation Parent Coordinate S <u>v</u> stem
	Sc <u>a</u> le
	Summary Report
	Detailed Report
	Edit/View Simplified Optical Source
	Edit/View Detailed Optical Source
•	Edit/View GRIN/Birefringent Material Position/Orie



Polarization Wavelengths Visualization Source Positions/Directions Location/Drientation Power Coherence Total Power: 1 Direction Apodization Type: Uniform Unit Apodization (equivalent to no Image: Comparison (equivalent t	OK Cancel Apply Help
Parameters: No Data Required No Data Required No Data Required	

Dialog Box and Controls - Power (Create New and Edit/View Detailed Source...)

<u>Control</u>	Inputs	<u>Defaults</u>
Total Power	The total power of the source. Rays in the source are scaled <i>after</i> both the position and direction apodization functions have been applied.	1
Position Apodization		
Туре	Pull down menu of available position apodization options: Uniform Gaussian R ⁿ distance from a given point	Uniform
Direction Apodization		

Туре	Pull down menu of available directionapodization options:UniformLambertianInverse LambertianCos ⁿ or Sin ⁿ Sampled (spherical angles)	Uniform
ОК	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

There are two options for the Position Apodization of the rays besides the first option of no apodization.

Г	Position Apodization
	Туре:
	Uniform Unit Apodization (equivalent to no 💌
	Uniform Unit Apodization (equivalent to no apodiza
	Gaussian Apodization (useful for Gaussian beams)
	R [^] n distance Apodization from a given point

There are four options for the Direction Apodization of the rays besides the first option of is no apodization.

- (Direction Apodization		
	Туре:		
	Uniform Unit Apodization (equivalent to no 💌		
	Uniform Unit Apodization (equivalent to no apodizat		
	Lambertian in a given direction Inverse Lambertian in a given direction		
	cos^n or sin^n in a given direction		
	Sampled as a function of spherical angles		

The Position Apodization options

Uniform Unit Apodization (equivalent to no apodization) Gaussian Apodization (useful for Gaussian Beams) R^n Distance Apodization from a Given Point

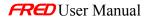
The Direction Apodization options <u>Uniform Unit Apodization (equivalent to no apodization)</u> Lambertian in a given direction



Inverse Lambertian in a given direction Cosⁿ or Sinⁿ in a given direction Sampled as a function of spherical angles

See Also... - Power (Create New and Edit/View Detailed Source...)

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength Visualization



Create Detailed Source - Power - Lambertian in a Given Direction Apodization

Description How Do I Get There? Dialog box and Controls

Description

Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

The Lambertian in a Given Direction Apodization option scales all the rays in the source to have a Lambertian intensity. This Lambertian option effectively apodizes the rays with a $\cos(\phi)$ factor where ϕ is a elevation angle in polar coordinates.

The Lambertian in a Given Direction Apodization option is radiometrically equivalent to having Uniform Direction Apodization and setting the source rays to be Lambertian on the Positions / Directions page. Although these two methods of generating a Lambertian source are radiometrically equivalent, they are represented with different distributions of rays. The Lambertian option on the Positions / Directions page distributes the rays equally in direction cosine space and the Isotropic option on the Positions / Directions page distributes the rays equally in angle space.

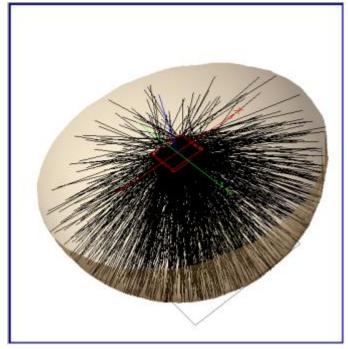


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with Lambertian in a Given Direction Apodization.

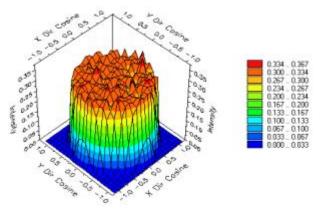


Figure 2. This Intensity Spread Function plot of an Isotropic source with a Lambertian in a Given Direction Apodization on the Power page.

<u>How Do I Get There?</u> Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

Objects	
👘 🖻 🕞 🕞	urces
- 🔤 Geometry	✓ <u>I</u> raceable
🕂 🏛 Analysis S 🕂 💼 Materials	Never Traceable (for trimming surfaces)
🕂 🧮 Coatings	Draw Outer Enclosing Volume
🕂 🔂 Scatterers	Coordinate Axes
🕂 💽 Raytrace	Visualization Attributes
	Position/Orientation
	Parent Coordinate System
	Sc <u>a</u> le
	Summary Report
	Detailed Report
	Create New Simplified Optical Source
	Create New Detailed Optical Source

Dialog Box and Controls

Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

The Direction Apodization section of the dialog:

(newport.frd) Edit Optical Source: "Source 1"		_ 🗆 🗙
Polarization Wavele Source Positions/Directions Locati	ion/Orientation Power Coherence	OK Cancel
Total Power:	Direction Apodization	Apply
Type: Uniform Unit Apodization (equivalent to no 💌	Type: Lambertian in a given direction	Help
Parameters:	Parameters:	
No Data Required	Parameter Description	
	X 0 X component of direction Y 0 Y component of direction	
	Y 0 Y component of directio Z 1 Z component of direction	



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Total Power	Total PowerThe total power of the source after both the position and direction apodization functions have been applied to the rays.					
	Position Apodization					
Туре	Pull down menu of available position apodization options.	Uniform				
Parameters	There are no parameters for this option.					
	Direction Apodization					
Туре	Uniform					
	Parameters					
X	X component of direction cosine vector of the given direction for the Lambertian intensity pattern.	0				
Y	Y component of direction cosine vector of the given direction for the Lambertian intensity pattern.	0				
Z Z Component of direction cosine vector of the given direction for the Lambertian intensity pattern.		1				
OK	Create a new Optical Source and close the dialog box.					
Cancel	Discard Source Power changes and close the dialog box.					
Apply	Apply Source Power changes and keep the dialog box open.					
Help	Access this Help page.					



Create Detailed Source - Power - Inverse Lambertian in a Given Direction Apodization

Description How Do I Get There? Dialog box and Controls

Description

Inverse Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

The Inverse Lambertian in a Given Direction Apodization option scales all the rays in the source to have an Inverse Lambertian intensity. The Inverse Lambertian option in effect apodizes the rays with a $1/\cos(\phi)$ factor where ϕ is the elevation angle in polar coordinates. If the source rays are set to be Lambertian on the Positions / Directions page and then the Inverse Lambertian in a Given Direction Apodization option would make the intensity pattern Isotropic in effect.

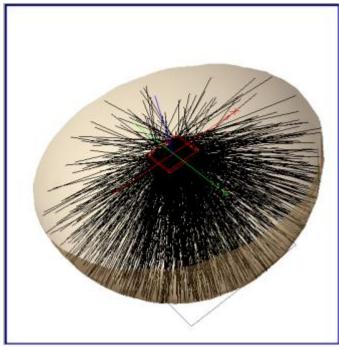


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with Inverse Lambertian in a Given Direction Apodization.

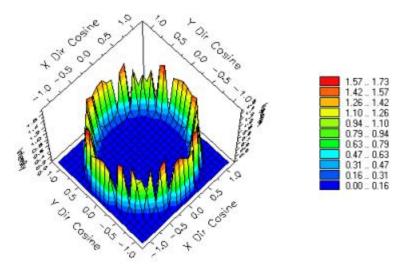


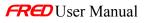
Figure 2. This Intensity Spread Function plot of an Isotropic source with a Inverse Lambertian in a Given Direction Apodization on the Power page. Note that the center of this intensity pattern in not zero as this Intensity Spread Function plot suggests.

How Do I Get There?

Inverse Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

Objects Optical Sources Traceable 🔁 Geometry 🛄 Analysis S Never Traceable (for trimming surfaces) 💼 Materials ÷ 🕂 📄 Coatings Draw Outer Enclosing Volume ∔ 🚾 Scatterers Coordinate Axes... 🕂 间 Raytrace Visualization Attributes,... Position/Orientation... Parent Coordinate System... Scale... Summary Report Detailed Report Create New Simplified Optical Source Create New Detailed Optical Source Edit/View GRIM/Birefringent Material Position/Orienta

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



Dialog Box and Controls

Inverse Lambertian in a Given Direction Apodization (Create New and Edit/View Detailed Source...)

•						
d) Edit Optical So	urce: "Source 1"					
arization	•	_	, I,		1	ОК
	xtions Locati	ion/Orient	ation	Power	Coherence	Cancel
,		Disastia		1		Apply
		Type:				Help
	valent to no 💌			ian in a given d	irection 🔽	
		Param		ter Descript	tion	
lequireu		x	0	-		
		Y	0			
			1			
		Angle] 89	Limiting a	ngle (deg) U<≕	
		•			Þ	
	d) Edit Optical So arization Positions/Directory ower: 1 odization	d) Edit Optical Source: "Source 1" arization Wavele Positions/Directions Location odization nit Apodization (equivalent to no v s: tequired	d) Edit Optical Source: "Source 1" arization Wavelengths Positions/Directions Location/Orient ower: 1 odization nit Apodization (equivalent to no . Required	d) Edit Optical Source: "Source 1" arization Wavelengths Positions/Directions Location/Orientation ower: Direction Apodization it Apodization (equivalent to no temperature in the second se	d) Edit Optical Source: "Source 1" arization Wavelengths Visu Positions/Directions Location/Orientation Power ower: 1 0 odization Type: Inverse Lambertian in a given of Parameters: it Apodization (equivalent to no .) Inverse Lambertian in a given of Parameter Description of Y of Y comport x 0 X comport Y 0 Y comport Angle 89 Limiting at the second of the	d) Edit Optical Source: "Source 1" arization Wavelengths Visualization Positions/Directions Location/Drientation Power Coherence ower: 1

The Direction Apodization section of the dialog:



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>					
Total Power:	Total power:Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.						
	Position Apodization						
Туре:	Pull down menu of available position apodization options.	Uniform					
Parameters:	There are no parameters for this option						
	Direction Apodization						
Туре:	Pull down menu of available direction apodization options. Choose Inverse Lambertian in a given direction.	Uniform					
	Parameters						
X	X component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.	0					
Y	Y component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.						
Ζ	Z component of direction cosine vector of the given direction for the Inverse Lambertian intensity pattern.	1					
Angle	Inverse Lambertian apodization factor, $1/\cos(\phi)$, goes to infinity as ϕ approaches zero. So, this apodization pattern is limited to angle less than 90° .	89					
ОК	Create a new Optical Source and close the dialog box.						
Cancel	Discard Source Power changes and close the dialog box.						
Apply	Apply Source Power changes and keep the dialog box open.						
Help	Access this Help page.						

Create Detailed Source - Power - Cosⁿ or Sinⁿ in a given direction

Description How Do I Get There? Dialog box and Controls

Description

Cosⁿ or Sinⁿ in a given direction (Create New and Edit/View Detailed Source...)

The \cos^n or \sin^n in a given direction option scales all the rays in the source to have an \cos^n or \sin^n intensity.

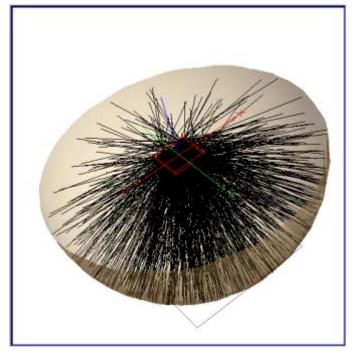


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with a \cos^{n} or \sin^{n} in a given direction apodization.

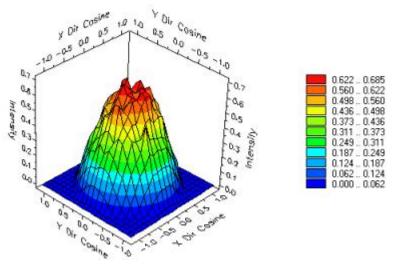


Figure 2. This Intensity Spread Function plot of an Isotropic source with a \cos^n or \sin^n in a given direction with \cos^n or \sin^n in a given direction where the Cos function was selected and the exponent set to three.

<u>How Do I Get There?</u> Cosⁿ or Sinⁿ in a given direction (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

Objects	
- Optical So	
- e Geometry	
- 🔛 Analysis S	
+ 📾 Materials	Never Traceable (for trimming surfaces)
+ 📄 Coatings	Draw Outer Enclosing Volume
🕂 🚾 Scatterers	
🕂 直 Raytrace	Visualization Attributes
	Position/Orientation
	Parent Coordinate System
	Sc <u>a</u> le
	Summary Report
	— • •
	Detailed Report
	Create New Simplified Optical Source
	Create New Detailed Optical Source

Dialog Box and Controls

Cosⁿ or Sinⁿ in a given direction (Create New and Edit/View Detailed Source...)

The Direction Apodization section of the dialog:



🗳 (newport.frd) Edit Optical Source: "Source 1	1 "	_ 🗆 X
· · · ·	elengths Visualization	ОК
Source Positions/Directions Loc	cation/Orientation Power Coherence	Cancel
Total Power: 1		Apply
Position Apodization	Direction Apodization	
Type: Uniform Unit Apodization (equivalent to no. 🔻	Type: cos^n or sin^n in a given direction	Help
Parameters:	Parameters:	
No Data Required	Parameter Descript	
	Type Cos I Sin Angle fun	
	Exp 1 Function 6	
	X 0 X compor	
	Y 0 Y compor	
	Z 1 Z compor	



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>		
Total Power:	otal Power:Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.			
	Position Apodization			
Туре	Uniform			
Parameters:	There are no parameters for this option.			
	Direction Apodization			
Туре	Pull down menu of available direction apodization options. Choose cos^n or sin^n in a given direction	Uniform		
	Parameters			
Cos/Sin	Apodization based on the Cosine or Sine function.	Cos		
Exp	The exponent of the Sin or Cos function. This exponent can be positive or negative and be integer or non-integer.	1		
Х	X X Component of direction cosine vector of the given direction for the intensity pattern.			
Y	Y component of direction cosine vector of the given direction for the intensity pattern.	0		
Ζ	Z component of direction cosine vector of the given direction for the intensity pattern.	1		
OK	Create a new Optical Source and close the dialog box.			
Cancel	Discard Source Power changes and close the dialog box.			
Apply	Apply Source Power changes and keep the dialog box open.			
Help	Access this Help page.			



Create Detailed Source - Power - Rⁿ Distance Position Apodization

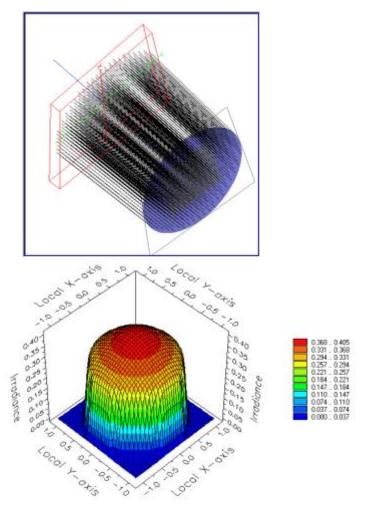
Description How Do I Get There? Dialog box and Controls

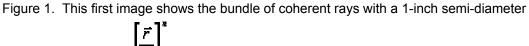
<u>Description</u> *Rⁿ* Distance Position Apodization (Create New and Edit/View Detailed Source...)

The Rⁿ Distance Position Apodization option scales all the rays in the source relative to their distance from the point, $\vec{P_0}$, defined in the dialog. The rays are scaled by:

$\begin{bmatrix} \vec{r} \\ \vec{r}_0 \end{bmatrix}^n$ Where $\vec{r} = \left| \vec{R}_p - \vec{P}_0 \right|$ is the distance from a given ray position, \vec{R}_p , to the reference point, \vec{P}_0 , set in the dialog with the X, Y, and Z coordinates. This distance can be normalized with the r_0 factor. The exponent, n, can be negative or positive and integer or non-integer.







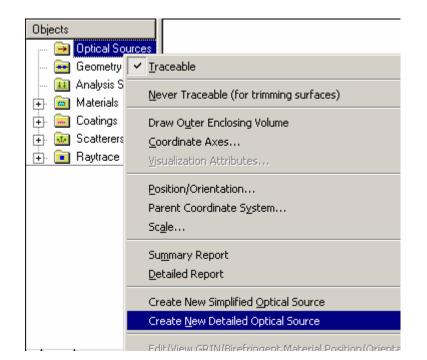
that have been scaled by $\left[\frac{\vec{r}}{r_0}\right]^{n}$ were n = -2, $r_0 = 1$, and $\vec{P}_0 = [0,0,1.5]$. The second image shows resulting irradiance profile.

How Do I Get There?

 R^n Distance Position Apodization (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.





Dialog Box and Controls

R ⁿ Distance Position Apodization	(Create New and Edit/View Detailed Source)
--	--

Source		tions/Directions Loca		gths Visualization n/Orientation Power Coherence	OK Cance
Position	al Power: 1		Г	Direction Apodization	Apply
Type:				Type:	Help
· · · · ·		zation from a given poir 💌		Uniform Unit Apodization (equivalent to no	
Param		Description		Parameters: No Data Required	
Ехр	-2	R'n function exponent (c		no bata Kedun eu	
X	0	X component of referenc			
Y	0	Y component of referenc			
Z	1	Z component of referenc			
Dist	1	Reference distance for n			
		Þ			

—

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Total Power	Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.	1
	Position Apodization	
Туре	Pull down menu of available position apodization options. Choose R^n distance Apodization from a given point .	Uniform
Exp	Exponent in the $\begin{bmatrix} \vec{r} \\ \vec{r_0} \end{bmatrix}^*$ scale factor.	-2
X	X component in \vec{r}_{0} vector, which is used to compute the distance $\vec{r} = \vec{R}_{y} - \vec{P}_{0} $.	0
Y	Y component in \vec{r}_{0} vector, which is used to compute the distance $\vec{r} = \vec{R}_{y} - \vec{P}_{0} $.	0
Z	Z component in \vec{F}_{0} vector, which is used to compute the distance $\vec{r} = \vec{R}_{p} - \vec{P}_{0} $.	1
Dist	Normalization value in the denominator of the scale factor $\left[\frac{\vec{r}}{r_0}\right]^{n}$	1
	Direction Apodization	
Туре	Pull down menu of available direction apodization options.	Uniform
Parameters	There are no parameters for this option.	
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

Create Detailed Source - Power - Sampled as a Function of Spherical Angles

Description How Do I Get There? Dialog box and Controls

Description

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source...)

The Sampled as a Function of Spherical Angles option scales all the rays in the source to an arbitrary intensity pattern defined in spherical angles. Apodization factors are entered for as a function of azimuth and polar angles. Between the specified azimuth and polar angles, the apodization factor is linearly interpolated. If data is entered for only one Azimuth angle then the apodization profile is considered rotationally symmetric.

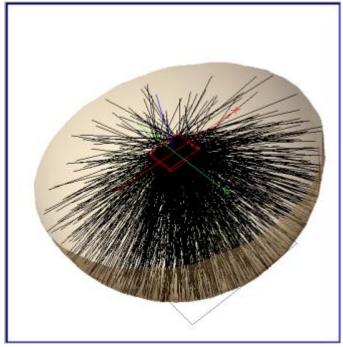
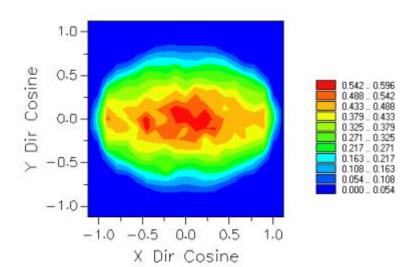


Figure 1. This figure illustrates an Isotropic plane of random rays emitting to a 90° cone with a Sampled as a Function of Spherical Angles apodization.



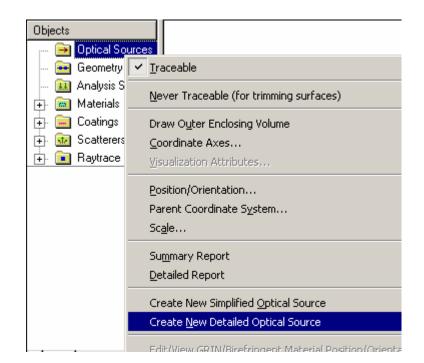
Sampled	as a fu	nction o	f spheri	cal angles						
Paramete	irs:									
	x	Y	z	Descri	ption					
Polar	0	0	1	Direction of polar axis						
Azimuth	1	0	0	Directio	n of azi	muth axi	\$			
	Polar	angles	(deg) -	down,	Azimuth angles(deg) - across					
	-180	-135	-90	-45	0	45	90	135	180	
0	1	1	1	1	1	1	1	1	1	
10	0.9	0.85	0.8	0.85	0.9	0.85	0.8	0.85	0.9	
20	0.8	0.7	0.6	0.7	0.8	0.7	0.6	0.7	0.8	
30	0.7	0.55	0.4	0.55	0.7	0.55	0.4	0.55	0.7	
40	0.6	0.4	0.2	0.4	0.6	0.4	0.2	0.4	0.6	
50	0.5	0.25	0.1	0.25	0.5	0.25	0.1	0.25	0.5	
60	0.4	0.1	0	0.1	0.4	0.1	0	0.1	0.4	
70	0.3	0	0	0	0.3	0	0	0	0.3	
80	0.2	0	0	0	0.2	0	0	0	0.2	
90	0	0	0	0	0	0	0	0	0	

Figure 2. This Intensity Spread Function plot of an Isotropic source where the rays have been scaled with a Sampled as a Function of Spherical Angles direction apodization. The apodization factors for this pattern are shown as well.

How Do I Get There?

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



Dialog Box and Controls

Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source...)

The Direction Apodization section of the	ne dialog:				
(newport.frd) Edit Optical Source: "Source 1"					_ 🗆 🗙
Source Positions/Directions Location/Orientation Power	Coherence Pol	larization 🛛 🕅	Wavelengths	Visualization	ОК
Total Power:					Cancel
Position Apodization Type:	– Direction Apodiza Type:	ation			Apply
Uniform Unit Apodization (equivalent to no apodiz	Sampled as a fu	unction of sp	oherical angle	es 💌	Help
Parameters:	Parameters:				
No Data Required		х	Y	Z	
	Polar	0	0	1	
	Azimuth	1	0	0	
	Polar Angles (0-180deg)	Azimuth /	Angles (-18	0<=ang<=+1	
	0	1			
	4			Þ	



—

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>					
Total Power	Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.	1					
	Position Apodization						
Туре	Pull down menu of available position apodization options.	Uniform					
Parameters	There are no parameters for this option.						
	Direction Apodization						
Type Pull down menu of available direction apodization options. Choose Sampled as a Function of Spherical Angles.		Uniform					
	Parameters						
Polar X, Y, Z	Direction of the polar axis in the apodization table.	0, 0, 1					
Azimuth X, Y, Z	Direction of the azimuth angle in the apodization table.	1, 0, 0					
Polar Angles(deg) – down, Azimuth angles(deg) - across	The apodization table is organized with the rows representing the polar angles and the columns representing the azimuth angles. Additional rows and columns can be added via a right click pop-up menu (shown in the figure above). The azimuth angles must be within the range of –180 to 180 and the polar angles must be within the range of 0 to 180. Note that previous versions of FRED limited the polar angles to 0 to 90. If polar angle data for only one azimuth angle (column) is entered, then the apodization is assumed to be rotationally symmetric. If polar data is entered for more than one azimuth angle is entered, then apodization for angles in between the entered data in linearly interpolated.	0					
ОК	Create a new Optical Source and close the dialog box.						
Cancel	Discard Source Power changes and close the dialog box.						
Apply	Apply Source Power changes and keep the dialog box open.						
Help	Access this Help page.						

<u>Application Notes</u> Sampled as a Function of Spherical Angles (Create New and Edit/View Detailed Source...)

 Tabulated data can be read into this option using the subroutine below. The file containing the data should have two or more columns. The first row contains the azimuthal angles (Note the first entry in the first column of the first row is a placeholder; its value is irrelavant). Subsequent rows contain the polar angle followed by apodization values. The data format for single/multiple azimuthal angles is shown below.

Data Format

Single azimuthal angle (rowz=18, colz=2)

Multiple azimuthal angles (rowz=18, colz=5)



File Edit Format View Help 0.00 1.00 5.32 0.98 9.83 0.95 15.16 0.91 19.67 0.87 24.59 0.81 29.50 0.74 34.83 0.67 40.16 0.56 57.73 0.24 59.01 0.12 67.21 0.07 73.77 0.05 79.50 0.02 I 85.65 0.05] 0.0 9.83 0.97 9.83 0.95	🗩 creex	CRangle.	txt - Notep	ad 📘		
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	File Edit	Format	View Help)		
File Edit Format View Help 0.0 -90 0 90 180 0.00 1.00 1.00 1.00 1.00 5.32 0.98 0.97 0.95 0.97 98 98 98 98 98 98 39	0.00 5.32 9.83 15.16 19.67 24.59 29.50 34.83 40.16 45.08 49.18 52.45 55.73 59.01 67.21 73.77 79.50	1.00 0.98 0.95 0.91 0.87 0.81 0.74 0.56 0.47 0.39 0.34 0.24 0.12 0.07 0.05 0.02		I		
File Edit Format View Help 0.0 -90 0 90 180 0.00 1.00 1.00 1.00 1.00 5.32 0.98 0.97 0.95 0.97 98 98 98 98 98 98 39					~	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	📕 CreeXC					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	- creene	.Rangle2	.txt - Notep	oad		>
				oad		>

In the following subroutine, it is necessary to enter the dimensions of the text file matrix of numbers for the array angles as constants rows and cols. (Recall that arrays in Enable Basic are zero-indexed.)

This example reads in either of the datasets shown above by changing the value of cols from 2 (for single) to 5 (for multiple).

Subroutine

'call and execute subroutine readdirapoddata "CreeXCRangle"

Sub readdirapoddata (fname As String) Dim filename As String Dim filedata As String Dim values() As Double Dim strings() As String Dim numang As Long

Const rowz=18'rows of data (not counting the first row)Const colz=2'number of columnsDim angles(rowz, colz-1) As Double

sid=FindName("Source 1")

filename=CurDir & "\" & fname & ".txt" numang=0

Open filename For Input As #1 Do While Not EOF(1) Line Input #1, filedata n=ParseString(filedata, " ", values, strings) For i=0 To colz-1 angles(numang,i)=values(i) Next i numang=numang+1 Loop Close #1

SetSourceDirApodSampled sid, angles, 1, 0, 0, 0, 0, 1

Print "Source apodized" Update

End Sub



Create Detailed Source - Power - Uniform Direction Apodization

Description How Do I Get There? Dialog box and Controls See Also...

Description Uniform Direction Apodization

The Uniform Direction Apodization option scales all the rays in the source to have uniform power as a function of ray direction. This is equivalent to having no direction apodization.

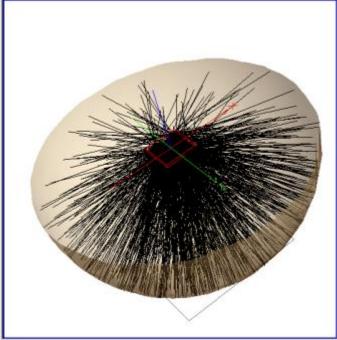
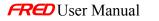


Figure 1. This figure illustrates a plane of random rays emitting to a 90° cone with Uniform Direction Apodization.



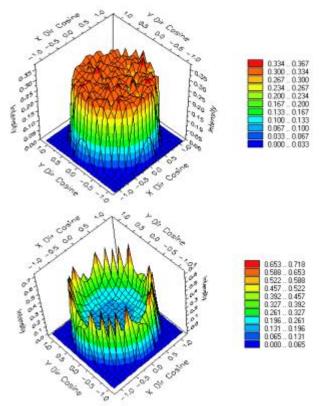


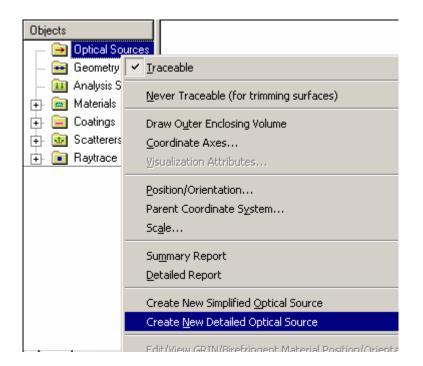
Figure 2. The first Intensity Spread Function plot is for a Lambertian source and the second Intensity Spread Function is for an Isotropic source, both have a Uniform Direction Apodization on the Power page.

How Do I Get There? Uniform Direction Apodization

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



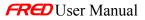
_



Dialog Box and Controls Uniform Direction Apodization

The Direction Apodization section of the dialog:

侯 (newport.frd) Edit Optical S	ource: "Source 1"		_ 🗆 🗵
Polarization	Wavelengths	Visualization	OK
Source Positions/Dire	ctions Location/Orientation	Power Coherence	Cancel
Total Power:			
Position Apodization	Direction Apodi	zation	Apply
Type: Uniform Unit Apodization (equ	ivalent to po : Type:	podization (equivalent to no (💌	Help
Parameters:			
No Data Required	No Data Requ	uired	

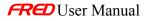


—

Control	Inputs	Defaults
Total Power	Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.	1
Position Apodiza	tion	
Туре	Pull down menu of available position apodization options.	Uniform
Parameters:	There are no parameters for this option	
Direction Apodiz	zation	
Туре:	Pull down menu of available direction apodization options.	Uniform
Parameters:	There are no parameters for this option	
_		
OK	Create a new Optical Source and close the dialog box.	
Cancel	Discard Source Power changes and close the dialog box.	
Apply	Apply Source Power changes and keep the dialog box open.	
Help	Access this Help page.	

See Also.... Uniform Direction Apodization

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength Visualization



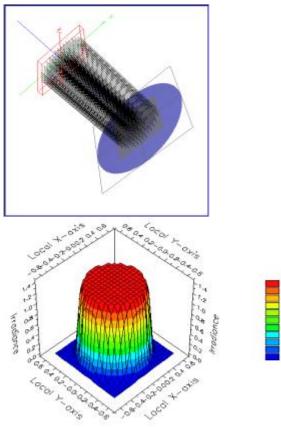
Create Detailed Source - Power - Uniform Position Apodization

Description How Do I Get There? Dialog box and Controls See Also...

Description

Uniform Position Apodization (Create New and Edit/View Detailed Source...)

The Uniform Position Apodization option scales all the rays in the source to have a uniform, equal power as a function of ray positions. This is equivalent to having not apodization.



<u>How Do I Get There?</u> Uniform Position Apodization (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.

1.14 1.01 0.09 0.75 0.63 0.51 0.38 0.25

0.51

Objects	urces
🔤 Geometry	Traceable
🕂 🛄 Analysis S 🕂 💼 Materials	Never Traceable (for trimming surfaces)
🕂 🧰 Coatings	Draw Outer Enclosing Volume
🕂 🐱 Scatterers 🕂 💽 Raytrace	<u>Coordinate Axes</u> Visualization Attributes
	Position/Orientation
	Parent Coordinate S <u>v</u> stem
	Scale
	Su <u>m</u> mary Report Detailed Report
	Create New Simplified Optical Source
	Create New Detailed Optical Source
	Edit/Wiew GRIN/Birefringent Material Position/Orienta

Dialog Box and Controls Uniform Position Apodization (Create New and Edit/View Detailed Source...)

The Position Apodization section of the dialog:	
🕻 (newport.frd) Edit Optical Source: "Source 1"	<u> </u>
Polarization Wavelengths Visualization	OK
Source Positions/Directions Location/Orientation Power Coherence	Cancel
Total Power:	Apply
Position Apodization	
Type: Uniform Unit Apodization (equivalent to no 🔻 Uniform Unit Apodization (equivalent to no 💌	Help
Parameters: Parameters:	
No Data Required No Data Required	

FRED User Manual

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>		
Total Power	Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.	1		
	Position Apodization			
Туре	Pull down menu of available position apodization options.	Uniform		
Parameters:	There are no parameters for this option			
	Direction Apodization			
Туре:	Pull down menu of available direction apodization options.	Uniform		
Parameters:	There are no parameters for this option			
ОК	Create a new Optical Source and close the dialog box.			
Cancel	Discard Source Power changes and close the dialog box.			
Apply	Apply Source Power changes and keep the dialog box open.			
Help	Access this Help page.			

See Also

Uniform Position Apodization (Create New and Edit/View Detailed Source...)

Source Positions / Directions Location / Orientation Power Coherence Polarization Wavelength Visualization



Create Detailed Source - Power - Gaussian Position Apodization

Description How Do I Get There? Dialog box and Controls

Description

Gaussian Position Apodization (Create New and Edit/View Detailed Source...)

The Gaussian Position Apodization option scales all the rays in the source to have a Gaussian power profile as a function of ray position. This is useful for modeling laser beams having a TEM_{00} Gaussian mode as well as the higher order Hermite or Laguerre modes. Note that it is important that the bundle of rays is significantly larger than the $1/e^2$ Gaussian power profile semi-diameter parameter set in the Power dialog.

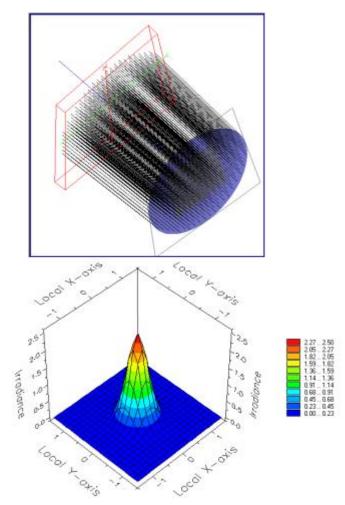


Figure 1. This first image shows the bundle of coherent rays with a 1-inch semi-diameter and the second image shows the Gaussian beam irradiance profile of these rays. Note that the $1/e^2$ Gaussian power profile semi-diameter is of the rays is 0.5.

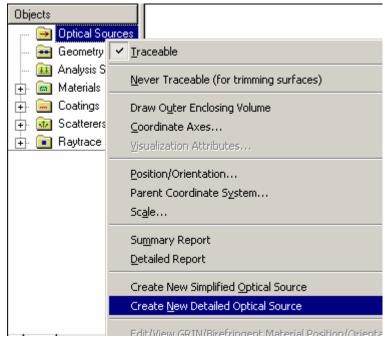
Note If a complete Gaussian profile is desired, then the beam bundle semi diameter should be roughly 2X larger than the 1/e² Gaussian power profile semi-diameter.

In the coherent case, the Gaussian beam profile is constructed with smaller Gaussian beamlets. As the number of rays in the Position/Direction page is increased, the sampling of the Gaussian profile with the Gaussian beamlets will be increased. As the ray sampling is increased, the diameter of the Gaussian beamlets is decreased resulting in Gaussian beamlets that diverge faster as they propagate. This faster divergence can result in a lower sampling on a later surface. A balance must be maintained between the increasing initial sampling of the Gaussian profile with more rays and decreasing the Gaussian beamlet divergence during propagation with fewer rays.

How Do I Get There?

Gaussian Position Apodization (Create New and Edit/View Detailed Source...)

This is an option in the Power page of the Create New Detailed Source... and Edit / View Detailed Source... dialogs.



Dialog Box and Controls

Gaussian Position Apodization (Create New and Edit/View Detailed Source...)

The Position Apodization section of the dialog:

RED2) C	ireate a New Oj	otical Source: "Opl	cal Sources"			
	olarization		velengths		alization	0К
Position A Type: Gaussia Paramet		Directions Li eful for Gaussian t	cation/Orientation Direction Apodiz Type: Uniform Unit Ap Parameters: No Data Requ	podization (equiv	alent to no (Cancel Apply Help
X width Y width X pos Y pos Type Mode N Mode M	0.5 0.5 0 Hermite 0	X semi-width of Y semi-width of X offset of Gaus Y offset of Gaus Mode type (Hern X mode index Y mode index				



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>			
Total Power	Total power of the source <i>after</i> both the position and direction apodization functions have been applied to the rays.	1			
	Position Apodization				
Туре	Pull down menu of available position apodization options. Choose Gaussian Apodization .	Uniform			
	Parameters				
X width	X semi-width of $1/e^2$ (13.5%) Gaussian power profile.	0.5			
Y width	Y semi-width of $1/e^2$ (13.5%) Gaussian power profile.	0.5			
X pos	X axis offset of the Gaussian power profile.	0			
Y pos	Y axis offset of the Gaussian power profile.	0			
	Direction Apodization				
Туре	Select Mode Type: Hermite Laguerre Laguerre Cosine Laguerre Sine	Hermite			
Mode N	Hermite X or Laguerre radial mode number.	0			
Mode M	Hermite Y or Laguerre azimuth mode number.	0			
ОК	Create a new Optical Source and close the dialog box.				
Cancel	Discard Source Power changes and close the dialog box.				
Apply	Apply Source Power changes and keep the dialog box open.				
Help	Access this Help page.				



Create Detailed Source - Power - Amplitude/Phase Mask Modify Values

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Amplitude/Phase Mask Modify Values

Specifies a subsection of the field data and modifies amplitude or phase values.

How Do I Get There? Amplitude/Phase Mask Modify Values

Modification of the Amplitude/Phase Mask values is accessed through the Detailed Source Power Tab dialog by right-clicking in the data values area:



(FRED1) Creat	e a New Optic	cal Se	ource: "Optical Sources"	_ 🗆 ×	
iource Positions/Directions Location/Orientation Power Coherence Polarization Wavelengths Visualization					
Total Power: 1					
– Position Apodia			Direction Apodization	· · ·	
Туре:	Lation		Туре:	Apply	
Amplitude/Ph	ase Mask on R	lectilir	ear Grid 🗾 Uniform Unit Apodization (equivalent to no apodization) 💌	Help	
Parameters:			Parameters:		
X across			No Data Required		
Y down	(0)				
(0)	-1	-0.	Set Sampling Array Size Modify Cell Values		
(0)	1 0	0	Import Bitmap to Cell 10ps		
(1)	1	1	Import Bitmap to Cell Bottoms		
-0.857143	0	0			
(2)	1	1	Display as Power		
-0.714286	0	0	Display as Amplitude		
(3) -0.571429	l	0	Display as Real Part		
(4)	1	1	Display as Waves		
-0.428571	0	0	Display as OPL		
(5)	0	0	Display as Phase (degrees)		
-0.285714 (6)	0	0	Display as Phase (radians)		
-0.142857	0	ō	Display as Imaginary		
(7)	0	0	Interpret as Power		
0	0	0	Interpret as Amplitude		
(8) 0.142857	0	0	Interpret as Real Part		
(9)	0	0	Interpret as Waves		
0.285714	0	0	Interpret as Waves		
(10)	0	0	Interpret as Phase (degrees)		
0.428571	0	0	Interpret as Phase (radians)		
(11) 0.571429	0	0	Interpret as Imaginary		
(12)	0	0			
0.714286	0	0	0		
(13)	0	0			

Dialog Box and Controls Amplitude/Phase Mask Modify Values



(FRED1) Modify Sample Values (using a highlighte 💶 🔲 🗙
Highlighted Region Cell Part To Modify Shape: Operate On: © Ellipse Inside © Rectangle Outside
Operation To Perform Operation: Functional Form: Set to Constant
Constant:
OK Apply Cancel Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>			
	Highlighted Region				
Shape	Choose Ellipse or Rectangle	Ellipse			
Apply the operation to	Inside or outside region	Inside			
	Cell Part To Modify				
Power/Waves	Modify the Power (cell tops) or Waves (cell bottom)	Unchecked			
	Operation to Perform				
Operation	Select from: Set To Multiply by Add To	Set To			
Functional Form	Choose from: Constant Linear $(aX + bY)$ Quadratic $(aX*X + bY*Y)$ Gaussian	Constant			
Input Values	Enter the (a,b) coefficients or 1/e widths per Function Form	0			
ОК	Accept modifications and close dialog box.				



Cancel	Discard modifications and close dialog box.	
Apply	Apply modifications and keep dialog box open.	
Help	Access this Help page.	

Application Notes Amplitude/Phase Mask Modify Values

See Also.... Amplitude/Phase Mask Modify Values

> Amplitude/Phase Mask Sizing the Amplitude/Phase Mask



Chapter 5 - Geometry Topics and Examples

This section has examples and topics concerning building geometry in FRED.

- Element Versus Custom Element
- Introduction to Curves
- Trimming Surfaces with Collections Curves

Creating a New Surface...

Description

How Do I Get There?

Dialog box and Controls

Description - Creating a New Surface...

Surfaces can be added to elements and custom elements only. They cannot be added to the geometry node or a sub-assembly directly. For example, to add a surface to a new Fred file, first create a new <u>Custom Element</u> or a new Element (Lens, Doublet, or Prism) via the right mouse click menu in the Geometry folder. Then add the surface to the element, also via the right mouse click menu. Note, that if a surface is added to an Element then the Element is converted to a Custom Element.

The Creating a New Surface... dialog is very flexible and has many options. In spite of the number of options, adding a surface to an element is generally fairly simple. Follow these basic steps to enter a surface. At each steps, press the Apply button, to see the effects of the changes on the surface as you create and edit the surface. Some of the steps are not applicable to all Surfaces and all of the steps have defaults values so some of the steps can be disregarded if the defaults are acceptable.

- 1. Expand the Geometry folder in Tree View (left mouse clicking on the 🕒)
- 2. Right-click on the Custom Element to add the new surface to,
- 3. Choose "Create New Surface..." from the pop-up menu and a dialog box with ten separate pages will open.
- 4. <u>Select the desired Surface type</u>.
- 5. Adjust the Trimming Volume, i.e. aperture, of the surface.
- 6. <u>Trim the surface with other Surfaces and/or Collection Curves.</u>
- 7. Position the surface using Location Primitives.
- 8. <u>Select the materials for both sides of the Surface.</u>
- 9. Select the Coating for the Surface.
- 10. Select the Ray Control for this Surface.
- 11. Assign desired Scatter Properties.
- 12. Adjust the Visualization of this Surface
- 13. Apply Glue layers between adjacent Surfaces
- 14. Apply Gratings to Surface

All of the ray traced objects in the geometry model are constructed with surfaces, i.e. there are no singular objects that represent a *volume* in FRED. "Volumes" are instead constructed of multiple surface objects. For example, a rectangular box is constructed from six



plane surfaces. All lens, doublet, and prism elements that can be directly entered in to FRED are also collections of curves and surfaces. By the way, Curves in FRED are used to construct or trim surfaces but are not themselves ray traced.

The default surface type is a plane but there are many surface types available, including those common to most lens design programs as well as the more general surface representations found in many CAD programs.

NOTE: If you add a surface to a mirror, singlet, or doublet element, then the element automatically becomes a custom element.

How Do I Get There? - Creating a New Surface...

- Objects 🦻 Optical Sources 📥 🔜 Geometry 🗬 Elem 1 Lens 1 (+) 🚺 Min 🖌 Traceable (†) No. Pris ĺ+Ì∙ Never Traceable (for trimming surfaces) 💷 Analysis 🕂 💼 Material Draw Outer Enclosing Volume 🕂 📄 Coating: Coordinate Axes... ∔ 🚺 Scattere Visualization Attributes... 🕩 间 Raytrac Position/Orientation... Parent Coordinate System... Scale... Summary Report Detailed Report • Edit/View Lens... Edit/View Mirror... Edit/View Prism... Convert to Custom Element Edit/View GRIN/Birefringent Material Position/Orientation... Edit/View Array Parameters... Delete Array Parameters Create New Surface... Create New Curve...
- Right click on the element to which you want to add surface, then select "Create New Surface...":



Dialog Box and Controls - Creating a New Surface...

There are ten tabs in the Create a New Surface... dialog box. Each page has a help file. There are hotlinks to these help files below.

((FRED1 *) Cr	eate a New Surface as Child of: "Elem 1"	_ 🗆 🗵
Scatter	Visualization Glue Grating Auxiliary Data Modifiers	ОК
SURFACE	Aperture Location/Orientation Materials Coating/RayControl	Cancel
Logical Parent	Elem 1	Apply
Name:	Surf 1	
Description:		Help
	Traceable (this surface can be raytraced) Use for trimming only (never raytrace)	
Type: Plane		
No data		

Help files for each page in this dialog are available at the following hotlinks.

The surface type page The aperture page The location/orientation page The materials page The coating / ray control page The scatter page The visualization page The glue page The grating page

The Auxiliary Data page

Edit/View Surface...

Description - Edit / View Surface...

The **Edit / View Surface...** dialog is very flexible and has many options. In spite of the number of options, editing / viewing a surface is generally fairly simple. The following options are available when editing a surface. At each steps, press the **Apply** button to see the effects of the changes on the surface as you edit the surface. Some of the steps are not applicable to all **Surfaces** and all of the steps have defaults values so some of the steps can be skipped.

- 1. Expand the **Geometry** node in Tree View (left mouse clicking on the or double click on the **Geometry** node)
- 2. Expand the **Custom Element** or **Element** node containing the surface to be edited (left mouse clicking on the (+)),
- 3. Double click on the surface or right mouse click on the surface choose "Edit / View Surface..." from the pop-up menu
- 4. A dialog box with nine separate pages will open. The **Edit / View Surface...** dialog is exactly the same as the **Create New Surface...** dialog. A description for the available operations on each page is provided below.

Scatter	Visualization	Glue	Grating	Auxiliary	Data	Modifiers
SURFACE	Aperture	Location/Orie	entation	Materials	Coatir	ng/RayControl

- <u>Select the desired Surface type</u>.
- Adjust the Trimming Volume, i.e. aperture, of the surface.
- Trim the surface with other defined Surfaces and/or Collection Curves.
- Position the surface using Location Primitives.
- Select the materials for both sides of the **Surface**.
- Select the Coating for the Surface.
- Select the Ray Control for this Surface.
- Assign desired Scatter Properties.
- Adjust the Visualization of this Surface
- Apply Glue layers between adjacent Surfaces
- Apply Gratings to Surface

How Do I Get There? - Edit / View Surface...

There are two different ways to execute this command:

- 1. Double click with the left mouse button on the surface to be edited.
- 2. Right click on a surface and choose "Edit / View Surface...".

Objects	Description
🕂 🖻 Optical Sources	
古 🚘 Geometry	
🕞 🗗 triplet	Imported from "d:\tripl
📄 🌗 Lens 1-2	surfaces 1 and 2
I Surface 1 I Surface 2	
🥒 Edge 🏕 Bevel 1	Never Traceable (for trimming surfaces)
- 🥜 Bevel 2	Draw Outer Enclosing Volume
🕂 🔐 🔂 🕀 🕀	<u>C</u> oordinate Axes
🕂 🌗 Lens 4-5	Visualization Attributes
🕂 🌒 Lens 6-7	Position/Orientation
🕂 🔐 Surface 8	Parent Coordinate S <u>v</u> stem
Elem 1	Sc <u>a</u> le
🕂 💷 Analysis Surface(s)	X Cut Ctrl+X
🕂 💼 Materials 🕂 📄 Coatings	· · · ·
+ Coatings	Ctrl+C
+ 💼 Raytrace Properties	Paste Ctrl+V
	Delete (all highlighted items) Del
	Summary Report
	Detailed Report
	Edit/View Surface
	Edit/View GRIN/Birefringent Material Position/Orientation
	Draw Surface Trimming Volume
	Edit/View Array Parameters
	Delete Array Parameters
4	Edit/View <u>⊂</u> urve

Dialog Box and Controls - Edit / View Surface...

There are nine tabs in the **Edit View Surface...** dialog box. Each page has a help file. There are hotlinks to these help files below.

(triple	t_ghost	frd) Edit Surface	e: "Surface 1'	•					_ 🗆 🗙
Scatte	er Í	Visualization	Glue	Grating	Auxiliary	Data	Modifiers	;	OK
SURF.	SURFACE Aperture Location/Orientation Materials Coating/RayControl							۱Ì.	Cancel
Logical	ogical Parent: Itriplet.Lens 1-2								
- Name:								- 1	Apply
Name.	 -	Surface 1						- 1	Help
Descrip	tion:	Axially Symmetric C	ionicoid Surface	Э					
	l. I.							.	
	,!	 Traceable (this : 	surface can be	raytraced) (Use for trimn	ning only (r	iever raytrace		
Туре:	I Conicoi	d (Cohoro Ellipso)							
турс.	Teorneon	u (opriere, cilipse,	Parabola, Hyp	erbola, etc.)				1	
турб. 	Value	Description		erbola, etc.)					
Rad	,		1	erbola, etc.)					
	, Value	Description Radius (= 1) /curvature)		oola, <0=ellipse,	0=sphere			
Rad	Value 27.3	Description Radius (= 1) /curvature)		oola, <0=ellipse,	0=sphere	<u>,</u> ,		
Rad	Value 27.3	Description Radius (= 1) /curvature)		ola, <0=ellipse,	0=sphere			
Rad	Value 27.3	Description Radius (= 1) /curvature)		oola, <0=ellipse,	0=sphere	<u>,</u>		

Help files for each page in this dialog are available at the following hotlinks.

The surface type page The aperture page The location/orientation page The materials page The coating / ray control page The scatter page The visualization page The glue page The grating page

Applying Aperture, Trimming Volumes, and Trimming Objects

Description How Do I Get There? Dialog box and Controls

Description

Applying Aperture, Trimming Volumes, and Trimming Objects

This dialog page allows the user to set the trimming volume outer and inner volumes. The trimming volume can be a box, ellipsoid, or cylinder. The trimming volume can also have an inner-hole (elliptical or rectangular, on-axis or decentered).



In addition, the user can trim the surface with dot products, other surfaces, and collection curves using the trimming Surfaces Specifications section on the aperture page of this dialog. A surface can be trimmed with multiple surfaces and collection curves using logical statements (AND, OR, grouping parentheses "()", and NOT).

NOTE: Although Surfaces may be trimmed with Collection Curves, they cannot be trimmed with regular Curves, Ruled Surfaces, Extruded Surfaces, or any other surface that is generated from curves. This is because the implementation of regular Curves, Ruled Surfaces, and Extruded Surfaces does not have a mathematical form that allows for quickly evaluating what side of the object that the surface to be trimmed is on.

How Do I Get There? Applying Aperture, Trimming Volumes, and Trimming Objects

This page is in the <u>Create New Surface...</u> and Edit/View Surface... dialogs.

Dialog Box and Controls

Applying Aperture, Trimming Volumes, and Trimming Objects

<mark>ể (FRED1 *)</mark> Create a New Surfac	e as Child of:	"Elem 1"					_ 🗆 🗙
Scatter Visualization	Glue	Grating	Auxiliary	Data	Modifiers		ОК
SURFACE Aperture	Location/Ori	entation	Materials	Coati	ng/RayControl	4	Cancel
Trimming Volume Outer Boundary-			Trimmin	g Volume	Inner Hole		
Semi-aperture: Center:		r as Min/Max		ni-ape:	Offset:		Apply
	cent	ad of semi-ape/ er					Help
Y: 1 0	Shape:	C Box	Y: 0		0		
Z: 1 0		oid 💿 Cylinder	Shape:	O Box	Z-Cylinder		
Advanced Dot-product Surface Tr	mming Specific	ation					
O None O X-axis Perp		Reference	e Vector:				
C Position C Y-axis Perp	X: 0	Y:]0		Z: 1			
O Direction O Z-axis Perp	9	ign of the dot p	roduct: 💽 F	ositive	O Negative		
Trimming Surfaces Specification—							
	& AND	(OR	! NOT	Di	irect Edit		
# Other Trimming Volume	0	()	Dele	te Selected		

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
	Trimming Volume Outer Boundary	
Semi-aperture	X,Y,Z semi-diameters or min/max dimensions of the trimming volume outer.	1,1,1
Center	Trimming volume X,Y,Z center.	0,0,0
Shape	Ellipsoid, Box, Cylinder	Cylinder
	Trimming Volume Inner Hole	
Semi-ape, offset	X,Y semi-diameters and offset for an inner hole boundary of the trimming hole.	Semi-ape 0,0 Offset 0,0
Shape	Box or Z-cylinder	Z-cylinder
Advance	d Dot Product Surface Trimming Specification	0 n
None Position Direction X/Y/Z axis perpendicular	Establishes the boundaries of a surface based on the local surface normal dot product with a given fixed vector. This would, for example, allow the user to exclude half of a sphere.	None
Reference Vector	Direction cosines of reference vector	0,0,1
Sign of Dot Product	Positive or negative dot product sign	Positive
	Trimming Surface Specification	
Trimming Expression	Boolean expression for surfaces, collected curves and/or trimming volumes used for trimming.	blank
Dropdown	FRED surfaces, collected curves	blank
Operations	Boolean AND, OR, NOT and ()	
Direct Edit	Allows direct edit of Trimming Expression.	
Delete Selected	Deletes highlighted from Trimming Expression.	
# Other Trimming Volume	Use other FRED surfaces, collected curves from dropdown in Trimming Surface.	
ОК	Accept Aperture changes and close dialog box.	
Cancel	Discard Aperture changes and close dialog box.	
Apply	Apply Aperture changes and keep dialog box open.	

Help	Access this Help page.

See Also

Applying Aperture, Trimming Volumes, and Trimming Objects

Follow this link to Trimming Examples.....

Applying Location Primitives

Description How Do I Get There? Dialog box and Controls Application Notes

Description Applying Location Primitives

The position of a FRED entity can be set to any location and any rotation using the location primitives. In addition, each **Location Primitive**'s operation, i.e. linear transformation, can be made relative to the global coordinate system or the coordinate system of any defined FRED entity (**Surface, Curve, Custom Element, Element**, or **Sub-Assembly**). The coordinate system of the **Location Primitive** is called the **Parent** coordinate system.

NOTE The Location Primitives operate relative to the origin of the Parent coordinate system, which is not always the center of the object. If uncertain of where the origin of a coordinate system is, make the Coordinate Axes for that system visible via the right mouse click pop-up menu.

How Do I Get There? Applying Location Primitives

This page is in the Surface Creation and Editing dialogs, as well as the Curve Creation and Editing dialogs.

Dialog Box and Controls Applying Location Primitives



侯 (FRED1	*) Cro	eate a Nev	/ Surfac	e as Child of:	"Elem 1"							×
Scatte	r	Visualiza	ition	Glue	Grating	i I	Auxiliar	y Data	Modifi	ers	OK	1
SURF/	SURFACE Ape			Location/Ori	entation	Ma	erials	Coat	ing/RayCon	trol	Cance	el
	Refe	rence Coo	rdinate	Action	Paramete	rs (rigl	nt mous	e-click f	or popup n	nen		-
	E	ng Coordina		n							Apply	y j
0	Geon	netry.Elem 1	0						_		Help	
I												
<u>Contro</u>	<u>9/</u>		Input	<u>ts</u>				Def	aults			
Reference Coordina		stem	which modif	oordinate s or about v fier will op the drop do	which the erate can	locati be sel	ion	syst	parent co em (syste ace was c	m the	e	
Action			primi	ype of loca tive can be down menu	selected		the		te coincic another c em			
Parameters The loca			locati	arameters a on modifience or angle	r / primit			0				

ОК	Accept Location/Orientation changes and close dialog box.	
Cancel	Discard Location/Orientation changes and close dialog box.	
Apply	Apply Location/Orientation changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes Applying Location Primitives

•

		X-pos	Y-pos	Z-pos
Geometry ()	▼ Place at s	• 🔽 0	0	0
		· · · ·	$\sqrt{7}$	

- Place at Place surface at specific XYZ point.

Shift in X, Y or Z - Shift only along the chosen coordinate direction.

			X	Y	Z	
Geomet	уО	▼ Shift	• 0	0	0	

Shift - Shift in each of the three coordinate directions.

			X-angle (deg)				
•	Geometry ()	▼ Rotate abc ▼	0				
	Rotate about X coordinate syst		tate by the	given ang	gle about	the selecte	bd
			X-angle (deg)	Y-axis pos	Z-axis pos		
	Geometry ()	👻 Rotate abc 👻	0	0	0		
-	Rotate about X angle about a v the given point.	ector paralle					
		:	i Alexaler Arlenañ	ісл. н	NY LOU	7 .6.	

			Angle (deg)	X-dir	Y-dir	Z-dir	
•	Geometry ()	▼ Rotate abc ▼	0	0	0	1	
	Potate about div	on direction	Dotato h	w the aive	n analo a	hout an ar	hil

Rotate about given direction - Rotate by the given angle about an arbitrary direction given by its direction cosines.

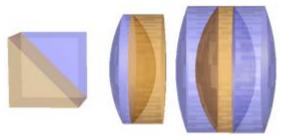
		Angle (deg)	X-pos1	Y-pos1	Z-pos1	X-pos2	Y-pos2	Z-pos2
•	Geometry () 🔹 Rotate abc 💌	0	0	0	0	0	0	1
	Rotate about given dire	ction three	ough poi	nt XYZ -	Rotate b	by the give	/en	
	angle about a vector wh	lose enc	l points a	s X1,Y1	,Z1 and J	X2,Y2,Z	2.	

- Z-dir1 Preserve nex X-dir X-dir2 Y-dir2 ▼ Rotate one ▼ 0 Geometry ∩ 0 0 1 0 1 0 0 Preserve 0 Rotate one vector into another vector - Rotate by the given angle from one vector direction into another vector direction. 'Preserve next' indicates that the vector direction Xdir3, Ydir3,Zdir3 should be in the new local coordinate system should be preserved (as much as possible) with respect to the original orientation of the Xdir3, Ydir3, Zdir3 direction.
- R12 R10 R11 R20 R22 Geometry () 🔻 General n 👻 1 0 0 0 0 1 0 0 General Matrix - General matrix operation. The first nine elements denote rotation while the last three denote translation.

Applying Glue

Description - Applying Glue

In the development of FRED, every effort was made to realistically represent optical components as they are built in the real world. For example Doublets, triplets, and beamsplitters are modeled in FRED using a **Glue** layer between adjacent optical components. The adjacent components are placed in close proximity but not touching and a glue layer is applied between the appropriate surfaces. The three components below all have glue layers.



WARNING Multiple surfaces in FRED should not be made precisely coincident because there might be an ambiguity on which surface is being intersected by a ray. This ambiguity may result in errors that halt the ray.

The mechanism for modeling glue between the surfaces is the **Glue** command. The **Glue** command allows the user to select the glue material and which surface to be glued to the surface being edited. More than one surface may be glued to the surface being edited and different glue materials maybe used between each surface pairs.

When the a ray intersects a surface with glued surfaces FRED first checks to see if the ray, when propagated forward, will intersect with the glued surface(s). If it will intersect, then the ray is traced assuming the glue material is present. If it does not intersect a glued surface,



then it propagates assuming there is no glue. Raytracing glue layers is elucidated in the <u>Glue</u> <u>layer raytracing example</u>.

How Do I Get There? - Applying Glue

This page is in the Create New Surface... and Edit/View Surface... dialogs.

Dialog Box and Controls - Applying Glue

<mark>८ (</mark> FRED1 *) Create a New Surf	ace as Child of: "Elem 1"	
SURFACE Aperture	Location/Drientation Materials Coating/RayControl	ОК
Scatter Visualization	Glue Grating Auxiliary Data Modifiers	Cancel
Surfaces glued to this surface	(right mouse click for context menu)	Apply
Glue Surface(s) 1 no selection	Glue Material(s) I no selection I no selection I no selection I	
		Help
1		



<u>Control</u> <u>Inputs</u>		<u>Defaults</u>				
	Surfaces glued to this surface					
Glue Surface(s)	All the surfaces in the geometry are listed in the glue surface pull down menu.	No selection				
Glue Material(s) All the materials in the geometry are listed in the glue surface pull down menu.		No selection				
ОК	Create a new Surface and close dialog box.					
Cancel	Discard new Surface and close dialog box.					
АррІу	Apply Glue changes and keep dialog box open.					
Help	Access this Help page.					

Examples - Applying Glue

See the <u>Glue layer raytracing example</u>.



ASAP Import

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

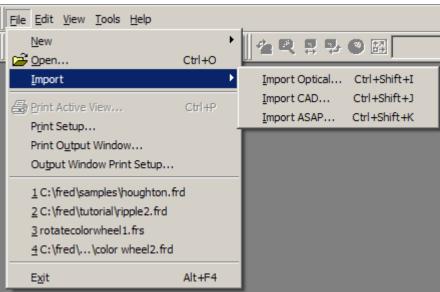
Description ASAP Import

FRED can import geometry from ASAP.

How Do I Get There? ASAP Import

There are two different ways to execute this command:

1. Menu



2. Keyboard Accelerator - Ctrl+Shift+K

Dialog Box and Controls ASAP Import



🕻 Import ASAP File	×
c:\fred\translators\asap\apachept.txt Comments: Summary: Number of objects found = 282 Number of surfaces/functions found = 214 Number of curves/edges found = 148 Number of lenses found = 0 Number of coatings found = 3	Import Options Render transmitting surfaces as transparent Units ASAP does not write out the system or wavelength units in the PRINT ed output. Select the appropriate units here. System Units Wavelength Units Millimeters Varelength Units
No errors encountered	Create Dismiss Help

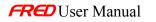
<u>Control</u>	Inputs / Description	<u>Defaults</u>			
Browse	Choose the ASAP file to be imported. (see App Note)				
Comments	Text comments from imported file.				
Summary	Summary of imported file contents.				
Import Status	Reports import status.				
	Import Options				
Render transmitting surface as transparent	Transmitting surfaces are given a "Transmit" coating and "Transmit Specular" Raytrace Control.	Unchecked			
Units	Select System units and wavelength units for import.	Inches, Millimeters			
Create	Create FRED model and keep dialog box open.				
Dismiss	Dismiss dialog box.				
Help	Access this Help page.				

Application Notes ASAP Import

- FRED imports either a *.out or *.txt file format produced by ASAP's PRINT statement. The INR file format cannot be imported. Use the following code to create a FRED-compatible file in ASAP: \$IO OUTPUT MYFILE PRINT \$IO OUTPUT CLOSE
- ASAP does not write out the system or wavelength units to the PRINTed output. These unit selection must be set by the user at import.
 - Sources are not imported.

See Also.... ASAP Import

> CAD Import Lens Import



CAD Import

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

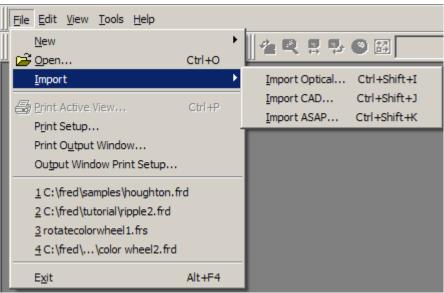
Description CAD Import

FRED imports geometry in IGES or STEP file formats.

How Do I Get There? CAD Import

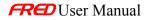
There are two different ways to execute this command:

1. Menu



2. Keyboard Accelerator - Ctrl+Shift+J

Dialog Box and Controls CAD Import



_

c:\fred\translators\iges\flashl.igs Comments: Comments: Comments: Comments: Comments: Comments: Comments: Com
Randomize unassigned colors on curves
Summary: Number of points found = 0 Number of surfaces found = 0 Number of surfaces found = 0 Number of B-Reps found = 0 System units = millimeters Scale modifier = 1.000000 Software name = Rhinoceros (Jan 21 1997) Author Organization = Not specified Author Organization = Not specified Urber of surface Control Halt all Reduce Order/Simplify Reduce NURB order per tolerance Simplify curves
Import Status No errors encountered Move Coordinate System Origin to Surface Move origin to surface
Create Dismiss Help
Control Inputs / Description Defaults
Browse Choose the CAD file to be imported. Taxt comments from imported

Browse	Choose the CAD file to be imported.			
Comments	Text comments from imported file.			
Summary	Summary of imported file contents.			
Import Status	Reports import status.			
Import Options				
Unassigned Colors	blors Randomizes colors for imported surfaces and curves.			
Independent Curves	Makes and draws independent curves on import.	Checked		

Surface Drawing Mode	Draws imported model as shaded surface of Wire frame (fast).	Shaded surface			
Default Raytrace Control	Sets the selected Raytrace Control on imported surfaces.	Halt All			
Reduce Order/Simplify	Reduces the order of imported NURBs or curves to the lowest value for which the maximum deviation between original and approximate surface is less than the given tolerance.	Unchecked			
Move Coordinate System Origin to SurfaceConverts the default global coordinate system of NURBs to local coordinate system on the surface. Location of that local origin is at a position where the parametric coordinates u and v are minimum. Note: In the case of some trimme surfaces, this local origin may no lie directly on the surface.		Unchecked			
Create	Create FRED model and keep dialog box open.				
Dismiss	Dismiss dialog box.				
Help	Access this Help page.				

Application Notes CAD Import

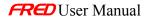
- Large models may result in slow response of the 3D view. For convenience, select Wire frame mode to increase video responsiveness and eliminate tesselation delays.
- As the order of NURB surfaces increase, so does the required trace time. Photon Engineering recommends reducing the order of NURBs to the lowest possible value consistent with the particular application to enhance raytrace speed.

• FRED internally models objects exactly as they are defined in the CAD file (as NURBs) instead of approximating with a FRED native entity. A <u>list of IGES</u> <u>objects</u> supported by FRED can be used to understand the Summary report.

• By default, NURBs are imported in the global coordinate system. As a result, NURBs do not have a local coordinate system affixed to their surface as all other FRED surfaces do. By selecting the *Move Coordinate System Origin to Surface* option, FRED endows each NURB with a local coordinate system. This local coordinate system origin is located at a point where the parametric coordinates *u* and *v* are minimum. In the case of some trimmed surfaces, the local coordinate origin may not lie directly on the surface but will be in the near vicinity.

See Also.... CAD Import

> Lens Import ASAP Import



Lens Import

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Lens Import

FRED imports lens prescriptions from CodeV, Zemax and OSLO.

How Do I Get There? Lens Import

There are two different ways to execute this command:

1. from the Main Menu....

<u>F</u> ile	<u>E</u> dit <u>V</u> iew <u>T</u> ools <u>H</u> elp		
Ē	<u>N</u> ew Open	Ctrl+O	▎▌◢▝▌▝▖▝▖▝
	<u>I</u> mport		Import Optical Ctrl+Shift+I
8	Print Active View	Ctrl+P	Import CAD Ctrl+Shift+J
-	Print Setup		Import ASAP Ctrl+Shift+K
Print Output Window			
	Output Window Print Setup		
<u>1</u> C:\fred\samples\houghton.frd			
2 C: \fred\tutorial\ripple2.frd			
3 rotatecolorwheel 1. frs			
	4 C:\fred\\color wheel2.frd		
	E <u>x</u> it	Alt+F4	

2. Keyboard Accelerator - Ctrl+Shift+I

Dialog Box and Controls Lens Import

🚰 Import From Lens Design Program	×
c:\fred\translators\iges\dbgauss.seq Browse	Import Options Render transmitting surfaces as transparent
Comments: Designer's initials '	Add Analysis Surface to image surface
	Create edges and bevels on lens elements
Summary:	Create default sequential paths
Number of surfaces found: 13 Units: Millimeters Wavelength range: 0.486100 to 0.656300 microns	Compute unassigned apertures from paraxial raytrace
Reference: 0.587600 microns Entrance pupil radius: 25.000000	Minimum thickness
Field: Angle X-field range: 0.000000 to 0.000000, Y-field range: 0.000000 to 14.000000	Default cement thickness 10
	Dummy Surfaces
	Show dummy surfaces
r Import Status	Same material both sides
Errors foundreview output window messages!	Zero thickness to previous surface
	Zero thickness to next surface
Create Dismiss Help	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Browse	Choose the lens file to be imported.	
Comments	Text comments from imported file.	
Summary	Summary of imported file contents.	
Import Status	Reports import status.	
	Import Options	
Render transmitting surfaces as transparent	Transmitting surfaces are given a "Transmit" coating and "Transmit Specular" Raytrace Control.	Checked
Add Analysis Surface to image plane	Adds an Analysis Surface and and attaches it to the image plane.	Unchecked
Create edges and bevels on lens elements	Constructs edges and bevels for all lens and mirror elements. (See App Notes below)	Checked
Create default sequential paths	Creates default sequential path definition and saves path to document.	Checked
Compute unassigned apertures from paraxial raytrace	Computes and assigns apertures to those unassigned in the prescription using a paraxial raytrace.	Unchecked

Minimum thickness	Minimum thickness between adjacent elements.	Unchecked (0)	
Default cement thickness in microns	Sets the default thickness of glue layers between doublets and triplets.	10	
	Dummy Surfaces		
Show dummy surfaces	Imports dummy surfaces when checked.	Unchecked	
Same material both sides	Assigns the same material to both sides of dummy surfaces.	Checked	
Zero thickness to previous/next surface	Sets a zero thickness to previous/next surfaces.	Checked	
Create	Create FRED model and keep dialog box open.		
Dismiss	Dismiss dialog box.		
Help	Access this Help page.		

Application Notes

Lens Import

• Selecting the option "Create edges and bevels on lens elements" breaks standard three-surface doublets (and four surface triplets) into four surfaces (into six surfaces) and adds a default glue thickness of 10 m between the elements. This operation causes small but noticeable changes in the prescription consistent with the actual manufacture of glued elements.

• If *Compute unassigned apertures from paraxial raytrace* is not checked, then FRED will prompt the user for aperture information (see <u>Import Apertures</u>).

See Also.... Lens Import

> CAD Import ASAP Import



Applying Gratings

Description How Do I Get There? Dialog box and Controls Application Notes Example

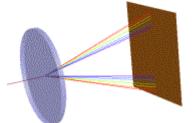
Description Applying Gratings

This option allows the user to apply a grating to the surface. The grating is not modeled physically as a grating in FRED. Instead, a phase profile representing the grating is added to the surface. After a ray refracts or reflects at a surface with a grating, the appropriate phase is added to the ray to model the grating affects.

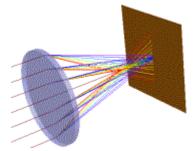
🕻 (triplet_ghost.frd *) Create a New Surface as Child of: "Elem 1"					
SURFACE Scatter	Aperture Visualizati		tion/Orientation Glue	Materials Grating	Coating/RayControl Auxiliary Data
Grating Type: None (no grating None (no grating	a)		Diffraction El	fficiency Table: click for popup me	nu)
Linear (Evenly s Two point expos	ng lines) optical ele	mei			

There are two types of phase gratings that can be added to a surface:

1. Linear Grating (evenly spaced linear grating lines)



2. Two point exposure holographic optical element with a polynomial phase departure option.



The user can also set the grating efficiency for any given order and at any given wavelength. During the raytrace, the grating efficiency rays with wavelengths inside the range



of user set efficiencies are determined by linear interpolation. The grating efficiencies for rays with wavelengths outside the range of the user set wavelengths are set to the efficiency of the closest wavelength with a defined efficiency. So, if only one wavelength is defined with a diffraction efficiency, then all the wavelengths will have that same efficiency.

How Do I Get There? Applying Gratings

This page is in the <u>Create New Surface</u> and Edit/View Surface dialogs.					
Objects		Description			
 ⊕ Optical Sour ⊕ Geometry ⊕ ⊕ triplet 	ces	Imported from ''d:\tripl			
💷 🧬 Elem 1 🕞 🔃 Analysis Su	✓ <u>T</u> raceable				
🕂 💼 Materials	Never Traceable (for trimming surfaces)				
	Draw O <u>u</u> ter Enclosing Volume <u>C</u> oordinate Axes <u>Vi</u> sualization Attributes				
	 Position/Orier				
	K Cut		Ctrl+X Ctrl+C		
	Paste		Ctrl+V		
		phighted items)	Del		
	Su <u>m</u> mary Rep Detailed Repo				
	Edit/View Len Edit/View Min Edit/View <u>P</u> ris	ο,			
		ustom Element IN/Birefringent <u>M</u> aterial Position/O	rientation		
	Edit/View Arra Delete Array	ay Parameters Parameters			
	Create New S Create New S	- 47			

Dialog Box and Controls Applying Gratings

		near grating lines) 💌	Diffraction Efficien	icu Table:	Cancel
	Value		(nght mouse eller i	for popup menu)	 Apply
Orientation		Description		Diffract Orders	Help
Freq(lp/mm)	0	Angle (deg). 0 de Grating frequenc	(microns)	1	
▼					

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Grating Linear - Orientation	Angle of the grating in degrees relative to the coordinate system of the surface.	0
Grating Linear - Frequency	The spatial frequency of the grating in lines per millimeter.	100
Grating Linear - Diffract Order	The user can specify the diffraction efficiency into each order. Multiple orders can be appended with a right mouse click.	1
Grating Linear - Wavelength	The wavelength for the efficiency at a given order can be specified. In addition, multiple wavelengths for each order can be specified (append multiple wavelengths with a right mouse click as well).	0.5892938 [um]

(FRED2 *) Crea	te a New Surface as Child	of: "Elem 1"	_ 🗆 🗙
SURFACE	Aperture Location/	Orientation Materials Coating/RayControl	0К
Scatter	Visualization Glue	Grating Auxiliary Data Modifiers	Canaal
Grating Type:			Cancel
	ure holographic optical el 💌	Diffraction Efficiency Table:	Apply
T wo point exposi	ure noiographic optical ei	(right mouse click for popup menu)	
	Value	Wavelengths Diffract Orders	Help
Source 1	Position O	(microns) 1	
Pos/Dir	Direction 🖲	0.5875618 1	
Source 2	Position O		
Pos/Dir	Direction 💿		
Source 1 Type	Real 💿 Virtual 🔿		
Source 2 Type	Real 💿 Virtual 🔿		
X1	0		
Y1	0		
Z1 X2	1		
Y2	0		
72 Z2	1		
Ref Index	1		
Wavlen (um)	0.5875618		
Phase Departure	None 🔻		
	None		
	Radial polynomial		
	XY polynomial		
	F		



<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Source 1 Pos/Dir	Determines whether the (X1,Y1,Z1) coordinates are treated as direction cosines or a position vector.	Direction
Source 2 Pos/Dir	Determines whether the (X2,Y2,Z2) coordinates are treated as direction cosines or a position vector.	Direction
Source 1 type	Is source 1 a real or virtual source?	Real
Source 2 type	Is source 2 a real or virtual source?	Real
X1, Y1, Z1	Position or direction coordinates of the first point.	0, 0, 1
X2, Y2, Z2	Position or direction coordinates of the second point.	0, 0, 1
Ref Index	The refractive index of the media being exposed to make the holographic grating.	1.00
Wavelen (um)	The wavelength of the sources being used to expose the two point holographic grating.	0.5892938 [um]
Phase Departure	A radial or XY polynomial phase departure can be added to the two point holographic grating using this pull down menu.	None
R0 or X0Y0	Constant term for the radial or XY polynomial phase departure. Additional terms can be added by type any number including zero, 0, on this term. NOTE, you must type a number even if it is zero to get the next term in the polynomial.	0
Diffract Order	Diffraction order(s) to be raytraced. Multiple orders may be entered with via a right mouse click pop-up menu.	1
Wavelens (um)	The wavelength corresponding to the diffraction efficiency of that order. Additional wavelengths maybe added via a right mouse click pop-up menu.	0.5892938 [um]

• The Phase Departure attribute can be used to create linear or radial gratings with variable spacing. The polynomial equation for grating spacing is

$$d(y) = \frac{\lambda_{ref}}{a + 2by + 3cy^2 + \dots}$$

where *ref* is the reference wavelength.

The corresponding FRED phase function is

$$f(y) = ay + by^2 + cy^3 + \dots$$

Example Applying Gratings

As an example, consider the case of a linearly chirped grating of width 50mm with reference wavelength 0.5 m. There are 1250 lpm at position y=-25mm and 1500 lpm at position y=+25mm.

The polynomial equation for grating spacing is used to solve a set of equations in two variable, a & b.

$$d(-25) = 1/1250 = 5E-04/[a + 2b^{*}(-25)]$$

Solving these two equation simulataneously yields

a = 0.625 ; b = 0.00125

Thus, in the Phase Departure subsection of the Grating dialog, choose XY polynomial and set

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X2Y0=0 X1Y1=0 X0Y2=0.00125

NOTE, you must type a number even if it is zero to get the next term in the polynomial.

Applying Surface Types

Description - Applying Surface Types

This page allows the user to select the surface type, i.e. the mathematical description of the surface. After selecting the surface type, enter any additional data required for that surface. There is a hot link below to a help page for each of the available surface types. The **Trimming Volume** is independent of the size and shape parameters entered on the **Surface** page. The **Trimming Volume** parameters on the **Aperture** page may need to be adjusted before the **Surface** appears as expected.

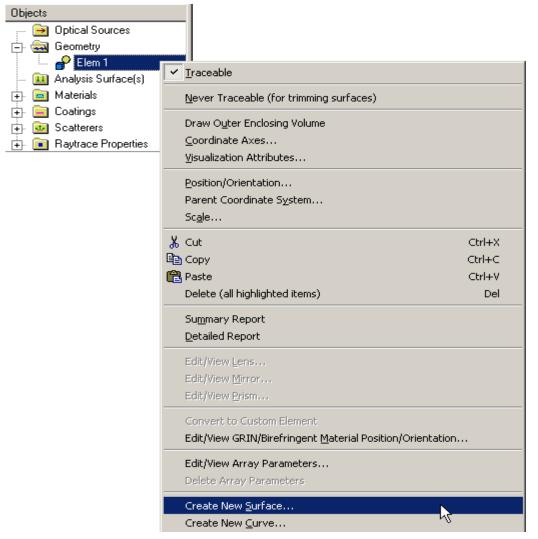
NOTE: The **Trimming Volume** is independent of the size and shape parameters entered on the **Surface** page. The **Trimming Volume** parameters on the **Aperture** page may need to be adjusted before the **Surface** appears as expected.

How Do I Get There? - Applying Surface Types



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This page is part of the <u>Create New Surface...</u> and Edit/View Surface... dialogs.





Dialog Box and Controls - Applying Surface Types

FRED1 *) Cr	eate a New Surface as Child of: "Elem 1"	_ 🗆
Scatter	Visualization Glue Grating Auxiliary Data	OK
SURFACE	Aperture Location/Orientation Materials Coating/RayControl	Canada I
agiaal Paranti		Cancel
ogical Parent:		Apply
lame:	Surf 1	
escription:		Help
·		
	🔽 Traceable (this surface can be raytraced) 🛛 🗖 Use for trimming only (never raytrace) 👘	
ype: Plane		
No dat Conic	id (Sphere, Ellipse, Parabola, Hyperbola, etc.)	
Stand	ard asphere (Conicoid plus even order radial polynomial terms)	
	al asphere (Conicoid plus even order radial polynomial terms)	
	er (aligned along the Z-axis)	
	Foci (Ellipsoid/Hyperboloid defined by two foci and a surface point)	
	ated Cylinder (straight line extruded curve)	
	Surface (collection of parametric (u,v) polynomial spline patches)	
	Surface (two connected curves)	
	e of Bevolution [curve revolved around an axis]	
	e of Revolution (curve revolved around an axis) Surface (Non-Uniform Bational B-Spline surface in U.V. parameters)	
NURE	Surface (Non-Uniform Rational B-Spline surface in U,V parameters)	
NURE Trimm	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves)	
NURE Trimm Toroid	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves) al Asphere (Toroid, Potato chip, etc. with non-symmetric aspheric terms)	
NURE Trimm Toroid XYTo	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves) al Asphere (Toroid, Potato chip, etc. with non-symmetric aspheric terms) oidal Asphere (X or Y toroid with even/odd aspheric terms)	
NURE Trimm Toroid XYTo Polyne	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves) al Asphere (Toroid, Potato chip, etc. with non-symmetric aspheric terms) oidal Asphere (X or Y toroid with even/odd aspheric terms) omial Asphere (Conic with X and Y polynomial aspheric terms)	
NURE Trimm Toroid XYTo Polyno Polyno	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves) al Asphere (Toroid, Potato chip, etc. with non-symmetric aspheric terms) oidal Asphere (X or Y toroid with even/odd aspheric terms) omial Asphere (Conic with X and Y polynomial aspheric terms) omial Surface (Polynomial function in terms of x, y, z)	
NURE Trimm Toroid XYTol Polynd Zernik	Surface (Non-Uniform Rational B-Spline surface in U,V parameters) ed Parametric (parametric surface with trimming curves) al Asphere (Toroid, Potato chip, etc. with non-symmetric aspheric terms) oidal Asphere (X or Y toroid with even/odd aspheric terms) omial Asphere (Conic with X and Y polynomial aspheric terms)	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Surface-Parent	No user inputs.	Element on which it was created
Surface-Name	An alphanumeric name of any length. Note that object names can start with numbers.	Surf n, where n is a sequential number
Surface-Description	User input description of any length	None
Surface-Type	The surface time can be selected from available surfaces in the pull- down menu	Plane

The following surface types are currently available in FRED:

<u>Plane</u> <u>Conicoid</u>

FRED User Manual

Standard Asphere **General Asphere** Cylinder Conic Foci **Tabulated Cylinder Spline Surface Ruled Surface** Surface of Revolution **NURB Surface Trimmed Parametric Toroidal Asphere** XY Toroidal Asphere **Polynomial Asphere Polynomial Surface** Zernike Surface **Bicubic Mesh Surface Implicit Script Surface**

Applying Visualization Properties

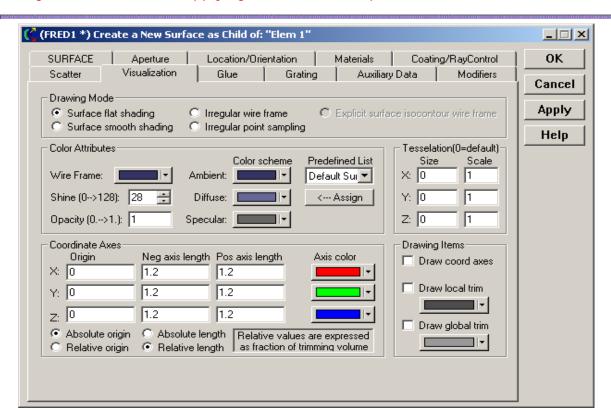
Description - Applying Visualization Properties

The appearance of the surface in the Visualization window can be modified on this page. The following items can be modified:

- 1. Drawing Mode
- 2. Color
- 3. Shine
- 4. Opacity
- 5. Tessellation (quality of the surface rendering)
- 6. Draw Coordinate Axes
- 7. Draw local Trimming Volume
- 8. Draw global Trimming Volume

How Do I Get There? - Applying Visualization Properties

This page is on the Surface Creation and Editing dialogs.



Dialog Box and Controls - Applying Visualization Properties

<u>Control</u>	<u>Control</u> <u>Inputs</u>			
Drawing Mode				
Drawing Mode	The way the surface is rendered. Options are:Surface flat shadingSurface smooth shadingIrregular wire frameIrregular point samplingExplicit surface isocontour wireframe	Surface flat shading		
Color Attributes				
Attributes	The wire frame color, shine, and opacity (transparency) of the surface when it is rendered.	Colors: default Shine: 128 Opacity: 1		
Color scheme	Sets ambient, diffuse, specular properties of rendered surface.			
Predefined List	Selects and assigns surface color.	Default Surface/ Curve/Grid Color		
Coordinate Axes				

Coordinate Axes	Sets the color, location, and size of the coordinate axes if they are drawn on that surface.	RGB 0,0,0 1.2, 1.2, 1.2			
Tessellation					
Tesselation	The tessellation determines how finely FRED samples the surface for rendering. The smaller the scale, the finer the sampling. Fine sampling increases the amount of time required to render the surface.	Size: 0 Scale: 1			
Visualization - Drawing Items	Determines whether these items will be drawn when the surface is rendered.	Unchecked			
ОК	Accept Visualization changes and close dialog box.				
Cancel	Discard Visualization changes and close dialog box.				
АррІу	Apply Visualization changes and keep dialog box open.				
Help	Access this Help page.				



Description - Applying Surface Deformations

Mathematically, deformations are implemented by shifting the zeros of the base surface's function. Let fb(x,y,z) = 0 define the base surface and fd(x,y,z) = 0 define the deforming surface.

Further, assume that the deforming surface is defined as a height map along z (e.g, fd(x,y,z) = z - gd(x,y)).

This is the "sagability" assumption. FRED doesn't enforce this, but it will generally print a warning

to the output window when it detects a deformer that's not "sagable".

When the deformation is applied to the base surface, the resulting combined surface is defined by

(ignoring coordinate system transformations):

 $0 = f(x,y,z) = fb(x, y, z - A^*gd(x,y)) = fb(x, y, A^*fd(x,y,z) - (A-1)^*z)$

... where A is the deformation scale factor (this scales the deforming surface's height).

Deformations can be applied to surfaces that are parts of Lens/Mirror elements. When a deformation

is applied the Lens/Mirror will use the optical surfaces to bound its outer tube, ensuring the element

won't leak rays. Currently, the bevel option is not handled correctly, so there can be leaks if a deformation is

applied to a lens/mirror with bevels.

Deformations cannot be applied to elements of a prism. The user interface tries to prevent this from

happening. If by chance the user finds a way to do this (by scripting perhaps) bad things are to be

expected.

If a non-sagable deformer is selected a warning will generally be written to the output window after the

base surface is tessellated. Because tessellation can occur more than once, when such warnings occur

they are frequently seen repeated multiple times.

To apply a sampled height map as a deformer, read the data into a bicubic mesh surface and apply it

as the deforming surface.

How Do I Get There? - Applying Surface Deformations

This page is in the Create New Surface... and/or Edit/View Surface... dialogs.

Dialog Box and Controls - Applying Surface Deformations

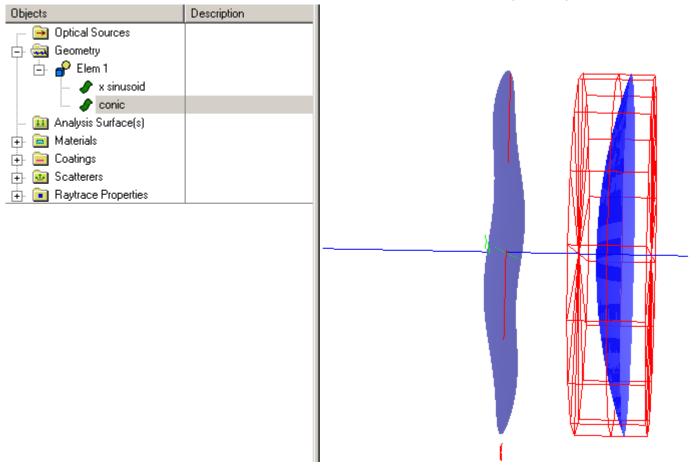
((FRED1 *) Cre	ate a New Surfa	ce as Child of:	"Elem 1"				_ 🗆 🗙
SURFACE	Aperture	Location/Ori	· ·	Materials		ng/RayControl	ОК
Scatter	Visualization	Glue	Grating	Auxilia	ary Data	Modifiers	Cancel
Sag Deformation	on ther surface's sag a	as a deformation	to this surface	2			Apply
Deforming Su						T	Help
Scale deforma	·						
	surface is applied	in coordinate su	stem of base s	urface			
Iteronning	i suitace is applieu	in coordinate sy	stelli oi base s	unace.			



<u>Control</u>	Inputs	<u>Defaults</u>			
Sag Deformation					
Apply another surface's sag as a deformation	Select whether the base surface will have a deformation	Unchecked			
Deforming Surface	Choose from a list of valid deforming surfaces	All valid surfaces			
Scale deformation by:	Scale factor multiplying the amplitude of the deforming surface.	1			
Deforming surface is applied in coordinate system of base surface	This check box controls whether coordinates are transformed before the deformation surface is evaluated. When checked it has the effect of placing the deformer in the same coordinate system as the base surface. This could be useful, for example, if the same exact deformation is being applied to several similar base surfaces each at a different location. When not checked it has the effect of applying the deformer globally to the base surface. This would be used, for example, to apply different parts of one large deformation to the spatially correspond parts of a segmented mirror.	Unchecked			
ОК	Accept Deformation changes and close dialog box.				
Cancel	Discard Deformation changes and close dialog box.				
Apply	Apply Deformation changes and keep dialog box open.				
Help	Access this Help page.				

Examples

1) This short example demonstrates how a sinusoidal surface is used to deform a conic mirror. The two surfaces are shown below. The sinusoidal surface is an Implicit Script Surface.



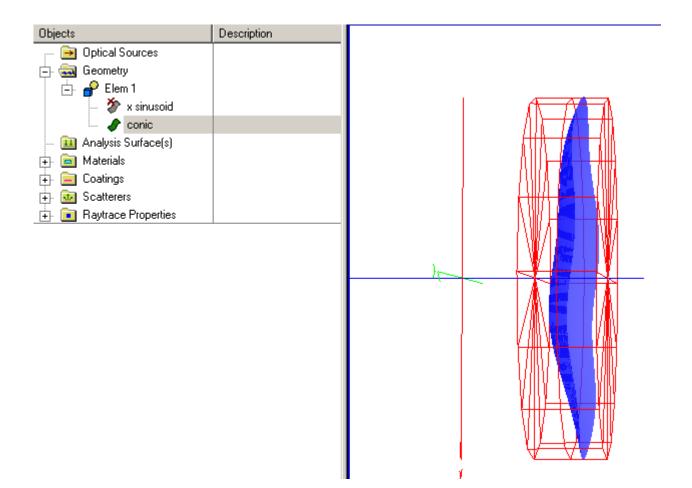
We now edit the conic surface and select the "Modifiers" tab:



🕻 (deform.frd *) Edit Surface: "conic"	<u> </u>				
SURFACE Aperture Location/Orientation Materials Coating/RayControl Scatter Visualization Glue Grating Auxiliary Data Modifiers	OK				
Sag Deformation Apply another surface's sag as a deformation to this surface	Cancel Apply				
Deforming Surface: Geometry.Elem 1.x sinusoid	Help				
Scale deformation by: 1					
Deforming surface is applied in coordinate system of base surface.					

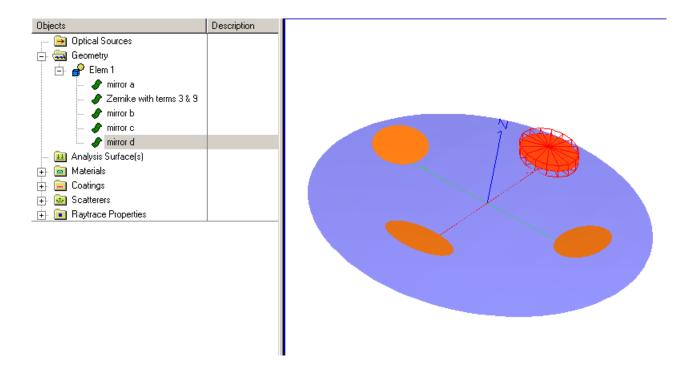
Check the "Apply another surface sag as a deformation..." to activate the deformation feature. The deforming surface "Geometry.Elem 1.x sinusoid" is selected from the dropdown list under "Deforming Surface". The "Deforming surface is applied in coordinate system of base surface" option is checked since both surfaces have the same aperture and lie on the z-axis. To finish, click OK. The deformed surface is shown in the view below after having set the sinusoidal surface to be NotTraceable.





2) This next example uses a Zernike base surface to deform a set of off-axis sections of a parabolic mirror. Once again, the base and deforming surfaces are created in FRED as shown below

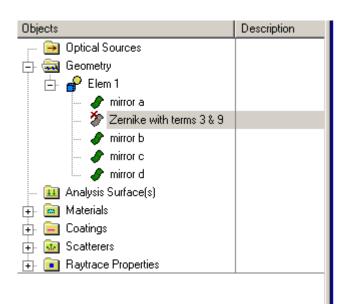




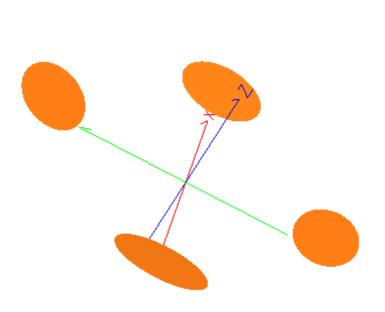
In this case, the desire is to use the single Zernike surface to deform each mirror section according to its radial position. Thus, the "Deforming surface is applied in coordinate system of base surface" option is unchecked which uses the deforming surface in the global coordinate system.

(C (FRED2 *) Edit Surface: "mirror a"	
SURFACE Aperture Location/Orientation Materials Coating/RayControl Scatter Visualization Glue Grating Auxiliary Data Modifiers	OK
Sag Deformation	Cancel Apply
Deforming Surface: Geometry. Elem 1. Zernike with terms 3 & 9	Help
Scale deformation by: 1	
Deforming surface is applied in coordinate system of base surface.	





The end result is that the mirror sections are deformed by the single base surface.





New Custom Element

Description Visualization How Do I Get There? Dialog Box and Controls

Description New Custom Element

In the tree geometry hierarchy, there are **Sub-Assemblies**, **Elements**, **Custom Elements**, **Surfaces**, **Curves**, and **Collection Curves**.

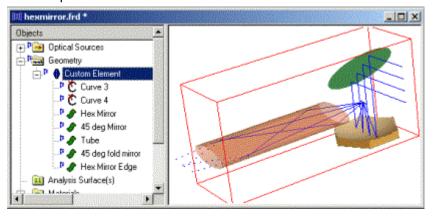
Custom Elements and Elements are collections of Surfaces, Curves, and Collection Curves. Surfaces and Curves can only be entered into Custom Elements, i.e. the user cannot enter surfaces directly into the Geometry folder, Elements, or Sub-Assemblies.

Elements are collections of surfaces constructing lenses, prisms, or mirrors that have been created with the lens, prism, and mirror dialogs or imported from the lens catalogs. The user has limited access to attributes of the surfaces in **Elements** because the surfaces are all part of a defined lens or mirror. For example, the aperture of the lens or mirror **Element** can be changed but the aperture of the individual surfaces in that **Element** cannot be changed independently.

Custom Elements can contain any number of **Surfaces** and **Curves**. But they cannot contain other **Custom Elements** or **Sub-Assemblies**. Unlike **Elements**, the user has complete access to attributes of the surfaces and curves in **Custom Elements**.

Elements can be converted to **Custom Elements** via an option in the right mouse click pop-up menu in the geometry folder.

Visualization (example) New Custom Element



An example of **Custom Element** with a number of surfaces and curves is shown below.

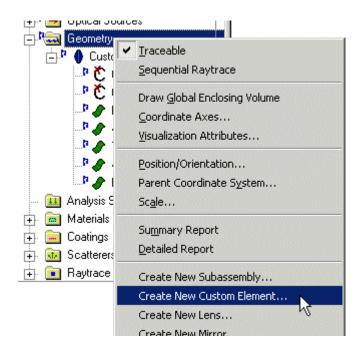
There are four ways to access this command:

- 1. On the Create Toolbar, click this button:
- 2. On the Create menu, select "New Custom Element...".

1 Zi can	e <u>A</u> nalyses	<u>W</u> indow	<u>H</u> elp				
🖈 N	ew Simplified	Source	Ctrl+A	lt+I			
_ ≾i N	Image: Source description Ctrl+Alt+D						
🚺 N	ew <u>L</u> ens		Ctrl+A	lt+L			
🔰 N	ew <u>M</u> irror		Ctrl+Al	t+M			
N	ew <u>P</u> rism…		Ctrl+Al	lt+P			
an N	ew <u>S</u> ubasser	nbly	Ctrl+Al	lt+S			
₽ N	ew Custom <u>E</u>	lement	Ctrl+A	t+E			
			~~				
🔷 N	ew Sur <u>f</u> ace		Ctrl+A	lt+F			
	ew Sur <u>f</u> ace ew Cur <u>v</u> e		Ctrl+Al Ctrl+Al				
Ĉ N	-			lt+V			
Č N	- ew Cur <u>v</u> e	Surface	Ctrl+A	lt+V t+N			
	ew Cur <u>v</u> e ew A <u>n</u> alysis :	Surface	Ctrl+Al Ctrl+Al	lt+V t+N lt+T			
	ew Cur <u>v</u> e ew A <u>n</u> alysis : ew Ma <u>t</u> erial.	Surface	Ctrl+Al Ctrl+Al Ctrl+Al	lt+V t+N lt+T t+C			

3. Select "Create New Custom Element..." in the right click pop-up menu on the Geometry node or any child node in the geometry folder





4. Use they keyboard shortcut Ctrl+Alt+E.

Dialog Box and Controls New Custom Element

Crea	te a Custom Element			<u>?</u> ×
Logical	l Parent:			OK
Geome	etry		▼	
Name:				Cancel
Elem 1				Help
Positior	n/Orientation:			v bounding box
		Action	Parameters (right mouse-clic)	k for popup me
0	Geometry ()			

This is a modal dialog. FRED does not respond to other commands until this dialog is closed.

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Logical Parent:	Parent name of the new custom element.	name of the Subassembly highlighted when the command is given
Name:	Name for the new Custom Element.	Elem 1
Description:	Informative description for the Custom Element.	blank
	Attributes	
Traceable	Makes the Custom Element affect rays during a raytrace.	Selected
Draw bounding box	Draws a box around the Custom Element.	not Selected
	Position/Orientation	
Reference Coordinate System, Action, Parameters	Set reference coordinate system and append position/orientation primitives.	Coordinates system of parent, none
ОК	Create new Custom Element and close the dialog box.	
Cancel	Discard new Custom Element and close the dialog box.	
Help	Access this Help page.	

Element Versus Custom Element

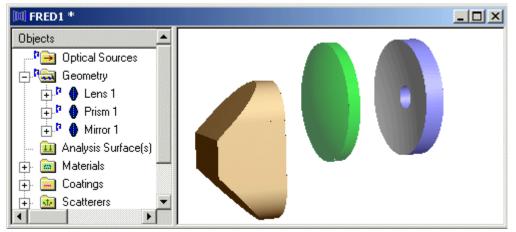
Description - Element Versus Custom Element

Elements in FRED are collections of **Surfaces** and **Curves** used to represent **Lenses**, **Prisms**, and **Mirrors**. The **Surface** and **Curves** in **Elements** can be viewed and edited and the **Surface** types, **Materials**, **Coatings**, **Scatter**, **Grating**, **Glue**, and **Visualization** properties can be altered but the **Surface Trimming Volumes**, i.e. apertures, cannot be altered on the individual **Surfaces**. The **Trimming Volume** can only be changed in the corresponding **Element** edit/view dialog, available in the right mouse click pop-up menu.

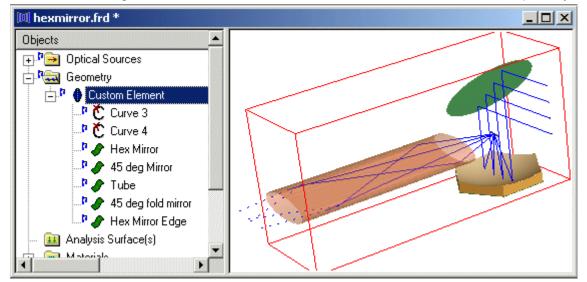
The advantage of an **Element** is that **Lens**, **Prism**, or **Mirror** properties can be edited vie the **Edit/View Lens...**, **Edit/View Prism...**, or **Edit/View Mirror...** dialogs respectively and all

of the surfaces making up that **Element** will be updated together. In contrast, if an **Element** is converted to a **Custom Element**, then each **Surface** must be edited separately. The figure below illustrates **Prism**, **Lens**, and **Mirror Elements**.

Surfaces and Curves can be added to Elements, but when the Element is edited only the Surfaces that are part of the original Element change. The Surfaces added to the Element do not change unless they are edited separately.



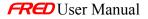
Custom Elements are arbitrary collections of **Surfaces** and **Curves** where the user can define any geometry. A **Custom Element** with the **Trimming Volume** drawn around it is illustrated in the figure below. In a **Custom Element**, each **Surface** must be edited separately.

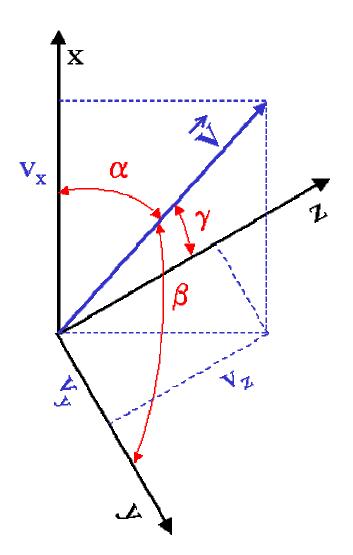


Description - Explaining Direction Cosines

The direction cosines, A,B,C, are simply the cosines of the angles, α , β , γ , made between a given vector, $\mathbf{V} = (v_x, v_y, v_z)$, and the positive local X, Y, and Z axes. Note that if \mathbf{V} is a unit vector, i.e. $|\mathbf{V}| = \text{Sqrt}[(v_x)^2 + (v_y)^2 + (v_z)^2] = 1$, then the direction cosines, (A,B,C), are simply equal to the vector elements, (v_x, v_y, v_z) , respectively.

$$A = \cos(\alpha) = \frac{v_x}{|\vec{V}|}$$
$$B = \cos(\beta) = \frac{v_y}{|\vec{V}|}$$
$$C = \cos(\gamma) = \frac{v_z}{|\vec{V}|}$$





Once two direction cosines have been defined, for example A and B, then the third, in this case C, is defined as well through the following relationship. In the two relationships below, the direction cosines have been normalized to 1. FRED does not require that the direction cosines be normalized to one when they are entered in a dialog or macro command. But, FRED will normalize any set direction cosines entered into a FRED dialog or macro command using the relationships below.

$$A^2 + B^2 + C^2 = 1$$

$$\cos(\alpha)^2 + \cos(\beta)^2 + \cos(\gamma)^2 = 1$$



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IGES Object Type Numbers and Titles

The complete list of the standard IGES entities is listed in numerical order below. The brief definitions below are quoted / paraphrased directly from IGES (Initial Graphics Exchange Specification) version 5.3 specification.

Туре	Form	Name	Description
0		Null Entity	The Null Entity type is intended to be ignored by a processor. When encountered by a processor, this entity shall be skipped over and not processed.
100		Circular Arc Type	A circular arc is a connected portion of a circle which has distinct start and terminate points. The definition space coordinate system is always chosen so that the circular arc lies in a plane either coincident with, or parallel to, the Xt and Yt plane. Supported in FRED as a Circular Arc.
102		Composite Curve Entity	A composite curve is a continuous curve that results from the grouping of certain individual constituent entities into a logical unit. A composite curve is defined as an ordered list of entities consisting of point, connect point, and parameterized curve entities (excluding the Composite Curve Entity).
104		Conic Arc Type	A conic arc is a bounded connected portion of a conic curve which has distinct start and terminate points. The parent conic curve is either an ellipse, a parabola, or a hyperbola.
106	1-3	Copious Data Entity	This entity stores data points in the form of pairs, triples, or sextuples. An interpolation flag value signifies which of these forms is being used.
106	11- 13	Linear Path Entity	The linear path is an ordered set of points in either 2- or 3- dimensional space. These points define a series of linear segments along the consecutive points of the path.
106	20- 21	Centerline Entity	The Centerline Entity takes one of two forms. The first appears as crosshairs and is normally used in conjunction with circles. The second type is a construction between 2 positions.
106	31- 38	Section Entity	A Section Entity is a defined as a Copious Data Entity. The form number describes how the data are to be interpreted. These descriptions are included for compatibility with previous versions of the specification. The Sectioned Area Entity (Type 230) provides a more compact method for transferring this information.
106	40	Witness Line Entity	A Witness Line Entity is a Copious Data Entity that contains one or more straight line segments associated with drafting

			entities of various types.
106	63	Simple Closed Planar Curve Entity	A Simple Closed Planar Curve defines the boundary of a region in the X-Y coordinate space.
108		Plane Entity	The Plane Entity can be used to represent an unbounded plane, as well as a bounded portion of a plane.
110	0	Line Entity	A line is a bounded, connected portion of a straight line which has distinct start and termination points.
110	1-2	Line Entity	Form 1 is a semi-bounded line bounded on one end and unbounded on the other end. Form 2 is an unbounded line, i.e. an infinite line.
112		Parametric Spline Curve Entity	The Parametric Spline Curve is a sequence of parametric polynomial segments.
114		Parametric Spline Surface Entity	The Parametric Spline Surface is a grid of parametric polynomial patches.
116		Point Entity	A point is defined by its coordinates in definition space.
118		Ruled Surface Entity	A ruled surface is formed by moving a line connecting points of equal relative arc length (Form 0) or equal relative parametric value (Form 1) on two parametric curves from a start point to a terminate point on the curves. The parametric curves may be points, lines, conics, parametric splines, rational B-Splines, composite curves, or any parametric curves defined in the specification.
120		Surface of Revolution Entity	A surface of revolution is defined by an axis of rotation (which shall be a line entity (Type 110, Form 0), a generatrix, and start and terminate rotation angles. The surface is created by rotating the generatrix about the axis of rotation through the start and terminating angles.
122		Tabulated Cylinder Entity	A tabulated cylinder is a surface formed by moving a line segment called the generatrix parallel to itself along a curve called the directrix. This curve may be a line, circular arc, conic arc, parametric spline curve, rational B-spline curve, composite curve, or any parametric curve defined in this specification.
123		Direction Entity	A direction entity is a non-zero vector in Euclidean 3-space that is defined by its three components with respect to the coordinate axes.
124		Transformation Matrix Entity	The transformation matrix entity transforms three-row column vectors by means of a matrix multiplication and then a vector addition.
125		Flash Entity	A flash entity is a point in the ZT=0 plane that defines the

		location of a specific instance of a particular closed area.
126	Rational B- Spline Curve Entity	The rational B-Spline curve may represent analytic curves of general interest.
128	Rational B- Spline Surface Entity	The rational B-spline surface represents various analytical surfaces of general interest.
130	Offset Curve Entity	The Offset Curve Entity defines the data necessary to determine the curve offset from a given base curve C.
132	Connect Point Entity	A Connect Point Entity defines a point of connection for zero, one, or more entities.
134	Node Entity	The node entity is a geometric point used in the definition of a finite element.
136	Finite Element Entity	A finite element is defined by an element topology (i.e. node connectivity), along with physical and material properties.
138	Nodal Displacement and Rotation Entity	The nodal displacement and rotation entity is used to communicate finite element post processing data. It contains the incremental displacement and rotations (expressed in radians) for each load case and each node in the model.
140	Offset Surface Entity	The offset surface is a surface defined in terms of an existing surface.
141	Boundary Entity	The Boundary Entity identifies a surface boundary consisting of a set of curves lying on the surface.
142	Curve on a Parametric Surface Entity	The curve on a parametric surface entity associates a given curve with a surface and identifies the curve as lying on the surface.
143	Bounded Surface Entity	The bounded surface entity is used to represent trimmed surfaces. The surfaces and trimming curves are assumed to be represented parametrically.
144	Trimmed (Parametric) Surface Entity	Equivalent to a Trimmed Parametric surface in FRED.
146	Nodal Results Entity	Not supported by FRED.
148	Element Results Entity	Not supported by FRED.
150	Block Entity	Represents a rectangular block. Not supported in FRED.
152	Right Angular Wedge Entity	A 3D block object with four rectangular faces and two quadratic faces. Not supported in FRED.
154	Right Circular Entity	A 3D cylinder object. Not supported in FRED.

156	Right Circular Cone Frustum Entity	A 3D cone object which may or may not come to a point. Not supported in FRED.
158	Sphere Entity	A sphere object defined as a point and a radius in 3 dimensions. Not supported in FRED.
160	Torus Entity	A circle revolved around an axis in the same plane as the circle. Not supported in FRED.
162	Solid of Revolution Entity	A solid 3D object formed by rotating a planar shape through an angle about an axis. Not supported in FRED.
164	Extrusion	A solid 3D object formed by extruding a planar shape through a distance. Not supported in FRED.
168	Ellipsoid Entity	A solid 3D object formed by rotating an ellipse about its major axis 180 degrees. Not supported in FRED.
180		An IGES entity that supports Boolean logical operations. Not supported in FRED.
182	Selected Component Entity	An IGES entity that supports a selected component of a CSG solid. Not supported in FRED.
184	Solid Assembly Entity	Not supported by FRED.
186	Manifold Solid B-Rep Object Entity	Not supported by FRED.
190	Plane Surface Entity	A plane surface. Not supported in FRED; the FRED plane is defined differently. This type is neither read in nor written out.
192	Right Circular Cylindrical Surface Entity	A cylinder defined by a point, a direction, and a radius. Not supported in FRED.
194	Right Circular Conical Surface Entity	A cone defined by a point, an axis direction, a radius, and an angle. Not supported in FRED.
196	Spherical	A sphere defined by a point and a surface (not a solid). Not supported in FRED.
198		A surface defined by a point, an axis, and two radii. Not supported in FRED.
202	Angular Dimension Entity	IGES entity that represents the annotation of an angle measurement. Not supported in FRED.

204		Curve Dimension Entity	IGES entity that represents the annotation of the length of a curve. Not supported in FRED.
206		Diameter Dimension Entity	IGES entity that represents the annotation of the diameter of a circular arc. Not supported in FRED.
208		Flag Note Entity	IGES entity that represents an annotation flag. Not supported in FRED.
210		General Label Entity	IGES entity that represents a general note. Not supported in FRED.
212		General Note Entity	IGES entity that represents a set of text strings. Not supported in FRED.
213		New General Note Entity	IGES entity like type 212 but able to accommodate more text characteristics. Not supported in FRED.
214	1-12	Leader (Arrow) Entity	IGES entity representing an arrow head point. Not supported in FRED.
216		Linear Dimension Entity	IGES entity that represents a dimension between two points. Not supported in FRED.
218		Ordinate Dimension Entity	IGES entity that represents a set of dimensions from a common base line. Not supported in FRED.
220		Point Dimension Entity	IGES entity that represents a text string surrounded by a circle or hexagon, annotating a point. Not supported in FRED.
222	0-1	Radius Dimension Entity	IGES entity that represents a point where annotating text is surrounded by a circle. Not supported in FRED.
228	0-1	General Symbol Entity	IGES entity that represents a set of notes that annotate a point, surrounded by a geometry entity. Not supported in FRED.
230		Sectioned Area Entity	IGES entity that represents an area that is filled with a line pattern. Not supported in FRED.
302		Associativity Definition Entity	IGES entity that represents a group. Not compatible with the FRED group.
304	1-2	Line Font Definition Entity	IGES entity that represents a line font. Not supported by FRED.
306		MACRO Definition Entity	IGES entity that represents a macro. Not supported by FRED.

308		Subfigure Definition Entity	IGES entity that allows for multiple instances of the same object. Not supported by FRED.
310		Text Font Definition Entity	IGES entity that defines the appearance of characters in a text font. Not supported by FRED.
312		Text Display Template Entity	IGES entity that sets parameters for displaying information from another entity. Not supported by FRED.
314		Color Definition Entity	IGES entity that stores the RGB color information for an entity. Not supported in FRED.
316		Units Data Entity	IGES entity that stores information about the unit's of a model in an IGES file. Not supported by FRED.
320		Network Subfigure Definition Entity	IGES entity similar to the type 308 subfigure definition, used to define a specialized subfigure. Not supported by FRED.
322		Attribute Table Definition Entity	IGES entity that defines a table of attributes for an entity. Not supported by FRED.
402			Identifies the type of associativity relation between two entities. Not supported by FRED.
402	1	Group Associativity	IGES entity that allows a collection of entities to be maintained as one. Not supported by FRED.
402	3	Views Visible Associativity	IGES entity that defines an associativity to a view entity. Not supported by FRED.
402	4	Views Visible, Color, Line Weight Associativity	IGES entity that defines an associativity between view entities of differing display styles. Not supported by FRED.
402	5	Entity Label Display Associativity	IGES entity that defines an association between displays for entity labels. Not supported by FRED.
402	7	Group Without Back Pointers Associativity	IGES entity that defines an association between groups without back pointers. Not supported by FRED.
402	9	Single Parent Associativity	IGES entity that defines an association between a single parent and multiple entities. Not supported by FRED.
402	12	External Reference File Index	IGES entity that defines an association between definitions in separate files. Not supported by FRED.

		Associativity	
402	13	Dimensioned Geometry Associativity	Deprecated by type 402 form 21. Not supported by FRED.
402	14	Ordered Group with Back Pointers Associativity	IGES entity that defines an association between ordered groups with back pointers. Not supported by FRED.
402	15	Ordered Group, no Back Pointers Associativity	IGES entity that defines an association between ordered groups without back pointers. Not supported by FRED.
402	16	Planar Associativity	IGES entity that defines an association between coplanar entities. Not supported by FRED.
402	18	Flow Associativity	IGES entity that defines an association between two entities with a flow path. Not supported by FRED.
402	19	Segmented Views Visible Associativity	IGES entity that defines an association between display parameters for two or more curves. Not supported by FRED.
402	20	Piping Flow Associativity	IGES entity that defines an association for a single fluid flow path. Not supported by FRED.
402	21	Dimensioned Geometry Associativity	IGES entity that defines an association between a dimension entity and the geometry entities it is dimensioning. Not supported by FRED.
404		Drawing Entity	IGES entity that defines a collection of annotation entities. Not supported by FRED.
406		Property Entity	IGES entity that contains numerical or textual data. Not supported by FRED.
406	1	Definition Levels Property	Not supported by FRED.
406	2	Region Restriction Property	Not supported by FRED.
406	3	Level Function Property	Not supported by FRED.
406	4	(OBSOLETE) – Region Fill Property	Not supported by FRED.

406	5	Line Widening Property	Not supported by FRED.
406	6	Drilled Hole Property	Not supported by FRED.
406	7	Reference Designator Property	Not supported by FRED.
406	8	Pin Number Property	Not supported by FRED.
406	9	Part Number Property	Not supported by FRED.
406	10	Hierarchy Property	Not supported by FRED.
406	11	Tabular Data Property	Not supported by FRED.
406	12	External Reference File List Property	Not supported by FRED.
406	13	Nominal Size Property	Not supported by FRED.
406	14	Flow Line Specification Property	Not supported by FRED.
406	15	Name Property	Not supported by FRED.
406	16	Drawing Size Property	Not supported by FRED.
406	17	Drawing Units Property	Not supported by FRED.
406	18	Intercharacter Spacing Property	Not supported by FRED.
406	19	Line Font Property	Not supported by FRED.
406	20	Highlight Property	Not supported by FRED.
406	21	Pick Property	Not supported by FRED.
406	22	Uniform Rectangular Grid Property	Not supported by FRED.
406	23	Associativity Group Type	Not supported by FRED.

		Property	
406	24	Level to LEP Layer Map Property	Not supported by FRED.
406	25	LEP Artwork Stackup Property	Not supported by FRED.
406	26	LEP Drilled Hole Property	Not supported by FRED.
406	27	Generic Data Property	Not supported by FRED.
406	28	Dimension Units Property	Not supported by FRED.
406	29	Dimension Tolerance Property	Not supported by FRED.
406	30	Dimension Display Data Property	Not supported by FRED.
406	31	Basic Dimension Property	Not supported by FRED.
406	32	Drawing Sheet Approval Property	Not supported by FRED.
406	33	Drawing Sheet ID Property	Not supported by FRED.
406	34	Underscore Property	Not supported by FRED.
406	35	Overscore Property	Not supported by FRED.
406	36	Closure Property	Not supported by FRED.
408		Singular Subfigure Instance Entity	Not supported by FRED.
410	1	Perspective View Entity	Not supported by FRED.
412		Rectangular Array Subfigure	Not supported by FRED.

		Instance Entity	
414		Circular Array Subfigure Instance Entity	Not supported by FRED.
416		External Reference Entity	Not supported by FRED.
418		Nodal Load / Constraint Entity	Not supported by FRED.
420		Network Subfigure Instance Entity	Not supported by FRED.
422		Attribute Table Instance Entity	Not supported by FRED.
422	0	Attribute Table Instance	Not supported by FRED.
422	1	Attribute Table Instance	Not supported by FRED.
430		Solid Instance Entity	Not supported by FRED.
502	1	Vertex List Entity	Not supported by FRED.
504		Edge List Entity	Not supported by FRED.
508		Loop Entity	Not supported by FRED.
510		Face Entity	Not supported by FRED.
514		Shell Entity	Not supported by FRED.

Chapter 6 – How to Create Curves and Curve-based Surfaces

Introduction to Curves and Curve-based Surfaces

Description Curve Types

- Line Segment
- Circular Arc
- <u>Conic Arc</u>
- <u>Segmented</u>
- <u>Composite Curve</u>
- <u>Spline</u>
- <u>Others</u>
- Surface Types
- Tabulated Cylinder
- Surface of Revolution
- Ruled Surface

Application Notes

Description Introduction to Curves and Curve-based Surfaces

FRED has a number of implicit, or curve-based surface types: the **Tabulated Cylinder**, the **Ruled Surface**, and the **Surface of Revolution**. These surfaces allow for a great deal of flexibility to generate complicated surface geometries, but have some simple rules and limitations that do not apply to more conventional surface functions.

First among these is that an implicit surface cannot be used to trim another surface. This is because the surfaces are generated as parametric functions, and, as such, do not have an easily identifiable positive and negative side. In other words, the +Z direction of the local surface normal, which is used to establish rules for trimming, is ambiguous. However, these surfaces are bounded and can be trimmed by function-based surface types.

Second, at least some portion of the generating curve must be located inside the bounding volume of the surface. Only that portion of the curve inside the bounding volume will be created. Putting both the curve and the surface in the same coordinate system most easily satisfies this requirement.

Third, curves are used to create surfaces, not volumes, although a fully enclosed volume may be the end result. For example, a rod lens uses a surface of revolution to create the cylinder must also include separate surfaces for each end to close the volume. Failure to do so may result in ray failures because FRED may propagate a ray that sees a change in the refractive index as it exits the volume occupied by the cylinder without intersecting a surface. Without a surface intersection, FRED cannot propagate the ray.

Curve Types Introduction to Curves and Curve-based Surfaces

Curves

FRED has number of simple curve types. In general, each curve is defined parametrically over an interval from [0,1]. The starting point is always at u = 0 and the ending point is at u = 1.

Curves alone are not traceable.

A brief description of each curve type follows.

Line segment

This is the simplest curve type. It is defined as the line connecting the point $(x, y, z)_{start}$ with the point $(x, y, z)_{end}$.

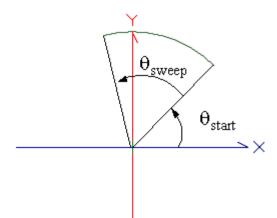
Type: Line segment (defined by start and end points)								
	Start Point	End Point						
	0	1						
	0	0						
	0	0						
			Start Point End Point 0 1 0 0 0 0 0 0					

Circular arc

As the name implies, this is a simple circular arc. By default, it is defined in the local XY plane. It is centered at (x_0, y_0) and has a radius *r*. The start and end points for the arc are given by the start angle and the sweep angle, respectively. These are polar angles are measured in degrees, counter-clockwise from the X-axis ($\theta = 0$). Both the start and sweep angles can be between 0 and 360 degrees.

Type: Circular arc				
	Value	Description		
Center X	0	X coordinate of the center		
Center Y	0	Y coordinate of the center		
Radius	1	Radius of the arc		
Start Angle	0	Start angle (deg). CCW from X-axis (0 to 360 degrees)		
Sweep Angle	360	Sweep angle (deg). CCW from start angle (0 to 360 degrees)		





Conic arc

	Value	Description				
	Curve described by: A*X*X+B*X*Y+C*Y*Y+D*X+E*Y+F=0					
A	1	Coefficient of X*X term				
В	0	Coefficient of X*Y term				
С	1	Coefficient of Y*Y term				
D	0	Coefficient of X term				
E	0	Coefficient of Y term				
F	-1	Constant term				
Start X	1	Curve's starting X value				
Start Y	0	Curve's starting Y value				
End X	1	Curve's ending X value				
End Y	0	Curve's ending Y value				

The **conic arc** is a more general form of the **circular arc**. It is used primarily for IGES[™] import. It is defined by the equation

$$f(x, y) = Ax^{2} + Bxy + Cy^{2} + Dx + Ey + F = 0$$

The function f(x,y) is a second-degree curve if both A and C are not 0. The curve is a parabola if the product AC = 0. The curve is an ellipse if the product AC > 0. It is a circle if A=C. The curve is a hyperbola if the product AC < 0. The B coefficient represents a rotation of the coordinate axes. If B = 0, the curves are not rotated about the local x- and y-axes. The D and E coefficients represent coordinate shifts.

User inputs include the desired coefficients and the range of values over which the curve is defined: x_{start} , y_{start} and x_{end} , y_{end} . These points do not have to lie on the curve. Rather they define the polar angle subtended by the curve, analogous to the convention used for the circular arc. The starting angle is simply

$$\theta_{\text{start}} = \arctan\left(\frac{y_{\text{start}}}{x_{\text{start}}}\right)$$

Likewise, the ending angle is

_

-

$$\theta_{\text{end}} = \arctan\left(\frac{y_{\text{end}}}{x_{\text{end}}}\right)$$

Parabola

A parabola in y has the form $Ey = Ax^2 + Bxy + Dx + F$. For any such parabola, the coefficients A and E cannot be zero and the C coefficient must be zero. The B and D coefficients rotate and shift the curve, respectively. The coefficient F is a constant offset that moves the curve up and down along the y-axis.

Ellipse

An ellipse centered at the point (x_0, y_0) has the form

$$\frac{(x - x_0)^2}{a^2} + \frac{(y - y_0)^2}{b^2} = 1$$

where a and b are the semi-major and semi-minor axis lengths, respectively. The coefficient values A..F can be found by equating the two forms. To create an ellipse in which both *a* and *b* are known and is not rotated in the XY-plane, the conversion to the curve coefficients is found in Table 1.

Curve Coefficient	Value
А	$\frac{1}{a^2}$
В	0
С	$\frac{1}{b^2}$
D	-2A·x0
E	-2C·y0
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

Table 1 Coefficient Conversion for an Ellipse

If the conic constant k and the radius of curvature r are known, then a and b can be computed using the following relationships $(-1 < k \le 0)$.

$$a = \frac{r}{1+k}$$

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Hyperbola

A hyperbola centered at the point (x_0, y_0) has the form

$$\frac{(x-x_0)^2}{a^2} - \frac{(y-y_0)^2}{b^2} = 1$$

which describes a curve that intersects the x-axis (A > 0, C < 0). If the signs are reversed (A < 0, C > 0) the curve intersects the y-axis. The terms *a* and *b* do not have the same geometric significance for a hyperbola as they do for an ellipse and are not used except to calculate the asymptotes of the curve

$$y - y_0 = \pm \frac{a}{b}(x - x_0)$$

When A > 0 both x_{start} and x_{end} should be greater than zero. Further, y_{start} and y_{end} should be chosen so that the start and ending angles are between the asymptote lines. When A < 0, chose y_{start} and y_{end} greater than zero and x_{start} and x_{end} to be between the asymptote lines. Following these rules will help avoid unexpected results arising from the creation of multiple branches of the curve.

The curve coefficients for the hyperbola are analogous to those of the ellipse except A and C have opposite signs. Table 2 shows a similar coefficient conversion based on knowledge of *a* and *b*.

Curve Coefficient	Value
A	$\frac{1}{a^2}$
В	0
С	$\frac{1}{b^2}$
D	- 2A · x ₀
Е	-2C·y0
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

Table 2 Coefficient Conversion for a Hyperbola (A>0)

Segmented

A segmented curve is simply a collection of points in (x, y, z) connected by straight lines. It is not necessary for the curve to be closed and FRED will not automatically close the surface. To close the surface, simply enter the same coordinates for the last point as were entered for the first. A right mouse click in the active cell area in the dialogue box allows for row addition or deletion. In addition, FRED can read an ASCII text file of consisting of rows of X, Y, and Z points separated by spaces.

	X coordinate	Y coordinate	Z coordinate
Point 1	0	0	0
oint 2	1]n	
		Append Point	
		Insert Point	
		Delete Point	
		Scale Coordinates	
		Generate Points	
		Replace With Data From	a File
		Show Last Accessed File	Name V

Composite Curve

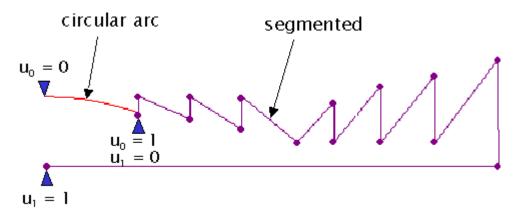
Composite curve (multiple connected curves)	<u> </u>
Curve Designation	Forward/Reverse
.Elem 1.Curve 1 ()	Reverse Sense
•	Reverse Sense
Elem 1.Curve 1 ()	
Elem 1.Curve 2 ()	
	Elem 1.Curve 1 ()

A composite curve is two or more curves joined in the following fashion,

start \rightarrow end, start \rightarrow end, ..., start \rightarrow end

The start point ($u_n = 0$) of each subsequent curve is coincident with the end point ($u_{n-1} = 1$) of the previous curve. The Reverse Sense check box flips the starting and ending points of the curve. When 2 or more curves are joined, the parameterization is renormalized so that the curve starts at $u_{composite} = 0$ and ends at $u_{composite} = 1$. The curves do not need to be the same type. Multiple composite curves can be joined as well.

In the following example, a composite curve is used to create a 'lighthouse' lens profile. The composite curve joins a circular arc and a number of segmented curves. Note that the curve is 'open'.



If the segments are not properly positioned, FRED issues an error message. A common error is to have the parameterization reversed so that FRED is trying to connect the start point

of one curve to the start point of a different curve, which is an invalid operation. It is often useful (but not required) to define the curves in that same coordinate system. The composite curve should also be located in the proper coordinate system as well. After creating the composite curve, it is recommended that each component curve be placed in the coordinate system of the composite. This way, the composite curve can be repositioned anywhere in the system and the component curves will automatically follow.

Any curve used to create the composite can be edited. Changes are reflected automatically. The rules governing the endpoint connections must still be obeyed. If a composite curve is copied, FRED automatically creates a duplicate set of the generating curves.

Spline

The spline is a parametric curve used mainly in the representation of CAD geometry. The position vector P along the curve as a function of the parameter t is given by

$$\mathsf{P}(t) = \sum_{i=1}^{n+1} \mathsf{B}_i \; \mathsf{N}_{i,k}(t) \qquad t_{\min} < t < t_{\max} \;, \qquad 2 \le k \le n+1$$

Knots or 'breakpoints' given in ascending order define the parametric range of the variable t.

For the ith normalized B-spline basis function of order k (degree = k-1), the basis functions $N_{i,k}(t)$ are defined by the Cox-de Boor recursion formulas:

$$N_{i,1}(t) = 1 \quad \text{ if } x_i \leq t \leq x_{i+1} \ , \qquad 0 \quad \text{ otherwise }$$

and

$$N_{i,k}(t) = (t - x_i) \cdot N_{i,k-1}(t) / (x_{i+k-1} - x_i) + (x_{i+k} - t) \cdot N_{i+1,k-1}(t) / (x_{i+k} - x_{i+1})$$

As an example, consider a 5^{th} order (degree = 4) curve defined over the breakpoint values <0 1>. The basis functions are then

$$N_{1,1} = 1$$
; $N_{1,2} = t$; $N_{1,3} = t^2$; $N_{1,4} = t^3$; $N_{1,4} = t^4$

These basis functions amount to the following polynomial expression with the U^n vector coefficients a, b, c, d, & f:

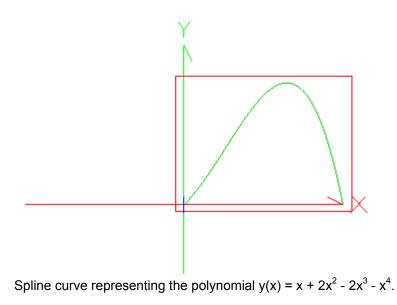
 $P(t) = a + b \cdot t + c \cdot t^{2} + d \cdot t^{3} + f \cdot t^{4}$

Consider the polynomial curve defined by $y(x) = x + 2x^2 - 2x^3 - x^4$. The dialog box below shows this curve cast in the form of a spline curve.



(FRED1 *) Edit Curve: "Curve 1"							
Curve Location/Orientation Visualization							
Logical Parent: Elem 1						Cancel	
Name:						Apply	
Description:						Help	
Type: Splin	ne (polynom	nial segments)			•		
	Polynomia	l degree (1=li	near, 2=quad	Iratic, etc.)			
Degree	4						
Breakpoints	Breakpoin	ts in ascendii	ng order				
0	0						
1	1						
Segment(0)	х	Ŷ	Z	(0.000000 <= U <= 1.000000)			
0	0	0	0	U^0 vector coefficient			
1	1	1	0	UM vector coefficient			
2	0	2	0	U^2 vector coefficient			
3	0	-2	0	U^3 vector coefficient			
4	0	-1	0	U^4 vector coefficient			
]						
,							

The x-coordinate is given by $P_x(t) = t$ and the y-coordinate by $P_y(t) = t + 2 \cdot t^2 - 2 \cdot t^3 - x^4$. As expected, FRED draws this curve in the 3D View:



Other curve types

FRED also has a number of special curve types that are used primarily to import IGES[™] files and lenses from CODE V[™], OSLO[™], and ZEMAX[™]. These surface types are: *NURB* (Non-Uniform Rational B-spline), *Spline* (polynomial segments), and *Aperture Curve Collection*. FRED automatically creates the fit coefficients for the NURB and Spline curves during a CAD system import. The user is not required to enter points manually. The Aperture Collection Curve is used to create complex or segmented apertures on a single surface (instead of creating multiple copies of the same surface). These curves must be closed and are used only to establish trimming boundaries in the aperture settings for the surface. Aperture curves will be created automatically during a lens file import. The user can also create and apply them manually.

Surface types

Tabulated Cylinder

The Tabulated Cylinder is a simple extrusion of a curve. The user is prompted for the directrix (generating) curve and the length of the extrusion (in lens units) along each of the local x-, y-, and z-axes. These lengths are used to form the vector that orients the extrusion axis. Although not a requirement, the curve is typically extruded along the axis perpendicular to the plane containing the generating curve. Except for extrusions in the plane of the curve, the cross section of an extrusion taken in the plane containing the generating curve between the exact same shape and form as the generating curve. Extrusions in the plane of the curve result in sheets with (possibly) irregular edges. If the curve is not closed, the neither will be the surface. It may be necessary to add the sides and ends separately if the surface is to be used as a refractive optical element to ensure the accuracy of the raytrace.

Type: Tabulated Cylinder (straight line extruded curve)						
	Parameters	Description				
Directrix Curve	Elem 1.Curve 2	Curve that determines the shape of the surface				
X Direction	0	$\sqrt[6]{X}$ extrusion. The directrix is extruded along this vector.				
Y Direction	0	Y extrusion. The directrix is extruded along this vector.				
Z Direction	1	Z extrusion. The directrix is extruded along this vector.				

Some examples of the tabulated cylinder are shown in the following figures.

The picture on the left shows an extrusion of the 'lighthouse' lens profile perpendicular to the plane of the curve. The picture on the right shows an extrusion in the plane of the same curve.

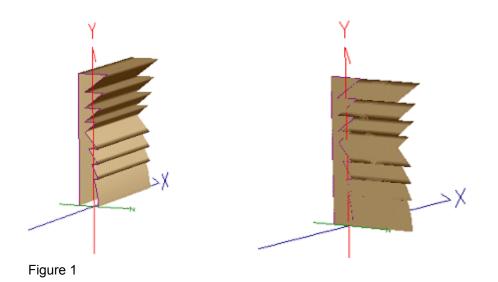
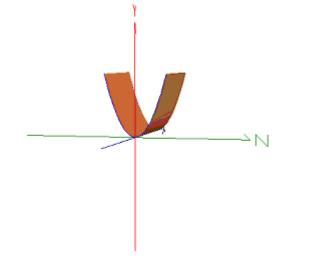


Figure 2 shows the extrusion of a parabolic curve defined in the YZ-plane along the Xaxis. Figure 3 shows the extrusion of a parabolic curve defined in the YZ-plane along an arbitrary axis. Note that any cross-section of the surface taken in the YZ-plane will have the same shape and dimensions as the base curve.





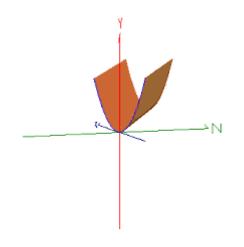


Figure 3

Surface of Revolution

A **Surface of Revolution** spins a curve about an arbitrary axis. The user is prompted for the generating curve, the start and ending rotation angles, and the local (x, y, z) coordinates for the rotation axis. Positive angles are measured counter-clockwise from the plane containing the generating curve. The start angle must be less than the end angle. The rotation axis is along the line connecting start and end points, entered by the user. Remember that FRED only creates surfaces. A closed volume requires bounding surfaces.

	Start Parameters	End Parameters	Description
Generatrix Curve			Curve that determines the shape of the surface
Rotation Angles	o h	360	Starting and ending rotation angles (deg). Ending angle > starting angle.
X Coord	0	0	Rotation axis X coords for starting and ending points on the rotation axis
Y Coord	0	0	Rotation axis Y coords for starting and ending points on the rotation axis
Z Coord	0	1	Rotation axis Z coords for starting and ending points on the rotation axis

Figure 4 shows two examples of a **surface of revolution**. The surface on the left shows a complete revolution. The surface on the right is only partially revolved, with the start and end angles shown.

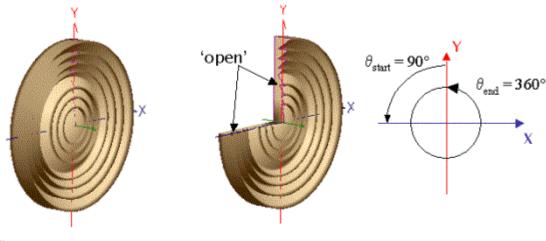
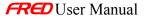


Figure 4



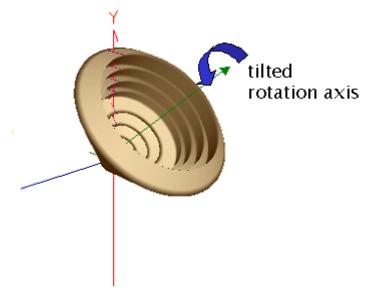
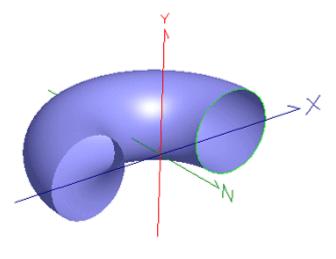


Figure 5 shows the same curve revolved around a tilted rotation axis.



Another example of a surface of revolution is a torus, which is simply a circle (Circular Arc) revolved around an offset axis, as shown in Figure 6.





A cone can be generated in a similar fashion, as shown in Figure 7. The cone was created by revolving a line segment defined in the YZ-plane about the z-axis.

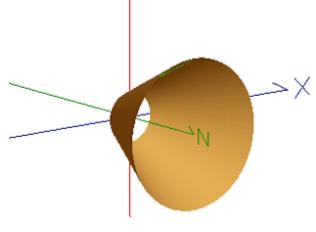


Figure 7

Ruled surface

The **Ruled Surface** type connects two curves. The curves may be of any type, open or closed, and do not have to have the same shape. The rule for connecting the two curves is selected by the user as one of two options. The first option is the default condition. It connects the start of the first curve to the start of the second curve. When this option is selected, each point *u* on curve 1 is connected to the same point *u* on curve 2. The second option connects the start of the first curve to the end of the second curve. Each point *u* on curve 1 is connected to the point 1-*u* on curve 2. This option is often the best choice if the curves are defined in opposite directions, i.e., clockwise and counter-clockwise for closed curves or with *u* increasing along +X and -X for open curves. A quick check of the system view after any change has been applied is usually sufficient to determine if the desired surface has been created.

Type: Ruled Surface (two connected curves)			1
	Curve Specification	Description	
Curve 1	.Elem 1.Curve 1 () 💌	First rail curve (connected to the second rail curve)	88
Curve 2	Elem 1.Curve 2 (🔨	Second rail curve (connected to the first rail curve)	
Connection	Connect START of MS Connect START of firs	t curve to START of second curve t curve to END of second curve	

The most common application of the **Ruled Surface** is to create a tube with different shapes on each end. Likewise, apertures, such as a round disk with a square hole in the center (really a zero length cylinder) can be modeled with this surface type (Figure 8) by connecting the inner square to the outer circle. As a side note, a much more efficient way to create a similar aperture is to start with a simple **Plane** surface. The ruled surface generates a smoother surface than the function based **Cylinder** surface when one or both of the ends has sharp corners.



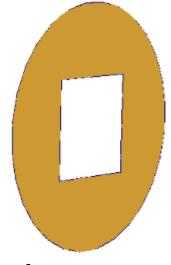


Figure 8

The following figures illustrate a **Ruled Surface** created with a square (**Segmented**) curve and a circle (**Circular arc**) to illustrate how the two curves are connected. Figure 9 shows a cylinder surface that is twisted because the starting points on each curve are rotated 45 degrees with respect to one another. In Figure 10, the curves have been properly oriented to create the 'correct' surface. The twist is removed by rotating the first square curve about its local z-axis.

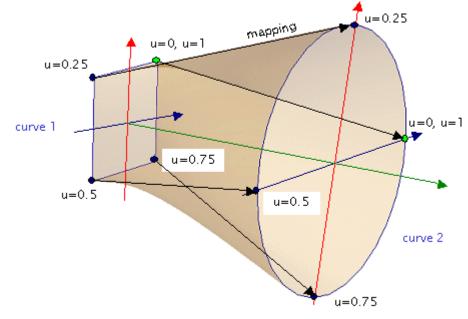
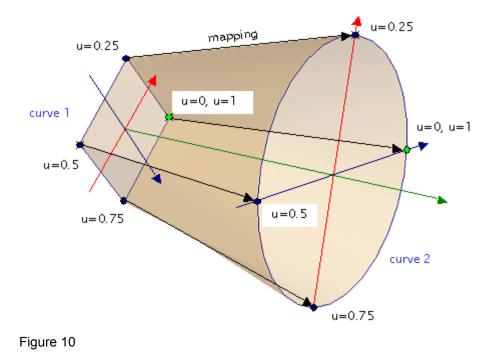


Figure 9



<u>Application Notes</u> Introduction to Curves and Curve-based Surfaces

- Values for x, y, and z are all evaluated in the local coordinate system of the surface (or curve). Limits for x, y, and z are determined by the trimming volume outer boundary settings.
- Curves and surfaces do not need to be defined in the same coordinate system. However, at least some portion of the generating curve must lie within the trimming volume outer boundary settings.
- A curve-based surface cannot be used to trim another surface.
- Copied surfaces also create duplicate generating curves.
- The same curve may be used to create multiple surfaces.

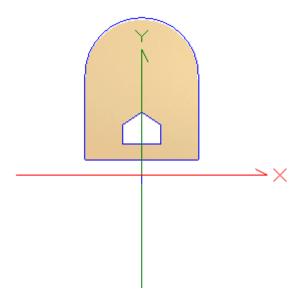


Description - Complex Surface Apertures: Aperture Curve Collection

Complex surface trimming boundaries or apertures can be created using the Aperture Curve Collection curve type. These are a special set of closed curves that are extruded into trimming surfaces that can then be applied to any FRED surface type. An aperture curve collection can be used to define inner and outer boundaries, holes, segmented apertures, etc. They are applied to the surface in the Trimming Surfaces Specification box, found under the Aperture tab of a Surface Dialog. An aperture curve collection can only be created from one or more closed curves.

<u>Visualization (example) - Complex Surface Apertures: Aperture Curve</u> <u>Collection</u>

The surface shown in the following figure has been trimmed by a single aperture curve collection.



How Do I Get There? - Complex Surface Apertures: Aperture Curve Collection

An aperture curve collection is defined under a Custom Element node.

<u>Dialog Box and Controls - Complex Surface Apertures: Aperture Curve</u> <u>Collection</u>



(apert	ure exan	nple.frd *) Ed	it Curve: "aperture collection"	_ 🗆 🗙
Curve [.ocation/0	Drientation Via	sualization	ОК
Parent:	Parent: Geometry.aperl		ture example	Cancel
Name:	Name: aperture colle		tion	Apply
Descrip	Description:			Help
	I			
Туре:	Aperture	curve collectio	n (uses closed curves only)	
	The loca	l Z-axis for 💌	Curve extrusion method	
<u> </u>	-	Curves in sar	ne group # are "AND"ed. Different group #s are "OR"ed.	
	Group#	Usage	Curve Designation (must be closed curve)	
1	1	Clear Aper 👻	.aperture example.outer composite ()	
2	1	Hole 💌	aperture example.inner segmented ()	
·				

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Parent	None.	Gives the parent object of the aperture curve collection. The aperture curve collection is always located under a Custom Element node.
Name	Name of curve.	Curve <i>n</i>
Description	Descriptive text for curve.	blank
Туре	Select 'Aperture curve collection' from the list of available curve types.	Circular arc
Curve extrusion method	Specifies the orientation and direction of the trimming surface extrusion.	Each curve is extruded along its local Z axis.
Group#	Enter the Group number of each curve. The Group number tells	All curves are "AND"ed together. The Group number is

1		
	FRED how to combine multiple curves.	1.
Usage	Choose one of the following: <i>Clear Aperture</i> <i>Edge</i> <i>Obscuration</i> <i>Hole</i> This control describes what happens to the area inside the curve.	Clear Aperture
Curve Designation	Select the closed curve or curves from the pull down list.	None
ОК	Create curve collection and close dialog box.	
Cancel	Discard curve collection changes and close dialog box.	
Apply	Apply curve collection changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Complex Surface Apertures: Aperture Curve Collection

- Line and arc segments must be joined together as a Composite Curve prior to specification as an Aperture Curve Collection.
- The curves defining the aperture curve collection must be closed. That is, the end point and the start point are the same and there are no gaps anywhere along the length of the curve.
- An aperture curve collection can contain one or more closed curves. The closed curves do not have to be connected.
- Usage definitions:
 - Clear Aperture (default) Keep the area of the surface inside the curve boundary. In the absence of an Edge specification, the surface is trimmed to the shape specified by the Clear Aperture. If an Edge is specified, then the Edge becomes the outer boundary of the surface and the Clear Aperture defines the region of the surface that will interact with the incident rays.
 - Edge The curve represents the physical outer boundary of the surface. In the absence of a Clear Aperture, any ray striking the surface inside the Edge is

halted. When used in conjunction with a Clear Aperture, the following rules apply:

- Rays incident outside of the area delineated by the Edge miss the surface
- Rays incident on the surface area inside of the Edge and outside of the Clear Aperture are halted on the surface
- Rays incident on the surface area inside of both the Edge and the Clear Aperture will interact with the surface according to the Raytrace Control and Coating specifications
- Obscuration Halt all rays incident on the area of the surface that lies inside the curve. This control does not trim the surface.
- Hole The area inside the curve is removed from the surface.
- Group definitions:
 - AND The resulting surface is the area represented by the intersection (overlap) of all the curves in the group. An annular ring is a Clear Aperture "AND"ed with a Hole.
 - OR The resulting surface is the area represented by the union (combination) of all the curves in the group. A segmented surface can be represented by a collection of "OR"ed apertures.

Examples - Complex Surface Apertures: Aperture Curve Collection

The following example illustrates the use of an aperture curve collection to trim the outer edge of a surface and cut an unusual shaped hole through the center. The surface is an XY Toroidal Asphere with an eccentric rectangular aperture. The aperture curve collection is composed of two curves: a Segmented curve for the inner hole and a Composite curve for the outer boundary (clear aperture). The surface is reflecting.

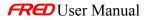
Create the base surface

Create or add a Custom Element node. Right click on the node and select Create a New Surface from the list of options. Go to the Surface tab and change the surface type from Plane to XY Toroidal Asphere, and enter the values shown below. Enter the appropriate values for the X and Y curvatures. Left click Apply to accept the changes.



SURFA	catter		isualization	Glue Glue	Grating Coating/RayControl	0K	
JOHIA	RFACE Aperture Location/Orientation Materials Coating/RayControl						
Parent:	Geometry.aperture example						
Name:	ellipse	reflector				Apply	
Descripti	ion:					Help	
Гуре:	XYT oroidal Asp	here (X or	Y toroid with even/	odd aspheric terms)	R		
			Y toroid with even/	odd aspheric terms) toroid selection	K		
Туре	XYToroidal Asp X toroid 🔿 0	here (X or Y toroid	d 🖲 🛛 Xor Y 1	toroid selection			
Type X Rad	X toroid 🔿		d ⊙ XorYt XRadiu		R		
Type X Rad	X toroid 🔿 0 -150		d ● X or Y1 X Radiu Y Radiu Y Radiu	toroid selection is (= 1/curvature) is (= 1/curvature)	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad Y Conic	X toroid 🔿 0 -150	Y toroid	d 💿 X or Y f X Radiu Y Radiu Y conic	toroid selection is (= 1/curvature) is (= 1/curvature)	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad	X toroid () 0 -150 -1	Y toroid	d 💿 X or Y f X Radiu Y Radiu Y conic	toroid selection is (= 1/curvature) is (= 1/curvature) : constant (<-1=hyperbi = Ai* Y^i	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad Y Conic Term	X toroid () 0 -150 -1 Ai coefficiem	Y toroid	d X or Y1 X Radiu Y Radiu Y Radiu Y conic Term :	toroid selection is (= 1/curvature) is (= 1/curvature) : constant (<-1=hyperbi = Ai* Y^i	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad Y Conic Term	X toroid () 0 -150 -1 Ai coefficiem	Y toroid	d X or Y1 X Radiu Y Radiu Y Radiu Y conic Term :	toroid selection is (= 1/curvature) is (= 1/curvature) : constant (<-1=hyperbi = Ai* Y^i	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad Y Conic Term	X toroid () 0 -150 -1 Ai coefficiem	Y toroid	d X or Y1 X Radiu Y Radiu Y Radiu Y conic Term :	toroid selection is (= 1/curvature) is (= 1/curvature) : constant (<-1=hyperbi = Ai* Y^i	ola, -1=parabola, <0=ellipse		
Type X Rad Y Rad Y Conic Term	X toroid () 0 -150 -1 Ai coefficiem	Y toroid	d X or Y1 X Radiu Y Radiu Y Radiu Y conic Term :	toroid selection is (= 1/curvature) is (= 1/curvature) : constant (<-1=hyperbi = Ai* Y^i	ola, -1=parabola, <0=ellipse		

Go to the Aperture tab and change the default *Trimming Volume Outer Boundary* to a box 36 units wide in X, 60 units tall in Y, centered at Y = 20 units, and 30 units deep in Z, centered at Z = -14 units, as shown in the dialog below. Left click on Apply to accept the changes.

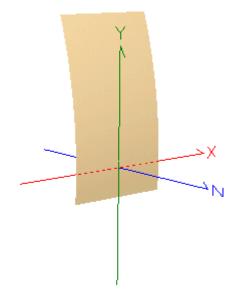


🕻 (aperture example.frd *) Edit Surface: "ellipse reflector"	_ 🗆 🗙
Scatter Visualization Glue Grating SURFACE Aperture Location/Orientation Materials Coating/RayControl	OK Cancel
Use this surface for trimming only (never raytrace) Trimming Volume Outer Boundary Semi-aperture: Center: X: 18 0 instead of semi-ape/ center Y: 30 Z: 15 ·14 Cultor Shape: Column Shape: Column Shape: Column Shape: Column Shape: Column Shape: Column Column Shape: Column Shape: Column Column Column Column <	Arroly Help
Advanced Dot-product Surface Trimming Specification None X-axis Perp Reference Vector: Position Y-axis Perp X: Y: Z: Direction Z-axis Perp Sign of the dot product: Positive Negative Trimming Surfaces Specification	
& AND I OR ! NOT Direct Edit # Other Trimming Volume () () Delete Selected	

Go to the **Coating/RayControl** tab to edit the raytrace properties of the surface. We are going to make the surface reflecting. To do so, first go to the *Coating* section and, with a left click, select the coating *Reflect* and then left click on the Assign button to apply the coating to the surface. Go to the *Raytrace Control* section and select *Reflect Specular* from the list with a left click. Assign the raytrace control property to the surface with a left click on the Assign button. Finally, change the color of the reflected rays by checking the box next to *Reflect* in the Ray Colors section. Choose a color different than that of the incident rays. Click on Apply to accept the changes, or OK to accept the changes and to close the dialog.

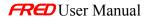
📢 (aperture exam	ple.frd *) Ed	it Surface: "ellipse	reflector"		_ 🗆 🗙
Scatter SURFACE	Visualization Aperture Location/Oriental		Glue ation Materials	Grating Coating/RayControl	OK Cancel
Ray Colors Change color	Coating	e raytraced) Reflect	100% Refle	ctive Coating	Apply
of rays that intersect this surface:	List of Available Coatings:	Name Absorb Reflect Transmit Standard Coating ◀	Description 100% Absorbing Coating 100% Reflective Coating 100% Transmissive Coatin 96% Transmitting 4% Ref	Assign	Help
Reflect	- Raytrace C Assigned:	ontrol Reflect Specular	Allow Refle	cted Specular Ray Only	
☐ Diffract ☐ Scatter	List of Available Raytrace Controls:	Name Halt All Transmit Specular Reflect Specular Allnux All	Description Halt All Ray Components Allow Transmitted Specular Allow Reflected Specular Allow Beflected and Trans	atEdit/View	

This is what the surface looks like in the Visualization window with the color set to Tan and the render mode set to Smooth Shading.



Create the outer boundary

The outer boundary of the surface will be a Composite curve [insert link to CURVES], which is a connected set of line segments and arcs. Each segment is a separate curve. FRED parameterizes every curve from 0 to 1 so that every curve, regardless of its shape, starts at u=0 and ends at u=1. A Composite curve connects multiple segments in the following fashion: Start \rightarrow End, Start \rightarrow End,...,Start \rightarrow End



The end of Curve N must coincide exactly with the start of Curve N+1 in order for the two to join. FRED renormalizes the parameterization after joining so that the new curve once again starts at u=0 and ends at u=1. In order for a Composite curve to be used in an Aperture Curve Collection, the curve must be 'closed', meaning that the start and end points coincide.

The first curve in the outer boundary is a semi-circular arc with a radius of 18 units and centered at Y = 32.

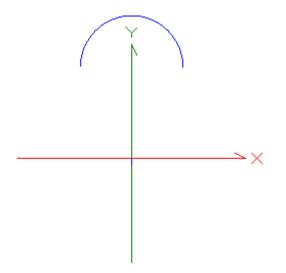
(aperture exa	mple.frd) Edit Curve: "semi-circular arc"		_ 🗆 X		
urve Location.	/Orientatio	n Visualization		0K		
Parent:	rent: Geometry.aperture example					
Name:	semi-circ	cular arc		Apply		
Description:				Help		
	I		- 1			
Type: Circular	r arc		- I			
1	Value	Description	Ξl			
Center X	0	X coordinate of the center				
Center Y	32	Y coordinate of the center				
Radius	18	Radius of the arc				
Start Angle	0	Start angle (deg). CCW from X-axis (0 to 360 degrees)				
Start Angle		Sweep angle (deg). CCW from start angle (0 to 360 degrees)				

The start angle is simply the angle, in degrees, of the starting point of the arc. It is measured counter-clockwise from the local X axis and can take any value from 0 to 360 degrees. For this example, use 0. Note that since the arc is not centered in the local coordinate system, the starting point will be physically located at (X,Y) = (18,32). The sweep angle is angle subtended by the arc, in degrees, beginning at the start angle. It too can take any value between 0 and 360 degrees, independent of the start angle. Enter a sweep angle of 180 degrees to trace a semi-circular arc. Go to the Visualization tab and click the check box next to Draw to render the curve in the selected color.



😭 (aperture example.frd *) Edit Curve: "semi-ci	rcular arc"
Curve Location/Orientation Visualization	
Curve	
Draw	
- Tesselation	
	E
Tesselation Step Size: 0	< Enter 0 for default
Scale Factor: 1	< Scale factor for step size
Bounding Volume	

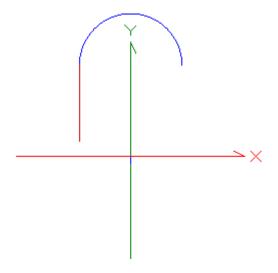
Left click on Apply to accept the changes or OK to accept the changes and close the dialog. The resulting curve is shown below.



The next curve in the sequence is a simple line segment, beginning at local coordinates (X,Y,Z) = (-18,32,0) and ending at (X,Y,Z) = (-18,5,0). Using the right click pop-up menu, choose **Create a New Curve** from the list of options and select the curve type "Line segment," as shown below. Note that the start of the segment is coincident with the end of the semicircular arc created above. Make the changes shown below, make the curve visible, and left click on Apply to accept the changes or OK to accept the changes and close the dialog.

🔆 (apei	ture exam	ple.frd *) Edit	Curve: "-x segment"		_ 🗆 X	
Curve	Curve Location/Orientation Visualization					
Parer	Parent: Geometry.aperture example					
Name	e: 🕞	k segment			Apply	
Desc	ription:				Help	
Туре:	Line segm	ent (defined by	v start and end points)	.		
	Start Poi	int End Point				
Х	-18	-18				
Y	32	5				
Z	0	0				

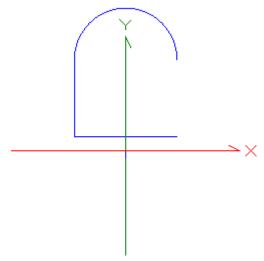
The two curves together look like this.



The third segment is a line starting at (X,Y,Z) = (-18,5,0) and ending at (X,Y,Z) = (18,5,0). It is created and rendered in the same way as the previous segment.

(aper	ture examp	le.frd *) Edil	t Curve: "bottom segment"				
Curve	Location/Orie	entation Visu	alization				
Paren	t Ge	Geometry.aperture example					
Name	: Бо	ttom segment					
Descr	iption:						
Туре:	Line segme	nt (defined b	y start and end points)				
	Start Poin	t End Point					
X	-18	18					
10	-10	1.0					
Ŷ	5	5					

The three curves together look like this.

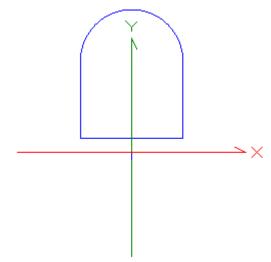


The last line segment encloses the area. It begins at (X,Y,Z) = (18,5,0) and ends at (X,Y,Z) = (18,32,0). It is created and rendered in the same way as the previous segment.

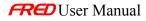


候 (aperti	(aperture example.frd *) Edit Curve: "+x segment"					
Curve	Location/O	rientation Vis	ualization			
Parent:	Parent: Geometry.aperture example					
Name:	F	•x segment				
Descrip	otion:					
Type:	Line segn	nent (defined t	by start and end points)			
	Start Po	int End Point				
Х	18	18				
Y	5	32				
Z	0	0				

The outer boundary of the mirror will look like the following.



The next step is to create a Composite Curve that combines the four curves that we have just defined into a single curve for subsequent use in the Aperture Curve Collection. To create a Composite Curve, go to the right click pop-up menu and choose Create a New Curve and select the Composite curve type. Name it 'outer composite.'



候 (aperti	ure example.frd *) Edit Curve: "outer composite"
Curve	_ocation/Orientation Visualization
Parent:	Geometry.aperture example
Name:	outer composite
Descrip	tion:
Type:	Composite curve (multiple connected curves)
	Circular arc Composite curve (multiple connected curves)
1	Conic arc (defined by coefficients of quadratic equation)
2	Line segment (defined by start and end points)
3	NURB (Non-Uniform Rational B-Spline) Spline (polynomial segments)
4	Segmented (points connected by line segments) Aperture curve collection (uses closed curves only)

Once the Composite curve type is selected, left click on the pull-down menu button under in the *Curve Designation* box and choose the semi-circular arc from the list of available curves, as shown below.

😭 (apertı	re example.frd *) Edit Curve: "outer composite"						
Curve L	ocation/Orientation Visualization	OK					
Parent:	Parent: Geometry.aperture example						
Name:	outer composite	Apply					
Descrip	ion:	Help					
Туре:	Composite curve (multiple connected curves)						
	Curve Designation Forward/Reverse	e					
1	.aperture example.semi-circular arc ()						
2 3 4 5	.aperture example.semi-circular arc () .aperture examplex segment () .aperture example.bottom segment () .aperture example.ext composite () .aperture example.inner segmented () .aperture example.aperture collection ()						

The remaining curves are added in the following order (moving counterclockwise around the group): '-x segment' (curve 2), 'bottom segment' (curve 3), '+x segment' (curve 4). The completed dialog is as follows.

(apert	ure exa	mple.frd *) Edit Curve: "outer composite"		_ 🗆 X			
Curve	ve Location/Orientation Visualization						
Parent		Geometry, aperture example		Cancel			
Name:		outer composite		Apply			
Descrip	otion:			Help			
Туре:	Compo	site curve (multiple connected curves)					
	Curve	Designation	Forward/Reverse				
1	.apertu	ure example.semi-circular arc () 🖉 💌	Reverse Sense				
2	.apertu	ure examplex segment ()	🗖 Reverse Sense				
3	.apertu	ure example.bottom segment ()	Reverse Sense				
4	.apertu	ure example.+x segment ()	Reverse Sense				
5		•	Reverse Sense				
•			Þ				

WARNING	The end of each curve must coincide <u>exactly</u> with the start of the subsequent curve in order for FRED to create a composite curve. If this condition is not met, then FRED pops up a warning dialog and omits the curve in question from the final construction.
Note	Checking the Reverse Sense box switches the start and end points of the curve in question, as may be required to successfully connect the curves.

Note To avoid inadvertently separating the curves at some later time, either make the coordinate system every curve in the referenced list coincident with the coordinate system of the composite curve, or put all the curves, including the composite curve, into the same coordinate system.

Create the inner hole

The hole in the center of the surface is a **Segmented** curve type. This curve consists of a collection of (X,Y,Z) points connected by simple line segments. It can used, for example, to create a square or a rectangle. The data points can be entered manually in the curve dialog or instead read from an ASCII text file containing rows of (X,Y,Z) coordinates. We will use the manual entry in this example. Go to the **Custom Element** node containing the outer boundary curve just described. Using the right click pop-up menu, select **Create a New Curve** and choose a **Segmented** curve type, as shown below. For this example the Name of the curve is 'inner segmented.'

<u>Қ</u> (aperture еха	mple.frd) Create a New Curve as Child of: "focus"	_ 🗆 🗙			
Curve Location	Curve Location/Orientation Visualization				
Parent:	Geometry.focus	Cancel			
Name:	inner segmented	Apply			
Description:		Help			
Point 2 Line se NURB Spline Segme	nted (points connected by line segments) arc site curve (multiple connected curves) rc (defined by coefficients of quadratic equation) gment (defined by start and end points) (Non-Uniform Rational B-Spline) (polynomial segments) nted (points connected by line segments) e curve collection (uses closed curves only)				

By default, the curve is created with two points already defined. We will edit these after adding four rows (for 6 points total). To add a row, right click inside the spreadsheet area at the bottom of the dialog and select the option *Append Point*, as shown below. Repeat this 3 more times.

Ġ (apertu	🕻 (aperture example.frd) Create a New Curve as Child of: "focus"							
Curve Location/Orientation Visualization								
Parent:	Parent: Geometry.focus							
Name:	inner segmente	ed				Apply		
Descrip	tion:					Help		
	I							
Type:	Segmented (points con	nected by line	segments)		▼			
	X coordinate	Y coo	ordinate	Z coordinat	e			
Point 1	0	0		0				
Point 2	1	0	Append Point	lin .				
			Insert Point	5				
			Delete Point					
			Scale Coordina	ates				
			Generate Poin	ts				
				Data From a File				
			Show Last Acc	essed File Name				



Once all the rows have been added, edit the enter the following (X,Y,Z) values for the 6 points

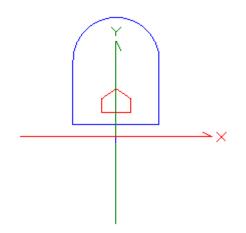
Point 1: (-6,10,0) Point 2: (6,10,0) Point 3: (6,16,0) Point 4: (0,20,0) Point 5: (-6,16,10) Point 6: (-6,10,0)

Parent:	Geometry.aper	ture example		Canc	
Name:	inner segmente	ed		Appl	
Descrip	Description:				
Туре:	Segmented (points con X coordinate	nected by line segments) Y coordinate	Z coordinate		
Point 1	-6	10	0		
- On It T	6	10	0		
Point 2	1°	40	0		
	6	16			
Point 2	-	20	0		
Point 2 Point 3	6		0 0		
Point 2 Point 3 Point 4	6 0	20	0		

Note In order to fully enclose an area with a segmented curve, the start and end coordinates must be the same.

Left click on $\ensuremath{\textbf{Apply}}$ to accept the changes, or $\ensuremath{\textbf{OK}}$ to accept the changes and close the dialog.

The outer and inner rendered curves should look like the following figure.



Create and apply the aperture collection curve to the surface

The last step is to now create the Aperture Curve Collection using the two curves defined in this example thus far: 'outer composite' and 'inner segmented'. Once again, go to the **Custom Element** node containing the surface you would like to trim and all of the curves defined so far. Using the right click pop-up menu, choose **Create a New Curve** and select the curve type *Aperture curve collection*.

📢 (aperture exa	mple.frd *) Edit Curve: "aperture collection"							
Curve Location.	/Orientation Visualization	OK						
Parent:	Geometry.aperture example	Cano						
Name:	aperture collection	Арр						
Description:		Hel						
Type: Apertur	e curve collection (uses closed curves only)							
Circular arc Composite curve (multiple connected curves) Conic arc (defined by coefficients of quadratic equation) Line segment (defined by start and end points) NURB (Non-Uniform Rational B-Spline) Spline (polynomial segments) Segmented (points connected by line segments)								
	Segmented (points connected by line segments) Aperture curve collection (uses closed curves only)							

Recall that FRED uses the Aperture curve collection to create an extruded surface that modifies the boundaries of the surface it is applied to. The user can specify the extrusion method from a list of options. Left click on the pull-down button next to 'Curve extrusion method' and choose *The collection curve's local Z-axis*. The extrusion extends to infinity in both directions along the defined axis. Further, the extrusion is never rendered or raytraced.



Гуре:	Aperture curve collection (uses closed curves only)						
	The collection curv Curve extrusion method						
	The collection curve's local Z-axis						
	The local Z-axis for each member cur∛e listed below	's are "OR"ed.					
	The best-average-plane's normal vector for each member curve	sed curve)					
1	The local surface normal vector						

The first curve is the outer boundary. Go to the pull-down menu and select the curve '...outer composite' from the list of available curves. Note that FRED will only list closed curves in this dialog.

Гуре:		Aperture curve collection (uses closed curves only)						
	The colle	The collection curve Curve extrusion method						
		Curves in same group # are "AND"ed. Different group #s are "OR"ed.						
	Curve Designation (must be closed curve)							
1	1	Clear Aper 🔻	.aperture example.outer composite ()					
2	1	Hole 🔻	aperture example.outer composite ()					
		·	aperture example.inner segmented () 🕅					

Append a new row by right clicking in the spreadsheet area and selecting that option from the list. Once again, display the pull down menu for the list of available curves and choose the curve '…inner segmented' from the list.

	0	Curves in same group # are "AND"ed. Different group #s are "OR"ed.						
	Group#	Usage	Curve Designation (must be closed curve)					
1	1	Clear Aper 🔻	aperture example.outer composite ()	Ŧ				
2	1	Hole 💌	.aperture example.inner segmented ()	•				
			aperture example.outer composite ()					
			aperture example inner segmented ()					

Make the second curve a **Hole** by selecting it from the pull down menu in the **Usage** column.

		Curves in same group # are "AND"ed. Different group #s are "OR"ed.				
	Group#	Group# Usage Curve Designation (must be closed				
1	1	Clear Aper 🔻	.aperture example.outer composite ()			
2	1	Hole 🔻	aperture example.inner segmented ()			
		Clear Apertur Edge Obscuration	e			
		Hole				

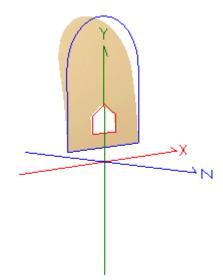
Notice that the group number for the two curves is the same. This means that their operations will be "AND"ed together so that FRED will keep the area of the surface outside of the **Hole** and inside of the **Clear Aperture**. Left click on the **Apply** button to accept the changes or OK to accept the changes and to close the dialog. At this point we can now use the aperture curve collection to trim the surface we created in the early stages of this exercise. To do so, right click on the surface and choose the option **Edit/View Surface**. Go to the **Aperture** tab and under *Trimming Surface Specification* click on the pull down menu button and select the curve '…aperture collection' that we just created.

候 (aperture example.frd *) Edil	: Surface: "ellipse r	eflector"			_ 🗆 🗙		
Scatter SURFACE Aperture	Visualization Location/Orientati	Glue ion Ma	iterials	Grating Coating/RayControl	OK Cancel		
Trimming Volume Outer Boundar, Semi-aperture: Center: X: 18 0 Y: 30 20	Enter as M instead of center Shape: (f semi-ape/ • Box	Sen X: 0 Y: 0	g Volume Inner Hole ni-ape: Offset: 0 0	Apply		
	O Position O Y-axis Perp X: 0 Y: 0 Z: 1 O Direction O Z-axis Perp Sign of the dot product: Image: Constitute of the constand the constitute of the constitute of the constitute						
aperture example.aperture colle .back.plane () .focus.plane ()	& AND	OR !	NOT	Direct Edit			

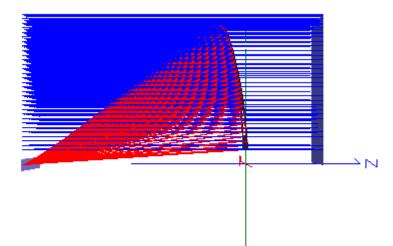
After selection, the curve name will appear in the box under *Trimming Surface Specification*, as shown below.

O Direction O Z-axis Perp	Sign of the dot product: 💿 Positive 🔘 Negative 👘
Trimming Surfaces Specification	
".aperture example.aperture collection"	
.aperture example.apertu 💌 🛛 & AND	OR I NOT Direct Edit
# Other Trimming Volume ()	() Delete Selected

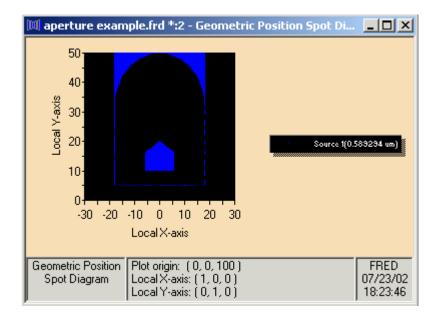
Left click on the **Apply** button to accept the changes or OK to accept the changes and to close the dialog. The surface should now look like the following.



Tracing and rendering a rectangular grid of collimated rays at the surface produces the following results. In the first figure, the reflected rays (shown in red) come to a line focus. In the second figure, a Positions Spot Diagram shows the rays that missed (passed through or around) the surface.









Chapter 7 – Analysis Topics and Examples

This section has examples and topics concerning building geometry in FRED. • <u>How Analysis Surfaces are sized</u>.

Analysis Planes

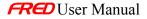
Description - Analysis Planes

Analysis Planes are used to evaluate ray distributions on Surfaces or Sources. All of the Analysis options: Position Spot Diagram, Polarization Spot Diagram, Directional Spot Diagram, Irradiance Spread Function, Intensity Spread Function, Energy Density, Coherent Scalar Wave Field require their use. An Analysis Plane does not intercept rays, so it is ignored in during the raytrace. Instead, Analysis Planes contain one or more ray filters that are used select the rays to be evaluated in the Analysis option. Created rays can be analyzed before and after they are raytraced. This process is made easier by Attaching an Analysis Plane to a Surface or a Source, which moves the analysis plane to be coincident and sets the appropriate ray filter to select the rays on the Surface or Source. Analysis Planes can only be used in conjunction with Surface or Source entities. More than one Analysis Plane can be attached to a surface or source. Further, an Analysis Plane need not be used exclusively to evaluate ray positions or angles; it may evaluate both simultaneously.

How Do I Get There? - Analysis Planes

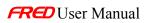
The Analysis Planes dialog is opened in one of two ways.

1. As a new Analysis Plane. Right mouse click on the Analysis Surfaces(s) folder to open a pop-up menu and select the option 'New Analysis Plane.'



Objects		Description	
🕂 🖻 Optical Sources			
🕂 🖮 Geometry			
🕂 💷 Analysis Surface(s)	Trace	eable	
🕂 💼 Materials 🛛 🗕	Пас		
🕂 🧮 Coatings	Neve	r Traceable (for trimming	surfaces)
🕂 🚾 Scatterers 👘	Drou	Outor Englacing Volume	
🕂 间 Raytrace Properties		Outer Enclosing Volume	
	_	dinate Axes	
	Alens	lization Attributes	
	<u>P</u> osit	ion/Orientation	
	Scale	h	
	, Cut		Ctrl+X
	🖞 Copy		Ctrl+C
	Paste	9	Ctrl+V
	Delet	e (all highlighted items)	Del
	Sumr	nary Report	
	_	iled Report	
_	<u>-</u>		
		Analysis Surface	
	Edit /	An Nysis Surface	
	Atta	ch Analysis Surface	
	Remo	ove Analysis Surface Plot	

2. Edit an existing Analysis Plane. Expand the Analysis Surfaces folder, right mouse click on the Analysis Plane to be modified to open the pop-up menu, and select the option 'Edit Analysis Plane.'



Objects		Description		
	(s)			
← 📩 Analysis 1 ← 💼 Materials ← 🧰 Coatings	<u>T</u> raceabl <u>N</u> ever Tr	e aceable (for trimming su	irfaces)	
 	Draw Outer Englacing Volume			
	<u>P</u> osition/ Sc <u>a</u> le	Orientation		
	K Cut Copy Paste Delete (a	all highlighted items)	Ctrl+X Ctrl+C Ctrl+∀ Del	
	Su <u>m</u> mary Detailed			
		ilysis Surface ysis Surface	<u></u>	
		nalysis Surface	7	



Dialog Box and Controls - Analysis Planes

(FRED1 *) Ana	lysis Surface			? _ 🗆	×
lame:				OK	
Analysis 1					·····
escription:				Cancel	
				Apply	
				Help	
-Analysis Area — Min	Max D	visions		🔽 Draw	
× -0.5	0.5		Scale Factor: 1	Grid Lines 🔻	1
Y -0.5	0.5	21 🕂	Min/Max vals: At e		
,					
		1 Aspect F	Ratio 📘 Interpret N	Min/Max as Angles (degree:	s]
-	(for drawing only)-			✓ Draw	
Min X -1	Max D	Divisions		Grid Lines 🔻	1
	L				
Y -1	1 2			+	Ŀ
Location					_
Refer	ence Coordinate	Action	Parameters	s (right mouse-click for	1
Startin	g Coordinate Syst	em			
	coordinate syster				
				•	
Ray Selection					
	ion Description				
Num Operati					
Num Operati 1 AND	All rays				
	All rays			Þ	

<u>Control</u> <u>Inputs</u>		<u>Defaults</u>			
Name	Enter the Name of the Analysis Plane (required).	Analysis <i>n</i>			
Description	Enter a brief description of the analysis plane (optional).				
	Analysis Area				
X/Y min max	Minimum/maximum X/Y window dimensions.	+/- 0.5			
Divisions	Enter the number of cells (pixels) across and down the analysis plane.	21 x 21			

Scale Factor	Enter the scale factor to apply to the Analysis Plane dimensions.	1			
Draw Check this box to draw the Analysis Surface. Choose appearance/color of the plane using the pull-down menu.		Checked, Grid Lines, Copper			
Autosize to Data	Check this box to automatically size the Analysis Plane based upon ray data only.	Checked			
Force 1:1 aspect ratio	Check this box to force 1:1 aspect ratio on the Analysis Plane dimensions. FRED automatically chooses the largest dimension if checked.	Checked			
Interpret Min/Max as Angles	Check this box to interpret window dimensions as angles.	Unchecked			
Min/Max values	At center or edge of window.	At edge			
	Rendering Area				
Min/Max, Divisions	Minimum and maximum X and Y coordinates and the number of divisions between each for rendering the Analysis Plane. For rendering purposes only.	X (-1,1) Y (-1,1) 21			
Draw	Draw Check this box to draw the rendering area. Select the render mode and color using the pull-down menu.				
	Location				
Table	Selects the Reference coordinate system and relative location of the Analysis Plane.	Global origin			
	Ray Selection				
Table	Tabulates the ray selection criteria. Right mouse click to open the ray filter dialog.	AND All rays			
ОК	Create a new Analysis Surface and close dialog box.				
Cancel	Discard Analysis Surface and close dialog box.				
Apply	Apply Analysis Surface changes and keep dialog box open.				
Help	Access this Help page.				

Application Notes - Analysis Planes...

- All new analysis planes are created at the origin of the global coordinate system.
- The default ray filter is 'All rays,' which will include every ray that has been created and/or traced.
- An analysis plane does not stop any rays. It is not a physical surface in the model.
- An analysis plane may be used simultaneously for Position and Angular (intensity) spread functions or spot diagrams.
 - o For position, the size of the analysis plane is given in system units
 - For angle, the size of the analysis plane is given by the X and Y direction cosines, measured from the surface normal. The default entries of -1 to 1 for both X and Y covers all angles in the hemisphere sitting over the Analysis Plane.
 - Auto-sizing for coherent sources usually results in the Analysis Plane being too small. Set the size manually instead.
- Attaching an analysis plane to a surface (or source) does 2 things:
 - It moves the analysis plane to be coincident with the local origin of the surface or source.
 - Coincidence is not a requirement. If the analysis plane is separated from the surface, FRED simply projects rays from the surface or source along their current trajectories until they intersect the shifted analysis plane.
 - It imposes a ray selection filter that tells FRED to consider only the rays currently halted on the surface or created on the source
 - Multiple filters can be ANDed and ORed together. A context menu to edit the Ray Selection Criterion is available with a right mouse click inside the Ray Selection spreadsheet area.
 - o An analysis plane is attached to a surface or a source by one of two methods:
 - Using a drag and drop from the analysis surface to the surface or source.
 - Selecting the option 'Attach Analysis Plane' using a right mouse click popup menu.
 - An analysis plane can only be attached to a single Surface or a single Source.
- An analysis plane is required for all of the following options:
 - Position Spot Diagram a conventional spot diagram showing the ray intercept location on the analysis plane. Rays lying on a curved surface are projected directly onto the analysis plane. Default plot colors are the same as the rendered color for the source.
 - Polarization Spot Diagram show the polarization ellipses of satisfying the Ray Selection Criterion assigned to the analysis plane. The source(s) must be polarized.
 - Directional Spot Diagram show the direction cosine projection of the rays satisfying the Ray Selection Criterion assigned to the analysis plane. Ray directions are plotted in the coordinate system of the analysis plane. Default plot colors are the same as the rendered color for the source.
 - Irradiance Spread Function plot the power/unit area of the rays satisfying the Ray Selection Criterion assigned to the analysis plane. Rays lying on a curved surface are propagated along their trajectories until they intercept the analysis plane. Use this option with a coherent source to generate a point spread function.

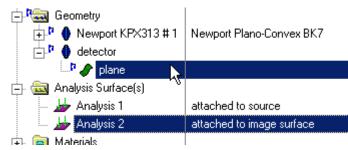
- Intensity Spread Function plot the power/unit solid angle of the rays satisfying the Ray Selection Criterion assigned to the analysis plane.Ray directions are plotted in the coordinate system of the analysis plane.
- Energy Density Coherent sources only. Plots the flux/unit volume of all rays satisfying the Ray Selection Criterion assigned to the analysis plane.
- Coherent Scalar Wave Field Coherent sources only. Plots the complex field of all rays satisfying the Ray Selection Criterion assigned to the analysis plane.
- For Sources, the Analysis options are typically used to evaluate the ray distribution after they have been created, but before they have been traced.
- For Surfaces, the Analysis options are typically used to evaluate the ray distribution at the conclusion of the raytrace.
- At the conclusion of any Analysis operation, FRED prints a table of summary data to the output window:
 - o Number of valid rays (coherent, incoherent, polarized).
 - o Total power.
 - Total average irradiance or intensity = Total power/area of analysis plane.
 - Valid average irradiance or intensity = Total power/total area of valid pixels. A valid pixel contains at least one ray.
 - o Analysis plane and pixel dimensions.

Examples - Analysis Planes...

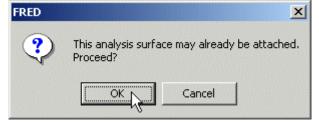
Example 1 - Attach an Analysis Plane to a Surface/Source

Method 1: Drag and Drop

Create a new Analysis Plane or expand the Analysis Surface(s) folder and left mouse click on an available analysis plane. While holding the left mouse button down, move the cursor to the desired surface or source. Release the mouse button.



If the analysis plane was already attached, a warning dialog pops up to confirm replacement.



Left mouse click on OK to proceed or Cancel to halt the drag and drop operation.

Method 2: Attach with the pop-up menu

Right mouse click on an existing analysis plane and select 'Attach Analysis Plane' from the list of options. to open a dialog to Attach Analysis Plane to Surface.

Analysis Surface(s) Analysis 1	attached to source
Analysis 2	Iraceable Sequential Raytrace
termination termination	Draw <u>G</u> lobal Enclosing Volume <u>C</u> oordinate Axes <u>V</u> isualization Attributes
	Position/Orientation Sc <u>a</u> le
	Su <u>m</u> mary Report Detailed Report
	New Analysis Plane Edit Analysis Plane
	Attach Analysis Plane

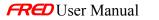
This opens a dialog to Attach Analysis Plane to Surface.

候 Attach Ar	? ×		
Name:	ОК		
Name.	Analysis 2		
Description:	attached to image si	urface	Cancel
Attach To:			Help
		B. 1.2	
Name		Description	
.Newport Ki	PX313 # 1.Surface 1	Axially Symmetric Conicoid Surface	
.Newport Ki	PX313 # 1.Surface 2	Axially Symmetric Conicoid Surface	
.Newport Ki	PX313 # 1.Edge	Bilaterally Symmetric Tubular Surface	
.detector.pla	ane 📐		
Optical Sou	rces.Source 1 🛛 场		

Select the appropriate surface with a left mouse click and then choose OK to accept and close the dialog. As with the drag and drop, if the analysis plane is already attached, a warning dialog asking for an override pops up. Choose OK to complete or Cancel to quit the operation.

Example 2 - Opening the Ray Selection Criterion dialog

Open the Analysis Plane Dialog. Move the cursor down to the Ray Selection spreadsheet. The 'Num' heading is simply a counter for the number of ray filters. The 'Operation' heading contains the logical operation between subsequent filters. The options are either a logical AND



or a logical OR. These operations are evaluated in sequential order. There is no explicit parenthetic grouping. The last column is the 'Description,' which is actual criterion that will be used to select rays. The 'Operation' and 'Description' can only be edited using the Ray Selection Criterion dialog.

Right mouse click in this region to open a pop-up context menu, as shown below.

-RaySe	lection ——			
Num	Operation	Description		
1	AND	All rays	N	
			K.	Cut
				Сору
				Paste
				Delete
				Edit
				Insert
				Append

The '*Cut*,' '*Copy*,''*Paste*,'and '*Delete*' options all operate on the selected row. The '*Edit...*', '*Insert...*', and '*Append...*' options all open the Ray Selection Criterion dialog, shown below.

🔆 Ray Selection Criterion		? _ 🗆 🗙
Criterion:		
All rays		ОК
Name:		
	v	Cancel
Value:	- Logical Operation	
0	AND C OR	Help
1.		

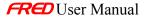
See Also....- Analysis Planes...

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

- <u>Analysis Plane</u> Dialog
- <u>Attach Analysis Plane</u> Dialog
- Ray Selection Criterion Dialog

Analysis Tools:

Position Spot Diagram Polarization Spot Diagram Directional Spot Diagram Irradiance Spread Function Intensity Spread Function Energy Density Coherent Scalar Wave Field



The following Tutorial shows how Analysis Planes can be used.

Building a Cassegrain

Ray Selection Criterion

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

Description Ray Selection Criterion

Ray Selection Criterion dialog is used to select the ray filters that are applied to Analysis Planes.

How Do I Get There? Ray Selection Criterion

> The Ray Selection Criterion dialog can be opened only from within the Ray Selection Region inside the Analysis Plane Dialog. Right mouse click in this region to open a pop-up context menu, as shown below.

F	Ray Sel	lection ——			
	Num	Operation	Description		
	1	AND	All rays	N	
				43	Cut
	•			1	Сору
Ľ					Paste
					Delete
					Edit
					Insert
					Append

The 'Edit...', 'Insert...', and 'Append...' options all open the Ray Selection Criterion dialog.



Dialog Box and Controls

Ray Selection Criterion

Ray Selection Criterion		? _ 🗆 🗵
Criterion:		
All rays	▼	OK
Name:		
	$\overline{}$	Cancel
Value:	Logical Operation	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Criterion:	Choose the ray selection criterion from the pull down menu.	All rays
Name:	Choose relevant object from the pull down menu. Name depends on the Criterion selection.	blank
Value:	Numeric entry for ray selection. This also depends on the Criterion selection.	0
Logical Operation	Choose relational AND or OR for Criterion selection.	AND
ОК	Accept Ray Selection Criterion and close dialog box.	
Cancel	Discard Ray Selection Criterion and close dialog box.	
Apply	Apply Ray Selection Criterion and keep dialog box open.	
Help	Access this Help page.	

<u>Application Notes</u> Ray Selection Criterion...

- The default ray filter is 'All rays,' which will include every ray that has been created and/or traced.
- Logical operations for multiple filters are carried out sequentially. There is no explicit parenthetic grouping.
 - \circ ~ The filters are applied to every ray. Each filter returns a TRUE or FALSE.

- TRUE → the ray satisfies the criterion
- FALSE → the ray does not satisfy the criterion
- The order of operation is important.
- Every operation is evaluated.
- Only the rays returning a TRUE at the end of the evaluation sequence are kept. Some examples:
 - TRUE AND TRUE OR FALSE = TRUE (ray is considered)
 - TRUE AND FALSE = FALSE (ray is not considered)
 - TRUE AND FALSE OR TRUE = TRUE
 - TRUE OR TRUE AND FALSE = FALSE
 - FALSE AND FALSE OR TRUE = TRUE
- The currently available ray selection criteria are:
 - o All rays
 - o No rays
 - o Coherent rays
 - o Incoherent rays
 - o Polarized rays
 - o Unpolarized rays
 - \circ Rays on the specified surface \rightarrow can be applied to sources as well
 - \circ Rays NOT on specified surface \rightarrow can be applied to sources as well
 - o Rays from the specified source
 - Rays NOT from the specified source
 - o Rays in the specified material
 - Rays NOT in the specified material
 - Every Nth ray
 - All rays EXCEPT every Nth ray
 - Incoherent power <= Value
 - Incoherent power > Value
 - Optical path length <= Value
 - Optical path length > Value
 - Wavelength <= Value
 - Wavelength > Value
 - X <= Value in the specified coordinate system
 - X > Value in the specified coordinate system
 - Y <= Value in the specified coordinate system
 - Y > Value in the specified coordinate system
 - Z <= Value in the specified coordinate system
 - Z > Value in the specified coordinate system
 - X direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
 - X direction component > Value in the specified coordinate system (between -1 and 1, inclusive)

- Y direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Y direction component > Value in the specified coordinate system (between -1 and 1, inclusive)
- Z direction component <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Z direction component > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from X axis <= Value in the specified coordinate system
- Radial distance from X axis > Value in the specified coordinate system
- Radial distance from Y axis <= Value in the specified coordinate system
- Radial distance from Y axis > Value in the specified coordinate system
- Radial distance from Z axis <= Value in the specified coordinate system
- Radial distance from Z axis > Value in the specified coordinate system
- Radial distance from X direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from X direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Y direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Y direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Z direction <= Value in the specified coordinate system (between -1 and 1, inclusive)
- Radial distance from Z direction > Value in the specified coordinate system (between -1 and 1, inclusive)
- o Ray on the specified ray path
- Ray NOT on the specified ray path
- o Scattered ray
- o Not Scattered ray
- o Scatter ancestry equal to Value
- Scatter ancestry NOT equal to Value
- Scatter ancestry <= Value
- Scatter ancestry > Value
- o Specular rays
- o Not Specular rays
- o Specular ancestry equal to Value
- Specular ancestry NOT equal to Value
- Specular ancestry <= Value
- Specular ancestry > Value
- Total ray intersection count equal to Value
- o Total ray intersection count Not equal to Value
- Total ray intersection count <= Value
- Total ray intersection count > Value

- o Consecutive ray intersection count equal to Value
- o Consecutive ray intersection count NOT equal to Value
- Consecutive ray intersection count <= Value
- Consecutive ray intersection count > Value
- o Rays with ray errors
- o Rays with no ray errors
- o Ray number N
- o All rays not ray number N
- Ray numbers <= N
- Ray numbers > N
- When an analysis plane is attached to a surface or a source, the default ray selection criterion is changed from 'All rays' to 'Rays on the specified surface.' This can be edited.

WARNING: When the ray selection spreadsheet contains multiple entries, FRED does not overwrite the criteria for an analysis plane attached to Object 'A' if it is subsequently attached to Object 'B.' The location of the Analysis Plane will move to be coincident with the new object, however the ray filters are not automatically updated to include Object 'B', which could lead to unexpected results. The filters should be edited and verified manually.

See Also.... Ray Selection Criterion...

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

Analysis Surface(s) Analysis Plane Dialog Attach Analysis Plane Dialog Analysis Tools: Position Spot Diagram Polarization Spot Diagram Directional Spot Diagram Irradiance Spread Function Intensity Spread Function Energy Density Coherent Scalar Wave Field The following Tutorial shows how Analysis Planes can be used. Building a Cassegrain



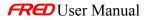
Description - Attach Analysis Plane

The Attach Analysis Plane dialog is used to manually select which surface or source the Analysis Plane will be attached to. Attaching an Analysis Plane has two effects. First, it moves the Analysis Plane to be coincident with the selected entity. The coordinate system of the Analysis Plane is re-parented to that of the entity. Any movement of the entity causes the Analysis Plane to move as well. Second, attaching an Analysis Plane to an entity replaces the existing Ray Selection Criterion.

How Do I Get There? - Attach Analysis Plane

The Attach Analysis Plane dialog is opened by right mouse clicking on an existing Analysis Plane to open a pop-up context menu and then selecting 'Attach Analysis Plane...'

Objects				Description	
	Optical Sources Geometry Analysis Surface	(s)			
	Analysis 1 Materials Coatings		Traceabl Never Tr	e aceable (for trimming su	irfaces)
⊕ <u>⊡</u> ⊕ ⊇	Scatterers Raytrace Proper		<u>C</u> oordina	ter Enclosing Volume Ite Axes tion Attributes,	
				Orientation	
			Cut Copy Paste Delete (a	all highlighted items)	Ctrl+X Ctrl+C Ctrl+∀ Del
			Su <u>m</u> mary <u>D</u> etailed		
			Edit Anal	lysis Surface ysis Surface	
				nalysis Surface Analysis Surface Plot	5



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Dialog Box and Controls - Attach Analysis Plane

Attach Ar	alysis Surl	face to a Surface	?)
Name:	Analysis Su	rface	OK OK
Description:			Cancel
Attach To:			Help
Name		Description	_
.M1.Reflect	ing Surface	Axially Symmetric Conicoid Surface	
.M1.Back S		Axially Symmetric Conicoid Surface	
.M1.Edge		Bilaterally Symmetric Tubular Surface	
.M2.Reflect	ing Surface	Axially Symmetric Conicoid Surface	
.M2.Back S	urface	Axially Symmetric Conicoid Surface	
.M2.Edge		Bilaterally Symmetric Tubular Surface	
.L1.Surface	1	Axially Symmetric Conicoid Surface	
L.LI.Junace	0	Axially Symmetric Conicoid Surface	
.L1.Surface	2	Axially Symmetric Conicola Sanace	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name: None		Name of the Analysis Plane
Description: None		Description of the Analysis Plane
	Attach To	
Name and DescriptionChoose the Surface or Source entity that the Analysis Plane will be attached to.		None
ОК	Attach Analysis Surface and close dialog box.	·
Cancel	Close dialog box without attaching Analysis Surface.	
Help	Access this Help page.	

Application Notes - Attach Analysis Plane...

- The default ray filter is 'All rays,' which will include every ray that has been created and/or traced.
- The default location for a new Analysis Plane is at the origin of the global coordinate system.
- An analysis plane can only be attached to a single Surface or a single Source entity.

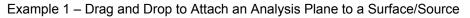
• When an analysis plane is attached to a surface or a source, the default Attach Analysis Plane is changed from 'All rays' to 'Rays on the specified surface.' This can be edited.

WARNING When the ray selection criteria includes multiple entries, FRED does not overwrite the criteria for an analysis plane attached to Object 'A' if it is subsequently attached to Object 'B.' The location of the Analysis Plane will move to be coincident with the new object, however, which could lead to unexpected results. The filters should be edited and verified manually.

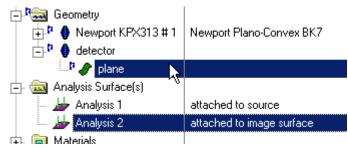
- An Analysis Plane can also be attached via the drag and drop method (see Examples).
- If an Analysis Plane is already attached to different entity, FRED pops up a dialog requesting confirmation before completing the action.

FRED	×
?	This analysis surface may already be attached. Proceed?
	OK Cancel

Examples - Attach Analysis Plane...



Create a new Analysis Plane or expand the Analysis Surface(s) folder and left mouse click on an Analysis Plane. While holding the left mouse button down, move the cursor to the desired surface or source. Release the mouse button.



If the Analysis Plane was already attached, a warning dialog pops up to confirm replacement.

See Also.... - Attach Analysis Plane...

For more detailed descriptions of Analysis Surfaces and their uses, select from among the following links.

<u>Analysis Plane</u> Dialog <u>Attach Analysis Plane</u> Dialog <u>Ray Selection Criterion</u> Dialog



Analysis Tools:

Position Spot Diagram

Polarization Spot Diagram

Directional Spot Diagram

Irradiance Spread Function

Intensity Spread Function

Energy Density

Coherent Scalar Wave Field

The following Tutorial shows how Analysis Planes can be used.

Building a Cassegrain



Chapter 8 - Defining and Applying Materials

Materials

Description Visualization (example) How Do I Get There? Dialog box and Controls Application Notes See Also...

Description - Materials

The **Materials** folder contains all of the default and optional user-defined Materials. The default materials Air, Vacuum, and Standard Glass are all defined as <u>Sampled Materials</u>. Once created, a material type (i.e. <u>Sampled Material</u> or <u>Model Material</u>) cannot be changed. Glass catalog materials may be added to the folder as well. This is done automatically with a lens import or copy from another FRED model.

Visualization (example) - Materials

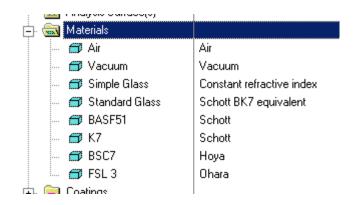
The Materials folder is near the middle of the tree.				
Objects	Description			
🕞 📄 Optical Sources				
🕂 📻 Geometry				
🕂 🂷 Analysis Surface(s)				
🕂 💼 Materials				
🕂 🥅 Coatings				
🕂 🔝 Scatterers				
🕂 💼 Raytrace Properties				

How Do I Get There? - Materials

A left click on the 😟 symbol next to the folder name will expand the tree.





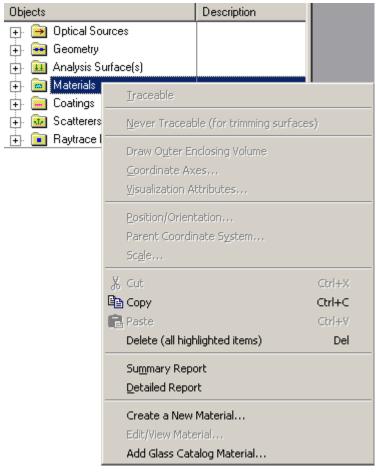


A left click on the \Box symbol next to an open folder will collapse the tree.

Sampled Materials and Model Materials can be edited and viewed with a right mouse click on the name and selecting the Edit/View option, or by simply double clicking on the material name. Glass catalog materials cannot be edited or viewed directly.

Dialog Box and Controls - Materials

A right mouse click on the Materials folder opens the following context menu.



The first option available on the context menu is a 'Summary Report.'



When this option is selected, FRED prints a list the Materials in the model and a brief description of each.

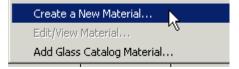
Air
Vacuum
Constant refractive index
Schott BK7 equivalent
Schott
Schott
Hoya
Ohara

The second option available on the right click menu is a 'Detailed Report.'

Summary Report	
<u>D</u> etailed Report	•

When this option is selected, FRED prints a detailed summary of all of the material properties. The output is too large to display, but includes names, dispersion coefficients, a table of refractive index as a function of wavelength, and more.

The third option available is to 'Create a New Material...'



Selecting this option opens the (New) Material Dialog. This is just one of a number of ways to access this dialog.



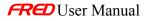
¢	(ghost.	frd) Create a New Mate	erial			
	Material Absorption Volume Scatter					
	Name:	Material 1			Cancel	
	Descripti	ion:			Apply	
					Help	
	Туре:	Sampled Material (ref	ractive indices for discrete wa	avelengths)		
		-				
	0	Wavelength (um) 0.5875618	Refractive Index	Imaginary Refractive Inde: 0		
	0	10.5075616		U		
	•			<u> </u>		
			Parameters and Other Parame			
	Step 9	Size Max # Steps 1000	X Offset Y C	Iffset Z Offset		
	10.1	1,000	10	Jo .		
					J	

Use this dialog to enter refractive index data as sampled points (<u>Sampled Material</u>) or by its Nd and Vd values (<u>Model Material</u>).

The last option available on the context menu is to add a new catalog material.

Create a New Material... Edit/View Material... Add Glass Catalog Material...

This selection option opens the following dialog, which provides access to a number of vendor material databases supplied with FRED.



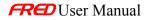
K	Material	Listing/S	election
	Material Cata		ichott
ł	Material Nam	ne:	
(Click on a m	aterial to s	elect it. Click on a header to sort by that header.
	Name	Nd	Vd 🔺
	BASF51	1.72373	38.11
	F2	1.62004	36.37
	F4	1.61659	36.63
	F5	1.60342	38.03
	K10	1.50137	56.41
	K7	1.51112	60.41
	KZESNA -	1.613/	AA 29
[(OK		Cancel Apply Help

Application Notes - Materials

- Default material properties
 - Air <u>Sampled Material</u>, constant refractive index, n = 1.0
 - Vacuum <u>Sampled Material</u>, constant refractive index, n = .999707 (relative to Air)
 - Simple Glass <u>Sampled Material</u>, constant refractive index, n = 1.5
 - o Standard Glass Schott BK-7 equivalent glass, cannot be edited
- The Material Type (either <u>Sampled</u> or <u>Model Material</u>) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A new material can be applied to a surface via drag and drop onto that surface

See Also - Materials

The following links contain details about editing existing materials and adding new ones. <u>Sampled Material</u> <u>Model Material</u> <u>Glass Catalog Material</u>



Description - Applying Materials

This dialog page allows the user to select the two materials associated with a surface.

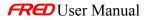
Any of the materials defined in the current FRED document file may be assigned to the surface. In addition, catalog materials and new materials can be added to the FRED document from this dialog. The process for adding a catalog material or new material is described in Creating New Materials... and Add Catalog Material help files. In addition, the user defined materials can be edited from this dialog. The materials added from catalogs cannot be edited directly at this time.

The ray data stored during a raytrace includes the currently assigned material and when the ray intersects the surface a check of the ray's currently assigned material against the two surface materials is performed. If the ray's currently assigned material matches one of the two surface materials, then the program knows that the other material is the next material. If no match is made between the ray's currently assigned material and the two materials assigned to the surface, then the ray is stopped and a warning is issued at the end of the ray trace.

NOTE or TIP It does not matter what order the materials are assigned in this dialog because the ray knows what material it is in when it intersects the surface.

How Do I Get There? - Applying Materials

This page is in the <u>Create New Surface...</u> and Edit/View Surface... dialogs.



Objects	Description	
🕂 📄 Optical Sou	rces	
😑 🔜 Geometry		
🕂 🗗 triplet	Imported from "d:\tripl	
💷 🧬 Elem 1 🗊 🕀 🛄 Analysis Su	V Tracaabla	
🕂 📠 Materials	Never Traceable (for trimming surfaces)	
🕂 📻 Coatings	Draw Outer Enclosing Volume	
	Countrate Arres	
🕂 📃 Raytrace Pr		
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	从 Cut	Ctrl+X
	Ba Copy	Ctrl+C
	🔁 Paste	⊂trl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Ori	entation
	Edit/View Array Parameters	
	Delete Array Parameters	
•	Create New <u>S</u> urface	
×	Create New <u>⊂</u> urve ¹ 5	



Dialog Box and Controls - Applying Materials

(² (FRED1 *) Create a New Surfa	ce as Child of: "Elem 1"	_ 🗆 🗵
Scatter Visualization SURFACE Aperture	Glue Grating Auxiliary Data Modifiers Location/Orientation Materials Coating/RayControl	ОК
Assigned Material 1 Name:	Description 1: Air	Cancel Apply
Assigned Material 2 Name:	Description 2: Air	Help
Available Materials Name Air Vacuum Simple Glass Standard Glass Optical Cement	Description Air Vacuum Constant refractive index Schott BK7 equivalent generic optical cement	
Assign to Material 1 As	sign to Material 2 Edit/View Create New	

<u>Control</u>	Inputs	<u>Defaults</u>
Assign Material 1 Name	List the name/description of Material 1.	Air
Assign Material 2 Name	List the name/description of Material 2.	Air
Available Material	Select/highlight a material with a left mouse click and then press the Assign to Material 1 or 2 button. Materials can be edited, viewed, or added to the list.	Existing Materials
OK	Accept Material changes and close dialog box.	
Close	Discard Material changes and close dialog box.	
Apply	Apply Material changes and keep dialog box open.	
Help	Access this Help page.	



Edit/Create a New Sampled Material

Description How Do I Get There? Dialog Box and Controls Application Notes Examples See Also...

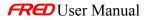
Description - Edit/Create a New Sampled Material

A Sampled Material uses a table of wavelengths and refractive indices to define a material type not found in the default glass catalogs. The refractive index can have real and imaginary parts (i.e., for metals). The table can be entered by hand, read from a simple text file, or entered using the Digitization tool. The default materials Air, Vacuum, and Standard Glass are all defined as Sampled Materials. Once created, a material Type (i.e. Sampled Material or Model Material) cannot be changed.

How Do I Get There? - Edit/Create a New Sampled Material

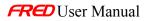
There are four ways to open a Material dialog.

1. Right mouse click on the <u>Materials</u> folder to open a context menu and select the option *Create a New Material...*



Objects		Description	
 ⊕ Optical Sou ⊕ end Geometry ⊕ III Analysis Su 			
 	Iraceable		
🕂 🐱 Scatterers		ble (for trimming surf	aces)
Tr 🖪 Hayudder			
	<u>P</u> osition/Orier Parent Coord Sc <u>a</u> le	ntation inate System	
	X Cut		Ctrl+X
	🖹 Сору		Ctrl+C
	Delete (all hid	hlighted items)	⊂trl+V Del
	Su <u>m</u> mary Rep Detailed Rep	port	
	Create a Nev Edit/View Mat Add Glass Ca		

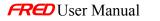
2. Expand the <u>Materials</u> folder and right mouse click on a specific material to open the pop-up context menu and select the option '*Edit/View Materials...*'



Objects		Description	
Optical Sources Optical Sources Geometry Analysis Surface(s) Materials Air Air Vacuum		Air Vacuum	
🗂 Simple Glass - 🗂 Standard Glas	Iracea		
- 🗇 Optical Cemer	Never	Traceable (for trimming	surfaces)
GAP3 GAP3	⊆oordi ⊻isuali Eositio	Dyter Enclosing Volume nate Axes zation Attributes n/Orientation : Coordinate System	
	X Cut E Copy Copy R Paste Delete	(all highlighted items)	Ctrl+X Ctrl+C Ctrl+∀ Del
	_	ary Report ed Report	
		e a New Material ew Material	
		ass Catalog Material	

3. Expand the <u>Materials</u> folder and, using the left mouse button, double click on the material name.

4. From the <u>Materials</u> tab in the **Surface** dialog, select a material and left mouse click on either the '*Edit/View...*' or '*Create New...*' material button.



Scatter	1	Visualiza			Glue	Grating
SURFACE	Aperture	Loca	ation/Orientatio	on	Materials	Coating/RayControl
Assigned Material Air	1 Name:	Desc Air	ription 1:			
Assigned Material Standard Glass ⊢Available Materia			ription 2: t BK7 equivale	ent		
Name			Description			
Air			Air			
Vacuum			Vacuum			
Simple Glass			Constant ref	ractive	index	
Standard Glass	S		Schott BK7	equival	ent	
BASF51			Schott			
BaC4			Hoya			
Assign to Ma	terial 1	Assign to N	Naterial 2		Edit/View	Create New

Dialog Box and Controls - Edit/Create a New Sampled Material



侯 (ghost	.frd) Create a New Mat	erial		_ 🗆 ×
Material	Absorption Volume Sca	tter		ОК
Name:	Material 1			Cancel
Descrip	tion:			Apply
				Help
Туре:	Sampled Material (re	efractive indices for discrete wa	avelengths)	
	Wavelength (um)	Refractive Index	Imaginary Refractive Inde:	
0	0.5875618	. 1	0	
•			Þ	
Comn	non Gradient Index Materia	Parameters and Other Parame	eters	
	Size Max # Steps		lfset Z Offset	
0.1	1000	jo jo]0	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Material name	Material n
Description	Brief description of the material.	blank
Туре	Select the data format.	Sampled Material
Wavelength	Enter 1 or more wavelengths in micrometers.	0.589
Refractive Index	Enter the refractive index of the material at the defined wavelength.	1
Imaginary Refractive Index	Enter the imaginary part of the refractive index (i.e., for metals).	0
ОК	Accept changes and close dialog box.	
Cancel	Cancel changes and close dialog box.	
Help	Help	

The imaginary component of the refractive index is directly proportional to the absorption (or gain) coefficient at the associated wavelength via the following formula: a = (2pi * n' / wav) where "a" is the absorption coefficient, "wav" is the wavelength and "n" is the imaginary part of the refractive index at that wavelength. Absorption is specified with a positive value, no absorption is specified with a value of zero, and gain may be specified with a negative value.

Application Notes - Edit/Create a New Sampled Material

- FRED linearly interpolates refractive index data between sampled wavelengths. If the source wavelength lies outside the minimum or maximum sampled wavelengths, then the interpolated refractive index equal to that of the nearest sampled wavelength.
- Summary data for all materials currently contained in the Materials folder can be displayed by right mouse clicking on the materials folder and selecting either the 'Summary Report' for a short summary table or the 'Detailed Report' for a complete listing of all the material properties.

Su<u>m</u>mary Report <u>D</u>etailed Report

- The Material type (either Sampled or Model Material) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A new material can be applied to a surface via drag and drop onto that surface

Examples - Edit/Create a New Sampled Material

The following examples illustrate how to use the context menu to enter, modify, import, and export data. The context menu is available with a right click inside the spreadsheet area used for data entry.

	Wavelength (um)	Refr	active Index	Imaginary Refractiv
1	0.5892938	1	Add Waveleng Insert Wavele Delete Wavele	ngth
			Append All So	urce Wavelengths
•			Show Last Acc	Data From a File essed File Name, Digitization Tool o a File

Example 1: Changing the wavelength

Changing the material wavelength is accomplished by either directly typing the new wavelength (in microns) into the wavelength cell, or by selecting a new wavelength the list of predefined values available using the pull down menu. The predefined wavelengths in FRED

include a large number of atomic emission lines in addition to a number of common laser wavelengths. Use the scroll bar on the right side of the list to scan through the entire range.

	Wavelength (um)
2	0.6328
	0.4861327 F (H)
	0.5460740 e (Hg)
	0.5875618 d (He)
	0.5892938 D (Na)
	0.6328 (He-Ne)
	0.6438468 C'(Cd) 🗏
	0.6562725 C (H)

Example 2: Adding or Inserting a wavelength

From the context menu, select either '*Add Wavelength*' or '*Insert Wavelength*.' *Add Wavelength* automatically appends the new wavelength row to the end of the list. *Insert Wavelength* puts the new wavelength row before the currently selected row. By default, the new wavelength is always 0.5893 microns. Change this value as appropriate. The wavelength order of entry is not important.

Туре:	Sampled Materia	al (i	refrac	tion indices for di	screte w	vavelengths)	•
	Wavelength (um)		Refr	active Index	Imag	inary Refrac	tive
1	0.5892938	•	1		0		
				Add Waveler	igth	N.	
				Insert Wavel	ength	14	

Example 3: Appending all source wavelengths

By selecting the 'Append All Source Wavelengths' from the context menu, FRED automatically appends a row for every unique wavelength defined by all the Sources currently in the model.

Туре:	Sampled Material	(refraction indices for d	iscrete wavelengths)
	Wavelength (um)	Refractive Index	Imaginary Refractiv
1	0.5892938	Add Wavelen Insert Wavele Delete Wavel	ength
		Append All So	urce Wavelengths

Note that once entered, any wavelength value can be changed.

Example 4: Deleting Wavelength Rows

If multiple wavelengths have been entered, any wavelength row can be deleted with a right click on the desired wavelength and selecting the *Delete Wavelength* option on the context menu.



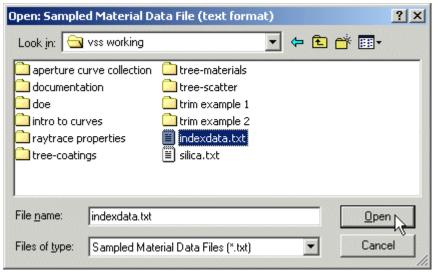
	Wavelength (ur	n) Refractive Index	Imaginary Refractive
1	0.5892938	1	0
2	0.4046561 h (H	a) 🔽 1	0
3	0.6328 (He-N	le) 📲 1	<u> </u>
4	0.7065188 r (Add Wavelength Insert Wavelength	
		Delete Wavelength	

Example 5: Importing refractive index data from a file

An alternative to manual data entry is to import the wavelength and refractive index data from an ASCII text file. The file should have on each row: wavelength (in microns), refractive index, imaginary refractive index. Delimeters may be any combination of spaces, commas, or tabs. Open the context menu and select 'Replace With Data From a File.'

Туре:	Sampled Material	(refraction indices for di	iscrete wavelengths)
	Wavelength (um)	Refractive Index	Imaginary Refractive
1	0.5892938	Add Wave Insert Wa Delete Wa	velength
		Append A	Il Source Wavelengths
•			Vith Data From a File

This will open a dialog showing the file list of the current working directory. The directory can be changed using the conventional Windows navigation tools. The file type must be ASCII text, but the extension is not important. Select the file and left click on the 'Open' button to finish.



The Material table will be filled with the new data. Any existing entries will be overwritten.

lame:	:	Material 1				OK
)escri	iption:	imported from ind	dex	:data.txt		Cancel Help
ype:		Sampled Materia	al (r	refraction indices for	discrete wavelengths)	-
_	1000	olongth (um)	_	Defrective Index	Imaginany Defractiv	ua Indau
1	_	elength (um)	•		Imaginary Refractiv	e Index
1	Wau 0.45 0.48		- -	Refractive Index 1.4656 1.4635	Imaginary Refractiv 0 0	ve Index
	0.45		▼ ▼ ▼	1.4656	0	ve Index
3	0.45		• • •	1.4656 1.4635	0	ve Index
3 4	0.45 0.48 0.5	5	• • • •	1.4656 1.4635 1.4623	0 0 0	ve Index
3 4 5	0.45 0.48 0.5 0.53	5	• • •	1.4656 1.4635 1.4623 1.4606	0 0 0	ve Index
1 2 3 4 5 6 7	0.45 0.48 0.5 0.53 0.57	5 4	• • • • • • • •	1.4656 1.4635 1.4623 1.4606 1.459	0 0 0	re Index

FRED can recall the name of the source file used to import the data by selecting the option '*Show Last Accessed File Name...*' from the context menu. FRED will pop a dialog with the source file name. Left mouse click on OK to close.

Most Recently Accessed File 🛛 🔀
E:\scott\vss working\indexdata.txt
OK

Example 6: Adding Wavelength and Refractive Index Data using the digitization tool

3 0.5 1.4623 Add Wavelength 3 0.5 1.4606 Insert Wavelength 4 0.535 1.4506 Delete Wavelength 5 0.574 1.459 Delete Wavelength 6 0.6 1.458 Append All Source Wavelengths 7 0.65 1.4565 Append All Source Wavelengths		Wavelength (um)		Refractive Index	Imaginary Refractive Index				
2 0.48 ▼ 1.4635 3 0.5 ▼ 1.4623 4 0.535 ▼ 1.4606 5 0.574 ▼ 1.459 6 0.6 ▼ 1.458 7 0.65 ▼ 1.4565 8 0.7 ▼ 1.4553	1	0.45	•	1.4656	0				
3 0.5 ▼ 1.4623 4 0.535 ▼ 1.4606 5 0.574 ▼ 1.459 6 0.6 ▼ 1.458 7 0.65 ▼ 1.4565 8 0.7 ▼ 1.4553	2	0.48	•	1.4635					
4 0.535 1.4606 5 0.574 ▼ 6 0.6 ▼ 7 0.65 ▼ 8 0.7 ▼ 1.4553 ■ Delete Wavelength Append All Source Wavelengths Replace With Data From a File	3	0.5	-	1.4623					
5 0.574 ▼ 1.459 P 6 0.6 ▼ 1.458 Append All Source Wavelengths 7 0.65 ▼ 1.4565 Replace With Data From a File	4	0.535	-	1.4606	-				
7 0.65 ▼ 1.4565 8 0.7 ▼ 1.4553 Replace With Data From a File	5	0.574	•	1.459	Delete Wavelength				
7 0.65 ▼ 1.4565 8 0.7 ▼ 1.4553 Replace With Data From a File	6	0.6	-	1.458	Append All Source Wavelengths				
	7	0.65	-	1.4565	Appona Ali Soarce Marciengais				
Show Last Accessed File Name	8	0.7	-	1.4553	Replace With Data From a File				
					Show Last Accessed File Name				
					Export Data To a File				

An alternate way of entering wavelength and refractive index data is to use the Digitization tool internal to FRED. Selecting '*Import Using Digitization Tool…*' from the context menu opens a FRED utility that allows the user to grab data from a bitmapped image. The image file may be created by scanning a plot of refractive index vs. wavelength or by copying an image into a bitmap file. Once loaded, the user sets the length of the ordinate axes to set the plot scale and then grabs each data point with a left mouse click on the curve. There is no limit to

the number of data points that can be entered. This utility is available to many other FRED functions as well.

Example 7: Export Data To a File

	Wavelength (um)	Refractive	Index	Imaginary Refractive Inde				
1	0.45	1.4656		0				
2	0.48	1.4635	Ado	dd Wavelength				
3	0.5	1.4623	Ins	Insert Wavelength				
4	0.535	1.4606	Delete Wavelength					
5	0.574	1.459						
6	0.6	1.458	Append All Source Wavelengths Replace With Data From a File Show Last Accessed File Name					
7	0.65	1.4565						
8	0.7	1.4553						

This opens a dialog showing the file list of the current working directory. The directory can be changed using the conventional Windows navigation tools. The file type must be ASCII text, but the extension is not important. Select a file to overwrite or type in a new file name and left mouse click on the *Save* button to finish.

Save As							? ×
Save jn: 🔂 vss working		•	+	£	d *		
 aperture curve collection documentation doe intro to curves raytrace properties tree-coatings 	tree-materials tree-scatter trim example 1 trim example 2 indexdata.txt						
File <u>n</u> ame: indexdata2.tx	t					Savi	e
Save as <u>t</u> ype:			•	-		Canc	el

The data format is exactly as shown in the dialog: Wavelength, Refractive Index, Imaginary Refractive Index

See Also - Edit/Create a New Sampled Material

Click on this link to show information about the $\ensuremath{\textbf{Materials}}$ folder.

Materials

The following links contain details about other options for editing existing materials and adding new ones.

Model Material Glass Catalog Material



Edit/Create a New Model Material

Description How Do I Get There? Dialog box and Controls Script Commands Application Notes Examples See Also...

Description - Edit/Create a New Model Material

A Model Material uses the refractive index and the Abbe V-number at the helium 'd' line (0.587562 microns) to define the material properties. This material type is an alternative to the <u>Sampled Material</u> for creating a glass model that is not available from any of the default catalogs. Once created, a material type (i.e. <u>Sampled Material</u> or Model Material) cannot be changed.

How Do I Get There? - Edit/Create a New Model Material

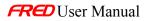
There are four ways to open a Material dialog.

1. Right click on the <u>Materials</u> folder to open a the pop-up menu and select the option 'Create a New Material...'



Objects		Description	
 ⊕ Optical So ⊕ end Geometry ⊕ Manalysis So 			
 ←	Iraceable	ble (for trimming surfac	:es)
🕂 💼 Raytrace F			
	<u>P</u> osition/Orien Parent Coordi Sc <u>a</u> le	tation nate S <u>y</u> stem	
	X Cut Copy Paste Delete (all high	hlighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Rep <u>D</u> etailed Repo		
	Create a New Edit/View Mati Add Glass Cat		

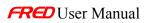
2. Expand the <u>Materials</u>folder and right mouse click on a specific material open a pop-up menu and select the option '*Edit/View Materials…*'



Objects		Description	
 ➡ Optical Source ➡ Geometry ➡ Analysis Surface ➡ Materials ➡ Air ➡ To Yacuum 		Air Vacuum	
📅 Simple Gla 🗇 Standard	Tracar	able	
🎒 Optical Ce	ener Never	Traceable (for trimming	surfaces)
🗇 LAF3 🗇 SF1 🎒 LAKN22 🎒 MgF2	⊆oord	Outer Enclosing Volume inate Axes zation Attributes	
 → image → image	Paren	n/Orientation : Coordinate System 	
	∦ Cut Bang Copy Copy Delete	(all highlighted items)	Ctrl+X Ctrl+C Ctrl+∀ Del
	_	ary Report ed Report	
	Create	e a New Material	
	Edit/Vi	ew Material	
	Add G	lass Catalog Material	V

3. Expand the <u>Materials</u> folder and double left mouse click on the material name.

4. From the Materials tab in the **Surface** dialog, select a material and left mouse click on either the '*Edit/View...*' or '*Create New...*' material button.



Scatter SURFACE	Aperture	Visualizat Loca	ion tion/Orientat	ion	Glue Materials	Grating Coating/RayControl
Assigned Materi Air	al 1 Name:	Descr Air	iption 1:			
Assigned Materi Standard Glass			iption 2: t BK7 equiva	lent		
Name Air Vacuum Simple Glass Standard Gla BASF51 BaC4	158		Description Air Vacuum Constant re Schott BK7 Schott Hoya	fractive		
Assign to M	faterial 1A	Assign to M	1aterial 2		Edit/View	Create New

Dialog Box and Controls - Edit/Create a New Model Material



候 (ghos	st.frd) Create a	a New Material	
Materia	Absorption	/olume Scatter	ОК
Name	: Material	1	Cancel
Descr	iption:		Apply
			Help
Туре:	Model M	aterial (Refractive Index and Abbe number)	
	Parameter	Description	
Nd	1.5	Refractive index at "d" wavelength	
Vd	64	ABBE number at "d" wavelength	
Com	mon Gradient Ind	dex Material Parameters and Other Parameters	
Ste	p Size N	Nax # Steps X Offset Y Offset Z Offset	
0.1		000 0 0 0	
	,	, , , , ,	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Required. Enter a material name.	Material n
Description	Optional. Enter a brief description of the material.	None.
Туре	Select Model Material from the pull down menu	Sampled Material
Nd	Enter the refractive index at the 'd' wavelength	1.5
Vd	Enter the ABBE number at the 'd' wavelength	64
OK	Accept changes and close the dialog	
Cancel	Cancel changes and close the dialog	
Help	Help	

Application Notes - Edit/Create a New Model Material

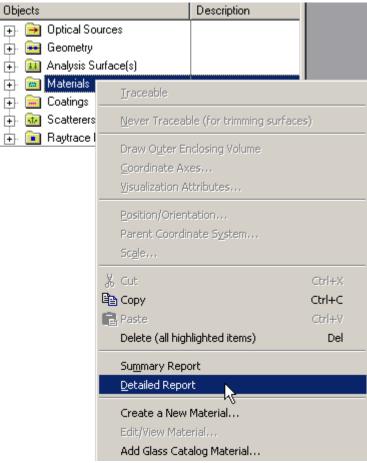
- The Model Material calculates non-linear refractive index values for an extended wavelength range based on the Nd and Vd settings.
- Summary data for all materials currently contained in the <u>Materials</u> folder can be displayed by right mouse clicking on the materials folder and selecting either the 'Summary Report for a short summary table or the 'Detailed Report for a complete listing of all the material properties.

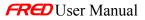
Su<u>m</u>mary Report

- The Material type (either Sampled or Model Material) cannot be changed after a new material has been created.
- Copies between FRED models will always transfer new material and coating information.
- A material can be applied to a surface via drag and drop onto that surface.

Examples - Edit/Create a New Model Material

Refractive index data for a Model Material can be displayed by right mouse clicking on the <u>Materials</u> folder and selected the 'Detailed Summary' option.





This option prints a detailed list of material properties for all the materials contained in the folder. The view below shows just one portion of the output. The Model Material properties are Nd = 1.8 and Vd = 43. The wavelength list is generated by searching through all the existing sources defined in the model for unique wavelengths. It does not matter if the source is designated Traceable or Not Traceable.

Wavelength vs.	Real Refractive	Index Table					
Wavelength uni	ts are um						
<u>0.4358343</u>	0.4861327	<u>0.546074</u>	<u>0.5892938</u>	<u>0.6328</u>	0.6562725	<u>0.7065188</u>	<u>Name</u>
1	1	٦	1	1	1	1	Air
1.82450429	1.81291653	1.80418883	1.79984843	1.79651726	1.79503696	1.79242341	Model Material
							1

See Also - Edit/Create a New Model Material

Click on this link to show information about the Materials folder.

Materials

The following links contain details about other options for editing existing materials and adding new ones.

Sampled Material Glass Catalog Material

Add Volume Scatter - Henyey-Greenstein

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Add Volume Scatter - Henyey-Greenstein

Adds a Henyey-Greenstein volume scatter model to a material. This model, originally developed for simulation of scatter in astronomical observation, has found application in the bio-medial field.

How Do I Get There? - Add Volume Scatter - Henyey-Greenstein

This command is accessed through the Tree or from the main menu:



Traceable	
Never Traceable (for trimming s	surfaces)
Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes	
Position/Orientation Parent Coordinate System Scale	
 ✗ Cut Image: Copy Image: Paste Copy 	Ctrl+X Ctrl+C Ctrl+V
Delete (all highlighted items) Summary Report Detailed Report	Del
Create a New Material	
Edit/View Material Add Glass Catalog Material	
Create Analyses Window Help	Ť
New Simplified Source Image: State S	Ctrl+Alt+I Ctrl+Alt+D
A New Long	and the advantage
New Lens New Mirror New Prism	Ctrl+Alt+L Ctrl+Alt+M Ctrl+Alt+P
New Mirror	Ctrl+Alt+M
New Mirror New Prism ■ New Subassembly ● New Custom Element	Ctrl+Alt+M Ctrl+Alt+P Ctrl+Alt+S
 New Mirror New Prism New Subassembly New Custom Element New Surface 	Ctrl+Alt+M Ctrl+Alt+P Ctrl+Alt+S Ctrl+Alt+E Ctrl+Alt+F
 New Mirror New Prism New Subassembly New Custom Element New Surface New Curye 	Ctrl+Alt+M Ctrl+Alt+P Ctrl+Alt+S Ctrl+Alt+E Ctrl+Alt+F Ctrl+Alt+F Ctrl+Alt+V

Dialog Box and Controls - Add Volume Scatter - Henyey-Greenstein

(FRED1	*) Edit Material: "Volu	me Scatterer"	>
aterial	Absorption Volume Scatt	ter	OK
	ve (uncheck to "turn off" v		Cancel
		volume scatter)	
1000	Maximum number of	f consecutive scatter events in the material	Apply
Туре:	Henyey-Greenstein		Help
	,		-
	p(a)=(1-g^2) / (4pi*(1-g*		4
	Wavelength (um)	g coefficient (-1 <= g <= +1)	4
0			
		on distance between scatter events)	
Scatter I	p(t) = exp(-a * t), a =	scattering coeff (right-click for menu)	
	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	
Scatter I	p(t) = exp(-a * t), a =	scattering coeff (right-click for menu)	
Scatter I Type	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	
Scatter I Type	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	
Scatter I Type	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	
Scatter I Type	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	
Scatter I Type	p(t) = exp(-a * t), a =	s cattering coeff (right-click for menu) (inverse sys units) O Mean free paths (sys units)	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Active	Turns volume scattering on or off	Unchecked
Maximum number of	Sets the maximum number of consecutive scatter events allowed in the material.	1000
Туре	Sets model type: None or Henyey- Greenstein	None
Wavelength	Wavelengths corresponding to g- coefficients	blank
g-coefficient	Sets the g-coefficient (-1 <= g <= +1)	blank
	Scatter Coefficients	
Туре	Specify a scattering coefficient or the mean-free paths	scattering coefficients
Wavelength	Wavelengths corresponding to Scatter Coefficient/Mean-free Path	blank

Scatter Coefficient/Mean- free Path	Scatter coefficient (inverse system units) Mean-free Path (system units)	blank
OK	Accept settings and close dialog box.	
Cancel	Discard changes and close dialog box.	
Apply	Accept changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Add Volume Scatter - Henyey-Greenstein

• The angular distribution associated with the Henyey-Greenstein volume scatter model is given by

$$p(\theta) = \frac{1}{4\pi} \cdot \frac{1 - g^2}{(1 + g^2 - 2g\cos(\theta))^{3/2}}$$

• The scattering anisotopy parameter g varies in the range $-1 \le g \le +1$; g=-1 corresponding to total backward scattering, g=0 to isotropic (Rayliegh) scattering and g=+1 to total forward scattering (Mie scattering for large particles).

• Concentration can be specified in terms of a scattering coefficient *a* (inverse system units) or as mean-free path (system units).

• A useful reference on the subject of tissue scattering is *Tissue Optics* by Valery Tuchin, ISBN 0-8194-3459-0, published by SPIE.

See Also - Add Volume Scatter - Henyey-Greenstein

Material - Absorption

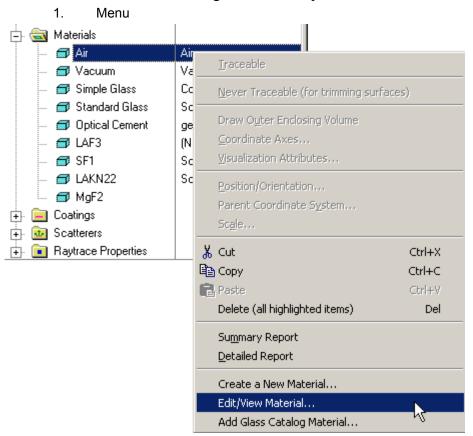
Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Material - Absorption

Adds absorption properties to any material. Absorption entered by this method overrides imaginary refractive indicies.



How Do I Get There? - Material - Absorption



This command is accessed through the Tree drop-down menu:

Dialog Box and Controls - Material - Absorption



	ngth vs. Absorption Ta		Cance Apply
Туре	_	ance Absorption Coefficient (inverse sys units)	
Thick		Reference distance for internal transmittance (system units)	Help
0	Wavelength (um)	Absorption Coefficient (inverse system units)	
-	I		
		verse system units (per unit distance). Positive	

<u>Control</u>	Inputs / Description	<u>Defaults</u>			
Active	Enables or disables this absorption feature	Checked			
	Wavelength vs Absorption Table				
Туре	Specifies absorption data as Internal Transmittance or Absorption Coefficient	Absorption Coefficient			
Thick	Reference distance for Internal Transmittance data	0			
Wavelength	Wavelength for corresponding absorption coefficient	blank			
Absorption Coefficient	Absorption coefficient for corresponding wavelength	blank			
ОК	Accept absorption data and close dialog box				
Cancel	Discard changes and close dialog box				

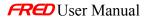
Apply	Apply absorption data and keep dialog box open	
Help	Access this Help page	

Application Notes - Material - Absorption

- This absorption model follows Beer's Law; I/I_o=Exp[- L]
- Absorption data is specified in inverse system units.

See Also - Material - Absorption

Edit/View Material Volume Scatter



Chapter 9 - Coatings

Description - Coatings

The **Coatings** folder contains the default and optional user entered Coatings that are applied to every surface in FRED. Used in conjunction with **Raytrace Controls**, coatings specify the relative transmission, reflection, or absorption of every ray incident on the surface. The default coatings are 100% Absorb, 100% Reflect, %100 Transmit, Standard Coating, and Uncoated (Bare). The user can edit any one of these except Uncoated, which requires no additional entries.

WARNING Changing the default Coatings can have unexpected consequences. It is recommended that the user create a new coating if different functionality is required.

The default Absorb, Reflect, Transmit, and Standard coatings are <u>Sampled Coatings</u>. Other coating options include <u>Uncoated (Bare)</u>, <u>Thin Film Layered</u>, <u>General Sampled Coating</u>, and <u>Polarizer/Waveplate</u> Coatings.

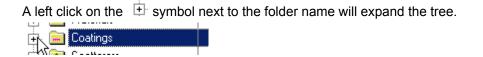
NOTE While FRED allows the user to change the coating parameters for an existing coating, FRED does not allow the user to change a Coating type once it has been defined.

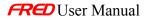
Visualization (example) - Coatings

The **Coatings** folder is near the bottom of the tree.

[III] FRED1	
Objects	Description
📑 🔁 Optical Sources	
P Geometry	
💷 Analysis Surface(s)	
🕂 🧰 Materials	
🕂 🧰 Coatings	
🕂 🔝 Scatterers	
🕂 💼 Raytrace Properties	

How Do I Get There? - Coatings





🕞 🔄 Coatings	
左 Absorb	100% Absorbing Coating
🛩 Reflect	100% Reflective Coating
🛩 Transmit	100% Transmissive Coating
🛩 Standard Coating	96% Transmitting, 4% Reflecting Coating
🦾 🛩 Uncoated	Bare Substrate

A left click on the \Box symbol next to an open folder will collapse the tree. Existing Coatings can be edited and viewed with a right mouse click on the name and selecting the Edit/View option, or by simply double clicking on the coating name.

Dialog Box and Controls - Coatings

right mous	e click on the Coati	ngs folder opens th	e following o
+ 💼 Geon + 🏨 Analy + 📠 Mate	sis Surface(s) ials	Description	
🕂 📻 Coati 🕂 🔂 Scatt	Iraceable		<u> </u>
🕂 🛄 Raytr		le (for trimming surface	s)
	Draw Outer En Coordinate Axe Visualization At	25	
	Position/Orient Parent Coordin Scale		
	∦ ⊂ut		Ctrl+X
	Copy		Ctrl+C
	Delete (all high	lighted items)	Ctrl+∀ Del
	Su <u>m</u> mary Repo Detailed Report		
	Create a New C Edit/View Coati		
	Plot		

A ontext menu.

The first option available on the context menu is a 'Summary Report.'

Su <u>m</u> mary Report
Detailed Report K
Create a New Raytrace Control Set
Edit a Raytrace Control Set,

When this option is selected, FRED prints a list the coatings in the model and a brief description of each.

Absorb	100% Absorbing Coating
Reflect	100% Reflective Coating
Transmit	100% Transmissive Coating
Standard Coating	96% Transmitting, 4% Reflecting Coating
Uncoated	Bare Substrate

The second option available on the right click menu is a 'Detailed Report.'

Su <u>m</u> mary Report
Detailed Report
NE
Create a New Raytrace Control Set
Edit a Raytrace Control Set,

When this option is selected, FRED prints a detailed summary of all of the coating properties.

tings				
<u>Refl Power</u>	<u>Refl Phase (deg)</u>	<u>Trans Power</u>	<u>Trans Phase (deg)</u>	<u>Name</u>
0	0	0	0	Absorb
1	0	0	0	Reflect
0	0	1	0	Transmit
0.04	0	0.96	0	Standard Coating
<u>tings</u>				
<u>e Coatings</u>				
	Bare Substrate			
led Coatings				
				-
	Refl Power 0 1 0 0.04 tings	Refl Power Refl Phase (deg) 0 0 1 0 0 0 0.04 0 tings e Coatings Bare Substrate	Refl Power Refl Phase (deg) Trans Power 0 0 0 0 1 0 0 1 0 0 1 0 0 0 0 1 0 0 0.04 0 0.96 0 0 tings Bare Substrate Bare Substrate D	Refl Power Refl Phase (deq) Trans Power Trans Phase (deq) 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0.04 0 0.96 0 tings Bare Substrate Bare Substrate Image: Continue Substrate

The third option available is to 'Create a New Coating...'

Su <u>m</u> mary Report Detailed Report	
Create a New Coating	
Edit/View Coating	

Selecting this option opens the Coating Dialog. This is just one of four ways to access this dialog.

Ҁ (FREL	01 *) Create a New	Coating			?
Name:	Coating 1				OK.
Descript	tion:				Cancel
Туре:	Sampled Coati	ng (reflection/transmis	sion for discrete wavele	engths) 💌	Help
	Wavelength (um)	Reflection	Coefficient	Tra	nsmission Co
	wavelength (um)	Power	Power Phase (deg) P		ver f
1	0.5875618 💌	0	0	0	0
-					10
					•
					<u>.</u>

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Enter a name for the Coating here.	Coating <i>n</i>
Description	Enter a short alpha-numeric description of the Coating here.	blank
Туре	Select the coating type from the pull-down menu. Options are: Sampled Coating	
OK Create a new Coating and close dialog box.		
Cancel	Discard new Coating and close dialog box.	
Help	Access this Help page.	

Application Notes - Coatings

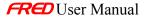
- Coatings are applied after Raytrace Controls.
- With the exception of Lens, Mirror, and Prism elements, the Coating for every surface created in FRED is 100% Absorbing by default, which stops ray propagation.

- The default coatings for a lens that was imported from a catalog or entered as a element are 100% Transmitting coatings on the front and back surfaces and 100% Absorbing on the edges and bevels (if any).
- The surface coating types for a prism imported from a catalog or entered as a primitive will vary according to function, but the coatings will be selected from the default set.
- The default coatings for a Mirror element are 100% Reflective on the reflecting surface and 100% Absorbing on the back surface, edge, and bevels.
- Copies between FRED models will always transfer material and coating information, as appropriate.

Examples - Coatings

Coating Dialogs: <u>Sampled Coating</u>

<mark>(</mark> (FRE	D1 *) Cre	ate a Ne	ew Co	ating				? ×
Name: Descrip		oating 1					Canc	
Туре:	S	ampled C	oating	(reflection/transmis	sion for discrete wave	elengths) 💌	Help	
)#/auolo	nath (un	D)	Reflection	Coefficient	Tra	ansmissio	n Co
	TTAVCIC	elength (um)		Power	Phase (deg)	Por	wer	P
1	0.58756	18	_ 0		0	0		0



Coating Dialogs: Uncoated

🕻 Coating		? ×
Name:	Coating 1	ОК
Description:		Cancel
Туре:	Uncoated (bare surface with no coating)	Help
No Data Req	uired	

Coating Dialogs: Thin Film Layered Coating

Coating						?
Name:	Coating 1					OK
Description:						Cancel
Гуре:	Thin Film Layer	ed Coating			-	Help
Wavelength	0.5875618 💌		(microns)	The desig	in waveler	ngth
Angle	0		(degrees)	The desig	yn angle	
Thickness	vVaves 🔿	Microns 💿 Geometry units	Length unit	s for layer	thickness	es
Substrate	At First Layer (🔿 🛛 At Last Layer 🖲	Coating ori	entation		
	Right mouse-cli	ck in table below for context menu				
Grp#Layer#	Designation	Thickness	Materi	al	Repe	at Count
1-1	Layer	0	Air	-		1



Coating Dialogs: Quarter Wave Single Layer Coating

Coating				? ×
Name: Description:	Coating 1		_ [OK Cancel
Туре:	Quarter Wave Sin			Help
	Parameter	Description		
Wavelength		(microns) The design wavelength		
Angle	0	(degrees) The design angle		
Material	Air	The film layer material		

Coating Dialogs: General Sampled Coating

Coating				? ×
Name:	Coati	ng 1		OK
Description:				Cancel
Туре:	Gene	eral Sampled (Coating (table of reflection/transmission coefficients)	Help
	F		ower coefficients: (Power, Phase(deg)): ate, Rp=p-state, Ts=Tran s-state, Tp=p-state	
Angle (deg)	Wav	0.5892938		•
	Rs	0	0	
0	Rp	0	0	
ľ	Ts	0	0	
	Тр	0	0	



Coating Dialogs: Polarizer/Waveplate Coating

Coat	ing			? ×			
Name:	Co	ating 1		OK			
Descrip	otion:			Cancel			
Туре:	Po	arizer/Waveplate	Coating (Jones matrix)	Help			
	Value		Description				
Туре	X Linear Po	olarizer 📃 💌	Type of polarization coating				
Coat	None	_	Coating in addition to the polarization coating				
	Amplitue	le Phase(deg)					
J00	1	0	Matrix element J(row,col)				
J10	0	0	Matrix element J(row,col)				
J01	0	0	Matrix element J(row,col)				
J11	0	0	Matrix element J(row,col)				

See Also ... - Coatings

The following links contain details about each of the coating models.
Sampled Coating
Uncoated
Thin Film Layered Coating
General Sampled Coating
Polarizer/Waveplate Coating
Quarter Wave Single Layer Coating

Applying Ray Controls and Coatings

Description - Applying Ray Controls and Coatings

This dialog page allows the user to select the surface coating and ray controls associated with a surface.

Any of the Coatings and Ray Controls defined in the current FRED document file may be assigned to the surface. In addition, new Coatings and Ray Controls can be added to the FRED document from this dialog. The process for adding a Coatings and Ray Controls are described in Creating New Coatings... and Creating New Ray Control... help files. In addition, the currently defined Coatings and Ray Controls can be edited from this dialog.

The coating determines power in the transmitted, reflected, total internal reflected (TIR), and absorbed rays based on the angle of incidence, polarization, and wavelength of the ray.

The ray controls determine whether transmitted, refracted, reflected, total internal reflected, split (due to Fresnel reflections), and/or scattered rays will be traced from the surface.

When a ray intersects this surface, FRED follows the this procedure:

- 1. First check the Ray Controls to determine what rays can be traced from the surface.
- 2. Then check the coating to determine what rays can be generated at the coating
- 3. Then check to see if there are scatter properties assigned to this surface
- 4. Then determine where the scatter rays are directed.
- 5. Generate the rays that meet all four criteria, i.e. rays that can be ray traced, would be generated by the coating, meet the scatter properties, and have the correct direction
- 6. Assign power to the created rays according to the coating and scatter properties.

NOTE or TIP When a ray intersects a surface, the Ray Controls are checked first and then the Coating. Further, the Ray Control check is a "yes" or "no" check where as the Coating check requires a calculation. Therefore, the fastest way to stop rays during a raytrace is to use the Ray Controls.

How Do I Get There? - Applying Ray Controls and Coatings

This page is in the Create New Surface... and Edit/View Surface... dialogs.

FRED1 *) Crea	ite a New Surf	ace as Child of: '	'Elem 1"					
Scatter	Visualization	Glue	Grating	Auxiliary	Data	Modifiers	l	0K
SURFACE	Aperture	Location/Orie	ntation	Materials	Coati	ng/RayControl		Cancel
- Ray Colors	T Coating							
Change color	Assigned:	Absorb		100% Absort	bing Coa	ting		Apply
of rays that intersect this		Name	Description	<u>ו</u>		Assign		Help
surface:	List of Available	Absorb Reflect		orbing Coating ective Coating				
Transmit	Coatings:	Transmit	100% Tran	smissive Coatin		Edit/View		
		Standard Coating	96% Trans	mitting, 4% Refl		Create New		
Reflect	⊢ Raytrace C	ontrol						
 *	Assigned:			Halt all ray c	ompone	nts		
Diffract		Name	Description	1				
v	List of	Halt All		components		Assign		
	Available Raytrace	Transmit Specular Reflect Specular		mitted specular sted specular ra		Edit/View		
C Scatter	Controls:	Allow All		y components				
v		•				Create New		

Dialog Box and Controls - Applying Ray Controls and Coatings

<u>Control</u>	Inputs	<u>Defaults</u>				
Ray Colors						
Transmit Reflect Diffract Scatter	Ray color can be changed based upon whether rays transmit, reflect, diffract, or scatter. Useful for tracking rays or identifying paths in the visualization window.	No change in color				
	Coating					
Coating	Assigns coating to surface. Coating properties establish what portion of the incident ray is reflected, transmitted, and absorbed. Coatings can be edited, viewed, or added to the list.	Absorb				
	Raytrace Control					
Raytrace Control	Assigns Raytrace controls to surface. Raytrace controls determine which possible rays will be traced from the surface after the intersection. Raytrace controls can be edited, viewed, or added to the list.	Halt All				
ОК	Accept Coating/RayControl changes and close dialog box.					
Close	Discard Coating/RayControl changes and close dialog box.					
Apply	Apply Coating/RayControl changes and keep dialog box open.					
Help	Access this Help page.					



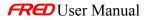
Description - Edit or Create a New General Sampled Coating

The General Sampled Coating type in FRED takes user-entered data for relative reflectivity, transmissivity, and phase change for S- and P-polarized light for one or more specified wavelengths and applies them to the surface. The General Sampled Coating type is similar to the Sampled Coating, but also allows for angular variation of the coating properties and includes polarization effects if the incident ray is polarized. The reflectivity and transmission coefficients cannot sum to more than one. It is not necessary to use the system wavelengths. If more than one wavelength is entered, FRED performs a linear interpolation to calculate the coefficients between adjacent wavelengths. If the system wavelength is outside the range specified in the coating dialog, then the coefficients are equal to those of the next highest or lowest wavelength in the range, as appropriate.

How Do I Get There? - Edit or Create a New General Sampled Coating

There are four ways to open a Coating dialog.

1. Right mouse click on the <u>Coatings</u> folder to open a context menu and select the option 'Create a New Coating...'.



Objects		Description	
⊕ Optical So ⊕ ⊕ Geometry ⊕ ⊡ Analysis S ⊕ ⊠ Materials			
 	Iraceable		
🕂 间 Raytrace	Never Traceab	le (for trimming surfa	ices)
	Draw Outer Er ⊆oordinate Ax ⊻isualization Al		
	Position/Orient Parent Coordin Sc <u>a</u> le		
	X Cut		Ctrl+X
	Copy		Ctrl+C
	Paste Delete (all high	lighted items)	⊂trl+V Del
	Su <u>m</u> mary Repo Detailed Repor		
	Creating a New Edit/View Coat		
	Plot		

2. Expand the <u>Coatings</u> folder and right mouse click on a specific coating open pop-up context menu and select the option '*Edit/View Coating*...'.



Objects		Description	
← ←		100% Absorbing Coati	
<mark>Reflect</mark> Transmil Standard		eable (for trimming surf-	aces)
Uncoate QW Scatterers Raytrace Pro	Draw Oute	r Enclosing Volume	
	Position/Or	ientation Irdinate S <u>v</u> stem	
	X Cut B Copy Paste Delete (all	highlighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary R <u>D</u> etailed Re		
	Create a N Edit/View C	ew Coating	
	Plot	.0	

3. Expand the <u>Coatings</u> and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the *'Edit/View...'* or *'Create New...'* coating buttons.



Scatter	1	Visualization) 6	ilue	Grating
SURFACE	Aperture	Location/Orient	ation	Materials	Coating/RayControl
✓ Traceable (this		e raytraced)			
- Ray Colors	Coating-	A h a sah		100% 45.5	aking Contine
Change color of rays that	Assigned:	Absorb			orbing Coating
intersect this		Name	Description		▲ Assign
surface:	List of Available	Absorb		rbing Coating	
Transmit	Coatings:	Reflect		ctive Coating smissive Coati	
		Standard Coating		nittina 4% Re	
· · · · · · · · · · · · · · · · · · ·		<u> </u>			
E Reflect	- Raytrace C	ontrol			
	Assigned:	Halt All		Halt All Ray	y Components
Diffract			Description	,	

Once the Coating dialog has been opened, the General Sampled Coating type can be selected from the list of options on the pull-down menu only if it is a new coating. Otherwise the Coating Type entry is grayed out (non-selectable) and only the coefficients can be changed.

Name:	Coating 1	ОК
Description:		Cancel
Туре:	General Sampled Coating (table of reflection/transmission coefficier 💌	Help
	Sampled Coating (reflection/transmission for discrete wavelengths) Uncoated (bare surface with no coating) Thin Film Layered Coating	
Angle (deg) General Sampled Coating (table of reflection/transmission coefficients) Polarizer/Waveplate Coating (Jones matrix)	T

Dialog Box and Controls - Edit or Create a New General Sampled Coating

Coating				<u>?</u> ×
Name:	Coati	ng 1		OK
Description:				Cancel
Туре:	Gene	eral Sampled	Coating (table of reflection/transmission coefficients)	Help
	F	-	ower coefficients: (Power, Phase(deg)): tate, Rp=p-state, Ts=Tran s-state, Tp=p-state	
Angle (deg)	Wav	0.5892938		•
	Rs	0	0	
n	Rp	0	0	
0	Ts	0	0	
	Тр	0	0	

The General Sampled Coating dialog is shown below.

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Enter the name of the Coating here	Coating <i>n</i>
Description	Enter a short alpha-numeric description of the Coating here	None
OK	Click on this button to accept changes and to close the dialog	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help	None
Туре	Select the General Sampled Coating type from the pull-down menu.	Sampled Coating
Wav	Enter coating wavelength(s) in microns	0.589
Rs	Enter the coefficient Rs for the relative reflected power of s-polarized light in column 1 and the phase change on reflection in degrees in column 2	0, 0
Rp	Enter the coefficient Rp for the relative reflected power of p-polarized light in column 1 and the phase change on reflection in degrees in column 2	0, 0

Ts	Enter the coefficient Ts for the relative transmitted power of s-polarized light in column 1 and the phase change on transmission in degrees in column 2	0, 0
Тр	Enter the coefficient Tp for the relative transmitted power of p-polarized light in column 1 and the phase change on transmission in degrees in column 2	0, 0

Application Notes - Edit or Create a New General Sampled Coating

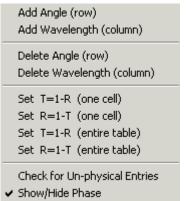
- Polarized rays
 - To ensure energy conservation, the sum of the reflection and transmission coefficients for each polarization state cannot exceed 1:
 - Rs+Ts ≤ 1
 - Rp+Tp ≤ 1
 - FRED does not automatically check for conservation of energy. Improper entries (i.e., Rs = 1, Ts = 1) can result in a net power gain, which is not physical. If requested, FRED can run a simple check to verify energy conservation (see example below)
 - Every polarized ray is decomposed into orthogonal (S and P) polarization states relative to the local coordinate axes of the surface. The coefficients Rs and Ts apply to the S-polarized component. Likewise, the coefficients Rp and Tp apply only to the P-polarized component.

Unpolarized rays

- FRED uses the average of the S- and P-polarized reflection coefficients to determine the power of the reflected ray component
- FRED uses the average of the S- and P-polarized transmission coefficients to determine the power of the transmitted ray component
- The averaging process may result in the sum of the transmitted and reflected power being less than the incident power in the ray
- The General Sampled Coating will not polarize a ray from an unpolarized source
- FRED linearly interpolates coefficients between angles and wavelengths.
- Coatings are used in conjunction with the Raytrace Controls to determine ray propagation.
 - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
 - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
 - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

Examples - Edit or Create a New General Sampled Coating

The following examples show how to edit input data and explain the uses of the various options available on the right click pop-up context menu.



Example 1: Edit the Design Wavelength

Changing the coating wavelength is accomplished by either directly typing the new wavelength (in microns) into the wavelength cell, or by selecting a new wavelength the list of predefined values available using the pull down menu. The predefined wavelengths in FRED include a large number of atomic emission lines in addition to a number of common laser wavelengths. Use the scroll bar on the right side of the list to scan through the entire range.



Example 2: Edit the Design Angle

The design angle(s) can be changed by selecting the Angle box with a left mouse click and typing the new value.

	F	Rs=Ret
Angle (deg)	Wav	0.5892
	Rs	0.25
15	Rp	0.65
	Ts	0.072
43	Тр	0.027

Example 3: Adding/Deleting Angle Rows and Wavelength Columns

Right mouse click in the data entry region to open the context menu and select the appropriate option to add or delete an angle row or wavelength column. The order of entry is not important. New entries are always appended to the end of the list. At least one angle row and



one wavelength column is required, but there is no upper limit on the number of angles or wavelengths. FRED will linearly interpolate between angles and wavelengths, as appropriate.

Add Angle (row) Add Wavelength (column)

Delete Angle (row) Delete Wavelength (column)

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state								
Angle (deg)	Wav	0.4046561 ŀ) (Hg)	_	Wav	0.7065188 r	(He)	☑
	Rs	0.96	0		Rs	0.96	0	
40	Rp	0.9	0		Rp	0.9	0	
	Ts	0.04	0		Ts	0.04	0	
	Тр	0.1	0		Тр	0.1	0	
	Rs	0.9	0		Rs	0.9	0	
50	Rp	0.8	0		Rp	0.8	0	
50	Ts	0.1	0		Ts	0.1	0	
	Тр	0.2	0		Тр	.2	0	

Based on the settings in the box above, a unit power linearly polarized ray at a wavelength of 0.55 microns and equal S and P components incident on the surface at an angle of 45 degrees will be split into a reflected and transmitted component. Relative to the power in the incident ray, the reflected component will have a relative power equal to $0.93^{*}S + 0.85^{*}P = 0.89$. The transmitted component will have a relative power equal to $0.07^{*}S + 0.15^{*}P = 0.11$, as shown below.

Ray <u>Count</u>	Incoherent <u>Power</u>	<u>Name</u>
1 1	0.11 0.89	.Subassembly 1.detector.transmitted .Subassembly 1.detector.reflected
2	1	

Example 4: Autofilling data

FRED can automatically fill transmission or reflection coefficient data when one of the following options is selected from the right click pop-up menu.

Set T=1-R (one cell) Set R=1-T (one cell) Set T=1-R (entire table) Set R=1-T (entire table)

A single cell refers to a single wavelength and a single angle, as shown below.

Angle (deg)	Wav	0.4046561 h	(Hg)
	Rs	0.96	0
40	Rp	0.9	0
40	Ts	0.04	0
	Тр	0.1	0

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state							
Angle (deg)	Wav	0.4046561 h	(Hg) 💌	Wav	0.7065188 r	(He) 🗾	
	Rs	0.96	0	Rs	0.96	0	
40	Rp	0.9	0	Rp	0.9	0	
	Ts	0.04	0	Ts	0.04	0	
	Тр	0.1	0	Тр	0.1	0	
	Rs	0.9	0	Rs	0.9	0	
50	Rp	0.8	0	Rp	0.8	0	
50	Ts	0.1	0	Ts	0.1	0	
	Тр	0.2	0	Тр	.2	0	

The entire table refers to all wavelengths and all angles.

The rules for the autofill is based on the following: For any single cell, Rs+Ts=1, Rp+Tp=1. Autofilling T for a single cell:

			Table of power coefficients Rs=Refl s-state, Rp=p-state, 1				
Angle (deg)	Wav	0.4046561		-	Wav	0.7065188	
	Rs	0.6	0		Rs	0.6	0
45	Rp	0.8	0		Rp	0.8	0
40	Ts	0	lu	_	Ts	0	0
	Тр	0	Add Angle (row) Add Wavelength (column)		Тр	0	0
•			Delete Angle (row) Delete Wavelength (column)				
			Set T=1-R (one cell) Set R=1-T (one cell)				

The result is

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state							
Angle (deg)	Wav	0.4046561	•	Wav	0.7065188		
	Rs	0.6	0	Rs	0.6	0	
45	Rp	0.8	0	Rp	0.8	0	
40	Ts	0.4	0	Ts	0	0	
	Тр	0.2	0	Тр	0	0	

Autofilling T for the entire table:

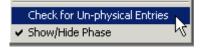
			•			ts: (Power, Ts=Tran s-s	
Angle (deg)	Wav	0.4046561		⊡	Wau	0.7065188	
	Rs	0.6	0		Rs	0.6	
45	Rp	0.8	0		Rp	0.8	
40	Ts	0	- N AA AA A	- 1	• • • - •	10	
	Тр	0	Add Angl				
			Add Wav	elengt	:h (co	lumn)	
			Delete Ar	ngle (r	ow)		
•			Delete Wavelength (column)				
		Set T=1-R (one cell) Set R=1-T (one cell)					
		Set T=1-R (entire table)					
			Set R=1-T (entire table) 场				

The result is

Table of power coefficients: (Power, Phase(deg)): Rs=Refl s-state, Rp=p-state, Ts=Tran s-state, Tp=p-state							
Angle (deg)	Wav	0.4046561		◄	Wav	0.7065188	
	Rs	0.6	0		Rs	0.6	0
45	Rp	0.8	0		Rp	0.8	0
40	Ts	0.4	0		Ts	0.4	0
	Тр	0.2	0		Тр	0.2	0

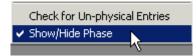
Example 5: Check for Un-physical Entries

When this option is selected from the right click pop-up menu, FRED sums the transmission and reflection coefficients to check to see if $Rs+Ts\leq1$ and $Rp+Tp\leq1$. FRED returns a dialog with the result, but does not alter the entries.



Example 6: Show/Hide Phase

Clearing the check next to this option on the right click pop-up menu hides the phase column in each cell.





See Also ... - Edit or Create a New Sampled Coating

The following links contain details about each of the remaining coating models. Sampled Coating Uncoated Thin Film Layered Coating Polarizer/Waveplate Coating For details about Raytrace Controls, select the following link. Raytrace Controls

Edit or Create a New Thin Film Layered Coating

Description - Edit or Create a New Thin Film Layered Coating

Use the Thin Film Layered Coating in FRED to create a single or multilayer thin film coating that can be attached to any substrate material. FRED uses the characteristic matrix of the coating to determine reflection and transmission properties as a function of wavelength and angle of incidence. Only those materials contained in the Materials folder on the tree can be used to define the multilayer coating. Coating thickness can be entered is waves or physical thickness. There is no limit to the number of layers that can be contained in a coating stack.

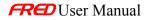
Visualization (example) - Edit or Create a New Thin Film Layered Coating

None.

How Do I Get There? - Edit or Create a New Thin Film Layered Coating

There are four ways to open a Coating dialog.

1. Right mouse click on the <u>Coatings</u> folder to open a context menu and select the option 'Create a New Coating...'.



Objects		Description	
⊕ ⊖ Optical So ⊕ ⊕ Geometry ⊕ ⊕ Analysis S ⊕ ⊕ Materials			
	Iraceable		
🕂 直 Raytrace	Never Traceabl	e (for trimming surface	s)
	Draw O <u>u</u> ter End Coordinate Axe Visualization Atl	5	
	<u>P</u> osition/Orient: Parent Coordin Sc <u>a</u> le		
	 ✗ Cut Image: Copy Image: Paste Delete (all high 	ighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Summary Report		
	Create a New C Edit/View Coati		

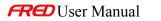
2. Expand the <u>Coatings</u> folder and right mouse click on a specific coating open the pop-up context menu and select the option '*Edit/View Coating*...'.



Objects			Description	
	Optical Source Geometry Analysis Surfa			
		300(3)		
Ē 👼	Coatings			
	左 Absorb		100% Absorbing Coati	
	🛥 Reflect 🛥 Transmi	Iraceable	100% D-8	
	左 Standar 左 Uncoate	Never Trace	able (for trimming surfa	ces)
	Z QW	Draw O <u>u</u> ter	Enclosing Volume	
÷ 🖬	Scatterers	⊆oordinate /		
÷ 主	Raytrace Pro	⊻isualization	Attributes	
		Position/Orie Parent Coor Sc <u>a</u> le	entation dinate S <u>v</u> stem	
		🔏 Cut		Ctrl+X
		🖹 Сору		Ctrl+C
		💼 Paste		Ctrl+∀
		Delete (all hi	ighlighted items)	Del
		Su <u>m</u> mary Re		
		<u>D</u> etailed Rep	port	
		Create a Ne	w Coating	
		Edit/View Co	oating	
		Plot		

3. Expand the $\underline{\text{Coatings}}$ and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the *'Edit/View...'* or *'Create New...'* coating buttons.



Scatter		Visualization	1 0	Glue	1	Grating	
SURFACE	Aperture	Location/Orientation		Materials	Coating/RayContr		
✓ Traceable (th Ray Colors	is surface can b	e raytraced)					
Change color	Assigned:	Assigned: Absorb 100% Absorbin				ng Coating	
of rays that intersect this surface:	List of	Name Absorb	Description	n Arbing Coating	-	Assign	
🔲 Transmit	Available Coatings:	Reflect Transmit	100% Refle 100% Tran:	ective Coating smissive Coati	nc	Edit/View	
.		Standard Coating	96% Transr	mittina 4% Be	fl≓⊥ ▶	Create New	
Reflect	Raytrace Control						
Y	Assigned:	Halt All		Halt All Ray	, Comp	onents	
D Diffract		Mama	Description			A :	

Once the Coating dialog has been opened, the Thin Film Layered Coating option can be selected if it is a new coating. Otherwise, the Coating Type entry is grayed out (non-selectable) and only the coating parameters can be changed.

Coating				?	
Name:	Coating 1	ОК			
Description:			Can	cel	
Гуре:	Thin Film Layered Coating			Help	
Wavelength	Sampled Coating Uncoated (bare s	(microns)	The		
Angle	Thin Film Layered Coating			The	
Thickness	General Sampled Coating (table of reflection/transmission coefficients)			Length units for I	
Substrate	Polarizer/Waveplate Coating (Jones matrix)			Coating orientatio	
	Right mouse-clicl	in table below for context menu			
Grp#Layer#	Designation	Thickness	M Repeat (Coun	
1-1	Layer	0	8	1	

Dialog Box and Controls - Edit or Create a New Thin Film Layered Coating

The Thin Film Layered Coating dialog is shown below.



Coating					<u>.</u>
Name:	Coating 1				OK
Description:					Cancel
Гуре:	Thin Film Layer	ed Coating		•	Help
Wavelength	0.5875618 💌		(microns)	The design	n wavelength
Angle	0		(degrees)	The desig	n angle
Thickness	Waves 🔿	Microns 💿 🛛 Geometry units 🔿	Length units for layer thicknesses		
Substrate	At First Layer (At Last Layer •	Coating ori	entation	
	Right mouse-cli	ick in table below for context menu			
Grp#Layer#	Designation	Thickness	Material	Repe	at Count
1-1	Layer	0	Air 💌		1

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Enter the name of the Coating here.	Coating <i>n</i>
Description	Enter a short alpha-numeric description of the Coating here.	None
OK	Click on this button to accept changes and to close the dialog.	None
Cancel	Click on the button to close the dialog. You will lose any changes.	None
Help	Get dialog help.	None
Туре	Select the Thin Film Layered Coating type from the pull-down menu.	Sampled Coating
Wavelength	Enter the coating design wavelength in microns.	0.589
Angle	Enter the coating design angle in degrees.	0 (normal incidence)
Thickness	Enter the length units for layer thicknesses.	Microns
Substrate	Enter substrate location (top or bottom).	At Last Layer
Grp#-Layer#	Grp# refers to the coating group; multiple layers may be assigned to a single group.	1-1
Thickness	Enter the layer thickness in the selected units.	0
Material	Enter the coating material from the pull-down menu.	Air

Repeat Count Number of times the layer or group is repeated. 1	
--	--

Application Notes - Edit or Create a New Thin Film Layered Coating

- Only the materials contained in the **Materials** folder can be used to define a coating. The material entry must be completed first.
- Coatings are used in conjunction with the <u>Raytrace Controls</u> to determine ray propagation.
 - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
 - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
 - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

Examples - Edit or Create a New Thin Film Layered Coating

The following examples illustrate how to apply the dialog controls for some commonly used multilayer thin film designs.

Example 1 - Quarter Wave AR coating

This example shows a single layer quarter wave thickness magnesium fluoride (n = 1.38) coating. It is sometimes referred to as V-coat because this describes the shape of the reflectance curve as a function of wavelength. For this example, minimum reflectance is achieved at a wavelength of 0.55 microns at a 45-degree angle of incidence. Note that the Wavelength, Angle, and Thickness settings are all used by FRED to calculate the physical thickness of the layer. The incident media is air and the substrate material is glass.



Coating						
Name:	quarterwave AR				OK	
Description:	quarterwave AR	uarterwave AR v-coat				
Гуре:	Thin Film Layered	I Coating		7	Help	
Wavelength	0.55 💌		(microns)	The desi	gn wavelength	
Angle	45		(degrees)	The des	ign angle	
Thickness	Waves 💿	Microns 🔿 Geometry units 🔿) Length units for layer thicknesses			
Substrate	At First Layer 🔿	At Last Layer 💿	Coating orig	entation		
	Right mouse-click	in table below for context menu				
Grp#Layer#	Designation	Thickness	Materia	I Rej	peat Count	
1-1	Layer	0.25	MgF2	-	1	

Example 2 - 2 layer AR coating

This example shows a coating with 2 thin film layers. Coating layers are appended, inserted, or deleted using the context menu that pops up with a right mouse click.

		k in table below for context menu		
Grp#Layer#	Designation	Thickness	Material	Repeat Count
1-1	Layer	0.25	MgF2	
		Append New Layer 💦 📘		
		Insert New Layer 5		
		Delete Layer		
		Make Into Group		
coat	Contraction of the local	Make into Individual Layers		

The second layer is a high index coating (Ti02, n = 2.2) one half-wave thick.



Name:	two layer AR				OK	
Description:	quarter-half w-co	iarter-half w-coat				
Гуре:	Thin Film Layere	d Coating				
Wavelength	0.55 💌		(microns) T	he design w	/avelength	
Angle	45		(degrees)	The design a	ngle	
Thickness	Waves 💿	Microns O Geometry units C	Length units for layer thicknesses			
Substrate	At First Layer 🤇) At Last Layer 💿	Coating orien	tation		
	Right mouse-clic	k in table below for context menu				
Grp#Layer#	Designation	Thickness	Material	Repeat	Count	
1-1	Layer	0.25	MgF2 💌		1	
2-1	Layer	0.5	TiO2 🔽		1	

The incident media for this coating is air and the substrate is glass. The order of intersection is Air | MgF2 | TiO2 | Glass. Note that the Group number of the second layer has been incremented by one. FRED allows grouping and repetition of multiple layers, as shown in the next example.

Example 3 - Dichroic Filter

This example shows a 3 layer coating sequence that is repeated multiple times. To group a sequence of layers, select the first layer in the sequence with a left mouse click and, while holding down the mouse button, drag the pointer down to the last layer. In this case, all three layers are highlighted. Release the left mouse button and right click to pop-up the context menu. Select the option '*Make Into Group*, ' as shown below.

	Right mouse-clic	k in table below for context menu	1	
Grp#Layer#	Designation	Thickness	Material	Repeat Count
1-1	Layer	0.125	TiO2 💌	1
2-1	Layer	0.25	MgF2 🔽	1
3-1		Append New Layer Insert New Layer Delete Layer	TiO2	1
Juai		Make Into Group Make into Individual Layers		

The resulting coating dialog looks like this.

Vame:	dichroic				OK	
Description:	multi-period coati	ng Cancel				
Гуре:	Thin Film Layere	d Coating				
Wavelength	0.65 💌		(microns)	The design	n wavelength	
Angle	45		(degrees) The design angle			
Thickness	Waves 💿	Microns O Geometry units O	Length units for layer thicknesses			
Substrate	At First Layer 🤇	At Last Layer 💿	Coating orie	ntation		
		k in table below for context menu				
Grp#Layer#	Designation	Thickness	Material	Repe	at Count	
1-1	Group	0.125	TiO2 💽		10	
1-2	Group	0.25	MgF2			
1-3	Group	0.125	TiO2			

The **Repeat Count** is the number of times this coating sequence is repeated. Note that the group number for all three layers is the same. A group can be undone by again dragging the mouse over all the layers in the group, opening the context menu with a right mouse click, and selecting the option '*Make into Individual Layers*'. The **Repeat Count** is automatically reset to 1 when a coating group is split into layers.

Example 4 - Narrowband Filter

A narrowband filter is constructed using long sequences of alternating high and low quarter wave layers separated by a half-wave high index layer, as shown below.

Name:	narrow band filter	harrow band filter				
Description:	single cavity filter					
Гуре:	Thin Film Layere	l Coating				
Wavelength	0.6		(microns)	The desig	gn wavelength	
Angle	45		(degrees)	The desi	ign angle	
Thickness	Waves 💿	Microns 🔿 Geometry units 🕻	r thicknesses			
Substrate	At First Layer 🤇) At Last Layer 💿 Coating orientation				
	Right mouse-clic	k in table below for context menu				
Grp#Layer#	Designation	Thickness	Materia	al R	epeat Count	
1-1	Group	0.25	TiO2	-	10	
1-2	Group	0.25	MgF2	-		
2-1	Layer	0.5	TiO2		1	
3-1	Group	0.25	MgF2		10	
3-2	Group	0.25	TiO2	-		

See Also ... - Edit or Create a New Thin Film Layered Coating

The following links contain details about each of the remaining coating models. <u>Sampled Coating</u>

Uncoated

General Sampled Coating

Polarizer/Waveplate Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

Uncoated (Bare) Surfaces

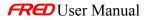
Description - Uncoated (Bare) Surfaces

The Uncoated (Bare) coating type in FRED has no user entries. When a ray intersects an Uncoated surface, FRED calculates the Fresnel reflection and transmission coefficients based on the refractive index change, angle of incidence, and wavelength. Refractive indices can be real (dielectrics) or imaginary (metals).

How Do I Get There? - Uncoated (Bare) Surfaces

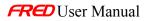
There are four ways to open a Coating dialog.

1. Right mouse click on the <u>Coatings</u> folder to open a the pop-up menu and select the option '*Create a New Coating...*'.



Objects		Description	
 ➡ Optical So ➡ Geometry ➡ Analysis S ➡ Materials 	Surface(s)		
🕂 🧰 Coatings	Traceable		
🕂 直 Raytrace	Never Traceab	le (for trimming surfac	es)
	Draw Outer En ⊆oordinate Ax ⊻isualization Al		
	Position/Orient Parent Coordir Scale		
	X Cut Copy Paste Delete (all high	lighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Repo Detailed Repor		
	Create a New Edit/View Coat		
	Plot		

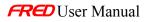
2. Expand the <u>Coatings</u> folder and right mouse click on a specific coating to open a popup context menu and select the option '*Edit/View Coating...*'.



Objects			Description	
	Materials Coatings <i>—</i> Absorb		100% Absorbing Coati	
	<i>➡</i> Reflect<i>➡</i> Transmi<i>➡</i> Standar	Iraceable <u>N</u> ever Trace	able (for trimming surfa	ces)
÷	Uncoate QW Scatterers Raytrace Pro	⊆oordinate /	Enclosing Volume Axes Attributes	
		<u>P</u> osition/Orie Parent Coor Sc <u>a</u> le	entation dinate S <u>y</u> stem	
		 ✗ Cut ✿ Copy ֎ Paste Delete (all h 	ighlighted items)	Ctrl+X Ctrl+C ⊂trl+V Del
		Su <u>m</u> mary Re <u>D</u> etailed Rep		
		Create a Ne Edit/View Co	w Coating bating	
		Plot	· \\	

3. Expand the $\underline{\text{Coatings}}$ folder and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the *'Edit/View...'* or *'Create New...'* coating buttons.



🔇 (5 layer AR coating.frd) Edil	Surface: "Reflect	ing Surface"		_ 🗆 X
Scatter Visualization SURFACE Aperture	Glue Glue Location/Orien	Grating Auxiliary Data tation Materials C	Modifiers oating/RayControl	OK Cancel
Ray Colors Coating				Apply
Change color Assigned: of rays that	5 layer AR coating			Help
intersect this surface: List of Available	Name Absorb	Description 100% Absorbing Coating	Assign	
Transmit	Reflect Transmit Standard Coating	100% Reflective Coating 100% Transmissive Coating 96% Transmitting, 4% Refle ↓	Edit/View	
Reflect Raytrace C	Control			
Assigned:	Allow All	Allow all ray comp	ponents	
Diffract	Name Halt All Transmit Specular	Description Halt all ray components Allow transmitted specular ray	Assign	
Scatter Raytrace Controls:	Reflect Specular Allow All	Allow reflected specular ray or Allow all ray components	Edit/View	
	•		Create New	

Once the Coating dialog has been opened, the Uncoated or Bare coating type can be selected from the list of options on the pull-down menu only if it is a new coating. Otherwise the Coating Type entry is grayed out (non-selectable).

🕻 Coating		? ×
Name:	Coating 1	OK
Description:		Cancel
Туре:	Sampled Coating (reflection/transmission for discrete wavelengths)	Help
Wave	Sampled Coating (reflection/transmission for discrete wavelengths) Uncoated (bare surface with no coating)	ransmission Cc
1 0.589	Thin Film Layered Coating General Sampled Coating (table of reflection/transmission coefficients) Polarizer/Waveplate Coating (Jones matrix)	0
•		▶

FRED User Manual

Dialog Box and Controls - Uncoated (Bare) Surfaces

	neoaled (Dale) coaling dialog is shown below.	
侯 Coating		<u>? ×</u>
Name:	Coating 1	ОК
Description:		Cancel
Туре:	Uncoated (bare surface with no coating)	Help
No Data Rec	quired	
1		

The Uncoated (Bare) coating dialog is shown below.

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>	
Name	Enter the name of the Coating here.		
Description	Enter a short alpha-numeric description of the Coating here.	description of the None	
OK	Click on this button to accept changes and to close the dialog.		
Cancel	Click on the button to close the dialog. You will lose any changes.		
Help	Get dialog help.	None	
Туре	Select the Uncoated type from the pull-down menu.	Sampled Coating	

Application Notes - Uncoated (Bare) Surfaces

- Coatings are use in conjunction with the Raytrace Controls to determine ray propagation.
 - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
 - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission

- Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

See Also... - Uncoated (Bare) Surfaces

The following links contain details about each of the remaining coating models.
Sampled Coating
Thin Film Layered Coating
General Sampled Coating
Polarizer/Waveplate Coating
For details about Raytrace Controls, select the following link.
Raytrace Controls

Edit or Create a New Polarizer/Waveplate

Description - Edit or Create a New Polarizer/Waveplate

The Polarizer/Waveplate coating type in FRED is used to create ideal polarizing optics. The coating type consists of a number of pre-defined polarizers and waveplates as well as one user-definable polarizing coating. The coatings are defined using Jones matrices and apply only to transmitted rays. This coating type can be kept as a standalone coating or it can be combined with any other existing coating that is contained in the model.

How Do I Get There? - Edit or Create a New Polarizer/Waveplate

There are four ways to open a Coating dialog.

1. Right mouse click on the <u>Coatings</u> folder to open a context menu and select the option 'Create a New Coating...'.



Objects		Description	
	Iraceable	le (for trimming surface	
	Draw Outer En <u>C</u> oordinate Axe <u>V</u> isualization At <u>P</u> osition/Orient Parent Coordin Scale	closing Volume es tributes ation	
	X Cut Copy Paste Delete (all high	lighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Repo Detailed Report		
	Create a New (Edit/View Coati		

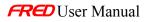
2. Expand the <u>Coatings</u> folder and right mouse click on a specific coating open a pop-up menu and select the option '*Edit/View Coating*...'.



Objects			Description	
	Materials Coatings <i>—</i> Absorb		100% Absorbing Coati	
	<i>➡</i> Reflect<i>➡</i> Transmi<i>➡</i> Standar	Iraceable <u>N</u> ever Trace	able (for trimming surfa	ces)
÷	Uncoate QW Scatterers Raytrace Pro	⊆oordinate /	Enclosing Volume Axes Attributes	
		<u>P</u> osition/Orie Parent Coor Sc <u>a</u> le	entation dinate S <u>y</u> stem	
		 ✗ Cut ✿ Copy ֎ Paste Delete (all h 	ighlighted items)	Ctrl+X Ctrl+C ⊂trl+V Del
		Su <u>m</u> mary Re <u>D</u> etailed Rep		
		Create a Ne Edit/View Co	w Coating bating	
		Plot	· \\	

3. Expand the <u>Coatings</u> folder and, using the left mouse button, double click on the coating name.

4. From the Coating/RayControl tab in the **Surface** dialog, left mouse click on either the *'Edit/View...'* or *'Create New...'* coating buttons.



Scatter	1	Visualization	1 0	Glue	1	Grating
SURFACE	Aperture	Location/Orient	ation	Materials	Co	oating/RayControl
✓ Traceable (this	surface can b — Coating —	e raytraced)				
Change color of rays that	Assigned:	Absorb		100% Abso	rbing (Coating
intersect this		Name	Description	I	-	Assign
surface:	List of Available	Absorb		rbing Coating		
🗖 Transmit	Coatings:	Reflect Transmit	100% Tran:	ective Coating smissive Coati mitting, 4% Re	nc	Edit/View
· ·		Standard Coating	36% Liansi	nitrina 4% Be		Create New
Reflect	∟ ⊢ Raytrace C	ontrol				
7	Assigned:	Halt All		Halt All Ray	, Comp	ponents
Diffract		Marca	Description			A : 1

Once the Coating dialog has been opened, the Polarizer/Waveplate type can be selected from the list of options on the pull-down menu only if it is a new coating.

Descrip	otion:	
Туре:		Polarizer/Waveplate Coating (Jones matrix)
	Value	Sampled Coating (reflection/transmission for discrete wavelengths) Uncoated (bare surface with no coating)
Туре	X Lines	Thin Film Layered Coating
Coat	None	General Sampled Coating (table of reflection/transmission coefficients)
	Ampl	Polarizer/Wayeplate Coating (Jones matrix)

Dialog Box and Controls - Edit or Create a New Polarizer/Waveplate

The Polarizer/Waveplate Coating dialog is shown below.



Coati	ing		?
Name:	Polar	zer/Waveplate	OK
Descrip	tion:		Cancel
Гуре:	Polar	izer/Waveplate	Coating (Jones matrix)
	Value		Description
Туре	General Matr	ix 💌	Type of polarization coating
Coat	None	_	Coating in addition to the polarization coating
	Amplitude	Phase(deg)	
J00	1	0	Matrix element J(row,col)
J10	0	0	Matrix element J(row,col)
J01	0	0	Matrix element J(row,col)
J11	0	0	Matrix element J(row,col)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Enter the name of the Coating here	Coating <i>n</i>
Description	Enter a short alpha-numeric description of the Coating here	
Туре	Select the Polarizer/Waveplate type from the pull-down menu.Sampled Coating	
OK	Click on this button to accept changes and to close the dialog None	
Cancel	Click on the button to close the dialog. You will lose any changes.	
Help	Get dialog help	None
Туре	Select the type of polarization coating using the pull-down menu	X Linear Polarizer
Coat	Select any other coating to be used in combination with the polarization coating using the pull-down menu	None
J00	Enter the amplitude and phase of the J00 (row,col) Jones matrix element	0, 0
J10	Enter the amplitude and phase of the J10 (row,col) Jones matrix element	0, 0
J01	Enter the amplitude and phase of the J01 (row,col) Jones matrix element	0, 0

Enter the amplitude and phase of the J11 (row,col) ones matrix element	0, 0

<u>Application Notes - Edit or Create a New Polarizer/Waveplate</u>

- The Jones matrix is applied only to transmitted rays.
 - A reflected ray is generated only if the polarizer is combined with a reflecting coating.
 - The polarizer will not affect the power of the reflected ray.
- The electric field vector of a polarized ray is decomposed into orthogonal components relative to the local z-axis of the surface. Any component of the electric field that projects onto the z-axis is not affected by the polarizer.
 - This case can arise when the direction of a ray is not parallel to the z-axis; i.e. a linear polarizer with its transmission axis parallel to the local X-axis will transmit a portion of any ray linearly polarized in the Y direction because the electric field has a component along the z-axis. The relative power of the transmitted component increases with angle of incidence.
- Polarized rays
 - The orientation of the fast axis (waveplates) or transmission axis (polarizers) is defined in the local coordinate system of the surface.
 - The electric field vector of polarized rays incident on the surface are decomposed into orthogonal components in the local coordinate system of the surface. The X and Y components are acted upon by the coating, the Z component is not.
 - Polarizing coatings are insensitive to wavelength.
- Unpolarized rays
 - In the absence of any other coating specification, the transmitted flux of an unpolarized ray incident on any of the linear polarizers is reduced by half.
 - In the absence of any other coating specification, the flux of an unpolarized ray incident on any of the waveplates is maintained on transmission.
 - A linear polarizer will polarize an unpolarized ray. Any other type will not.
- Coatings are used in conjunction with the <u>Raytrace Controls</u> to determine ray propagation.
 - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection.
 - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission.
 - Scattered rays are subject to the same limitations. Currently, an absorbing surface cannot generate scattered rays.
- Copies between FRED models will always transfer new material and coating information.
- Once defined, a coating type cannot be changed.

Examples - Edit or Create a New Polarizer/Waveplate

The following examples show all of the available polarization coatings. These are selected from the pull-down menu in the Type column.

	Value		Description
Туре	Left Circular Polarizer	•	Type of polarization coating
Coat	General Matrix		Coating in addition to the polarization coating
J00 J10 J01 J11	X Linear Polarizer		Matrix element J(row,col) Matrix element J(row,col) Matrix element J(row,col) Matrix element J(row,col)

A polarizing coating can be combined with any other coating defined in the model. Use the pull-down menu in the Coat column to select one.

	Value		Descript
Туре	Left Circular Polarizer	•	Type of p
Coat	None		Coating in
	None		1
J00	Absorb 💦		Matrix ele
J10	Reflect		Matrix ele
J01	Transmit Oten devel Constinue		Matrix ele
J11	Standard Coating		Matrix ele
	quarterwave AR	•	



General Matrix

This is the only polarizing coating that can be edited by the user. Manually enter values for the amplitude and phase angle (in degrees) for each of the Jones matrix element. A positive phase angle advances the relative phase and a negative phase angle retards it.

Name:	Polaria	zer/Waveplate		OK
Descri	ption:			Cancel
Туре:	Polari	zer/Waveplate	Coating (Jones matrix)	Help
	Value		Description	
Туре	General Matri	× 💌	Type of polarization coating	
Coat	None	-	Coating in addition to the polarization coating	
	Amplitude	Phase(deg))	
J00	1	0	Matrix element J(row,col)	
J10	0	0	Matrix element J(row,col)	
J01	0	0	Matrix element J(row,col)	
J11	0	0	Matrix element J(row,col)	

X Linear Polarizer

The transmission axis is parallel to the local X-axis of the surface.

Coat	ing				? ×
Name:	P	olarize	r/Waveplate		ОК
Descrip	otion:				Cancel
Гуре:	P	olarize	r/Waveplate	Coating (Jones matrix)	Help
	Value			Description	
Туре	X Linear	ar Polarizer 🛛 🔽		Type of polarization coating	
Coat	None			Coating in addition to the polarization coating	
	Amplitu	ude I	Phase(deg)		
J00	1	C)	Matrix element J(row,col)	
J10	0	C)	Matrix element J(row,col)	
J01	0	C)	Matrix element J(row,col)	
J11	0	C)	Matrix element J(row,col)	



Y Linear Polarizer

The transmission axis is parallel to the local Y-axis of the surface.

lame:	Polari	zer/Waveplate		OK	
Descrij	otion:			Cancel	
Гуре:	ype: Polarizer/Waveplate (Coating (Jones matrix)	Help	
	Value		Description		
Туре	Y Linear Pola	arizer 🔽	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating		
	Amplitude	Phase(deg)			
J00	0	0	Matrix element J(row,col)		
J10	0	0	Matrix element J(row,col)		
J01	0	0	Matrix element J(row,col)		
J11	1	0	Matrix element J(row,col)		

+45 Linear Polarizer

The transmission axis is rotated 45 degrees about the local Z-axis of the surface.

lame:	Pola	rizer/Waveplate	9	OK
Descrij	otion:			Cancel
Гуре:	ype: Polarizer/Waveplate		e Coating (Jones matrix)	Help
	Value		Description	
Туре	1/2wave +4	wave +45 Fast Axis 💌 Type of polarization coating		
Coat	None		Coating in addition to the polarization coating	
	Amplitude	e Phase(deg		
J00	0	0	Matrix element J(row,col)	
J10	1	0	Matrix element J(row,col)	
J01	1	0	Matrix element J(row,col)	
J11	0	0	Matrix element J(row,col)	

-45 Linear Polarizer

The transmission axis is rotated -45 degrees about the local Z-axis of the surface.

lame:	Polari	zer/Waveplate		OK	
Descrij	ption:			Cancel	
Гуре:	ype: Polarizer/Waveplate		Polarizer/Waveplate Coating (Jones matrix)		
	Value		Description		
Туре	-45 Linear Po	olarizer 🗾	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating		
	Amplitude	Phase(deg)			
J00	0.5	0	Matrix element J(row,col)		
J10	0.5	180	Matrix element J(row,col)		
J01	0.5	180	Matrix element J(row,col)		
J11	0.5	0	Matrix element J(row,col)		

1/4 Wave X Fast Axis

The fast axis is of the waveplate is parallel to the local X-axis of the surface.

lame:	Polari	zer/Waveplate		OK		
Descrij	otion:			Cancel		
Гуре:	ype: Polarizer/Waveplate		Coating (Jones matrix)	Help		
	Value		Description			
Туре	1/4wave X F	ast Axis 💌	Type of polarization coating	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating			
	Amplitude	Phase(deg)				
J00	1	0	Matrix element J(row,col)			
J10	0	0	Matrix element J(row,col)			
J01	0	0	Matrix element J(row,col)			
J11	1	-90	Matrix element J(row,col)			

1/4 Wave Y Fast Axis

The fast axis is of the waveplate is parallel to the local Y-axis of the surface.

lame:	Polari	zer/Waveplate		OK	
Descrij	otion:				
Гуре:	ype: Polarizer/Waveplate I		Coating (Jones matrix)	Help	
	Value		Description		
Туре	1/4wave Y F	ast Axis 💌	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating		
	Amplitude	Phase(deg)			
J00	1	-90	Matrix element J(row,col)		
J10	0	0	Matrix element J(row,col)		
J01	0	0	Matrix element J(row,col)		
J11	1	0	Matrix element J(row,col)		

1/4 Wave +45 Fast Axis

The fast axis is of the waveplate is rotated 45 degrees about the local Z-axis of the surface.

lame:	Polari	zer/Waveplate		ОК	
Descri	ption:			Cancel	
ype: Polarizer/Waveplate		zer/Waveplate	Coating (Jones matrix)	Help	
	Value		Description		
Туре	1/4wave +45	i Fast Axis 💌	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating		
	Amplitude	Phase(deg)			
J00	0.707106781	-45	Matrix element J(row,col)		
J10	0.707106781	45	Matrix element J(row,col)		
J01	0.707106781	45	Matrix element J(row,col)		
J11	0.707106781	-45	Matrix element J(row,col)		

1/4 Wave -45 Fast Axis

The fast axis is of the waveplate is rotated -45 degrees about the local Z-axis of the surface.

Name: Polarizer/Waveplate		izer/Waveplate	۲O ا	<
Descrij	ption:		Can	Cancel
Гуре:	ype: Polarizer/Waveplate		e Coating (Jones matrix)	lp
	Value		Description	
Туре	1/4wave -4	5 Fast Axis 💌	Type of polarization coating	
Coat	None		Coating in addition to the polarization coating	
	Amplitude	Phase(deg))	
J00	0.70710678	-45	Matrix element J(row,col)	
J10	0.70710678	-135	Matrix element J(row,col)	
J01	0.70710678	-135	Matrix element J(row,col)	
J11	0.70710678	-45	Matrix element J(row,col)	

1/2 Wave X Fast Axis

The fast axis is of the waveplate is parallel to the local X-axis of the surface.

lame:	Polari	zer/Waveplate		OK
Descri	ption:			Cancel
Гуре:	ype: Polarizer/Waveplate		Coating (Jones matrix)	Help
	Value		Description	
Туре	1/2wave X F	'ast Axis 🛛 💌	Type of polarization coating	
Coat	None		Coating in addition to the polarization coating	
	Amplitude	Phase(deg)		
J00	1	180	Matrix element J(row,col)	
J10	0	0	Matrix element J(row,col)	
J01	0	0	Matrix element J(row,col)	
J11	1	0	Matrix element J(row,col)	

1/2 Wave Y Fast Axis

The fast axis is of the waveplate is parallel to the local Y-axis of the surface.

Vame:	Polari	zer/Waveplat	te	ОК
Descrij	otion:			Cancel
Гуре:	ype: Polarizer/Waveplate		te Coating (Jones matrix)	Help
	Value		Description	
Туре	1/2wave Y F	ast Axis 📑	 Type of polarization coating 	
Coat	None		Coating in addition to the polarization coating	
	Amplitude	Phase(de	0	
J00	1	0	Matrix element J(row,col)	
J10	0	0	Matrix element J(row,col)	
J01	0	0	Matrix element J(row,col)	
J11	1	180	Matrix element J(row,col)	

1/2 Wave +45 Fast Axis

The fast axis is of the waveplate is rotated 45 degrees about the local Z-axis of the surface.

lame:	Polar	izer/Waveplate	e	OK	
Descrij	otion:			Cancel	
Type: Polarizer/Wavepla		rizer/Waveplati	e Coating (Jones matrix)	Help	
	Value		Description		
Туре	1/2wave +4	5 Fast Axis 💌	Type of polarization coating		
Coat	None		Coating in addition to the polarization coating		
	Amplitude	Phase(deg)		
J00	0	0	Matrix element J(row,col)		
J10	1	0	Matrix element J(row,col)		
J01	1	0	Matrix element J(row,col)		
J11	11 0 0 Ma		Matrix element J(row,col)		

1/2 Wave -45 Fast Axis

The fast axis is of the waveplate is rotated -45 degrees about the local Z-axis of the surface.

lame:	Pola	rizer/Waveplate		OK	
)escrij	ption:			Cancel	
Type: Polarizer/Waveplat		rizer/Waveplate	e Coating (Jones matrix)	Help	
	Value		Description		
Туре	1/2wave -4	ave -45 Fast Axis 💌 Type of polarization coating			
Coat	None		Coating in addition to the polarization coating		
	Amplitude	e Phase(deg			
JOO	0	0	Matrix element J(row,col)		
J10	1	180	Matrix element J(row,col)		
J01	1	180	Matrix element J(row,col)		
J11	0 0		Matrix element J(row,col)		

See Also ... - Edit or Create a New Sampled Coating

The following links contain details about each of the remaining coating models.

Sampled Coating

<u>Uncoated</u>

General Sampled Coating

Thin Film Layered Coating

For details about Raytrace Controls, select the following link.

Raytrace Controls

For reference information regarding Jones Matrices, select the following link.

Optical References



Chapter 10 - Scatterers

Description Visualization (example) How Do I Get There? Dialog box and Controls Application Notes Examples See Also...

Description Scatterers

The **Scatterers** folder contains the default and optional user entered scatter models that may be applied to any surface in FRED. Each model calculates the appropriate threedimensional Bidirectional Scatter Distribution Function (BSDF) based on the incident ray angles and orientation of the local surface normal. Alternate definitions of the BSDF are the Bidirectional Reflectance Distribution (BRDF) and the Bidirectional Transmission Distribution Function (BTDF).

FRED comes with three default scatter models: Black Lambertian (4% reflectivity diffuse black), White Lambertian (96% reflectivity diffuse white), and Harvey-Shack (polished surface). Additionally, parametric models for the following types of scatterers are also available in FRED: Flat Black Paint (TIS), ABg, Surface Particle (Mie), and Phong. More than one type of scatter model can be applied to a surface. Reflected and transmitted scatter components are allowed or halted per the Raytrace Controls currently applied to the surface. Every scatter surface must have at least one scatter direction, which can be set automatically, using the menu bar option Tools: Determine Scatter Importance Sampling, or manually, from the Scatter tab in the Surface dialog. Every scatter direction is applied to every scatter model assigned to the surface.

NOTE Only the coefficients for an existing scatter model can be changed. Once created, the model Type (i.e., Lambertian, TIS, Harvey-Shack, ABg, Mie, Phong) is permanent. A new scatter model must be created and assigned to geometry objects to change the scatter model type.

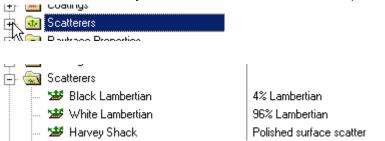
Visualization (example) Scatterers

The **Scatterers** folder is near the bottom of the tree.

Objects
🕂 🖻 Optical Sources
🕂 🚘 Geometry
🕂 🂷 Analysis Surface(s)
🕂 💼 Materials
🕂 🧰 Coatings
🕂 🚾 Scatterers
🕂 直 Raytrace Properties

How Do I Get There? Scatterers

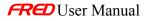
A left click on the $\textcircled{\pm}$ symbol next to the folder name will expand the tree.



A left mouse click on the \Box symbol next to an open folder will collapse the node.

Dialog Box and Controls Scatterers

A right mouse click on the **Scatterers** folder opens the following context menu.



🕂 📄 Coatings				
🖃 🔙 Scatterers				
😕 Black Lambertian	4% Lambe		Iraceable	
😕 White Lambertian	96% Lamb		Never Traceable (for trimming surfa	resì
📖 😕 Harvey Shack	Polished s		Bever maccable (for drimning same	
🕂 直 Raytrace Properties			Draw Outer Enclosing Volume	
			⊆oordinate Axes	
			⊻isualization Attributes	
			Position/Orientation	
			Parent Coordinate System	
			Scale	
		Х	Cut	Ctrl+X
			Сору	Ctrl+C
		R	Paste	Ctrl+V
			Delete (all highlighted items)	Del
			Summary Report	
			Detailed Report	
			Create a New Scatterer	
			Edit/View Scatterer	

The first option available on the context menu is a 'Summary Report.'

Summary Report
Create a New Scatterer
Edit/View Scatterer

When this option is selected, FRED prints a list the Scatterers in the model and the Description of each.

SCATTER SPEC	CIFICATIONS:	
Black Lambert	tian	
	Description:	4% Lambertian
White Lamber	tian	
	Description:	96% Lambertian
Harvey Shack		
	Description:	Polished surface scatter
		1

The second option available on the right click menu is a 'Detailed Report.'



When this option is selected, FRED prints a detailed summary of all of the existing scatter model properties.

<u>Black Lambertian</u>	
Scatter Type:	Lambertian
Description:	4% Lambertian
Reflectivity:	0.04
White Lambertian	
Scatter Type:	Lambertian
Description:	96% Lambertian
Reflectivity:	0.96
Harvey Shack	
Scatter Type:	Harvey Shack
Description:	Polished surface scatte
BSDF at B-BO:	0.1
Slope:	-1.5

The third option available is to 'Create a New Scatterer...'



Selecting this option opens the Scatter Dialog. This is just one of four ways to access this dialog.

🕻 Scatter		<u>?</u> ×
Name:	Scatter 1	OK
Description:		Cancel
Туре:	Lambertian (equal scatter in all directions)	Help
Vali	رو المعدد المعند الم	

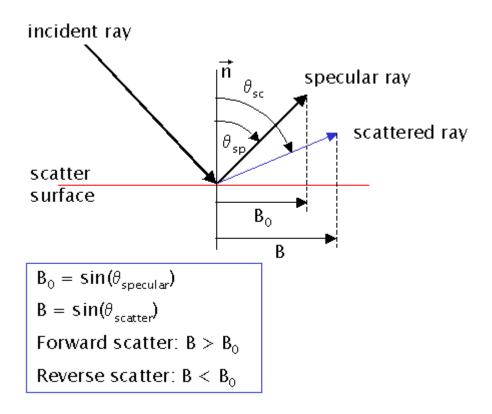
Application Notes Scatterers

- Definitions:
 - BSDF Bidirectional Scatter Distribution Function = Brightness (L) / Incident Irradiance (E)

- Units are inverse steradians (sr⁻¹)
- Defined over a hemisphere = 2π steradians
- BRDF Bidirectional Reflectance Distribution Function BSDF for reflected scatter
- BTDF Bidirectional Transmission Distribution Function BSDF for transmitted scatter
- Total Integrated Scatter (TIS) total scattered power from a surface divided by the incident power. It is an integral of the BSDF carried out over the hemisphere.
 - TIS is related to RMS surface roughness by the following expression

$$TTS = \left(\frac{2\pi(\Delta n)\sigma_{rms}}{\lambda}\right)^2$$

- Δn = change in refractive index change across the surface boundary. Note: Δn = -2 n_0 for reflected scatter
- $\sigma_{\rm rms}$ = RMS surface roughness
- λ = wavelength of incident light
- Valid only when $\sigma_{rms} \ll \lambda$
- Projected solid angle (PSA) projected area of a surface divided by the distance squared
 - PSA for a hemisphere = π
 - PSA for a tilted plane = $A^*\cos(\theta)/d^2$
- Lambertian surface any surface with equal scatter (brightness) in all directions.
 - BSDF_{lambertian} = TIS/π
- Plane of incidence the plane containing both the incident and specular rays. The 2-dimensional representation of the BSDF commonly shown in the plane of incidence as a function of B-B₀ or log(|B-B₀|).
 - B₀ = sine of the angle from the surface normal to the specular ray in the plane of incidence
 - B = sine of the angle from the surface normal to the scattered ray in the plane of incidence
 - In the case of forward scatter \rightarrow B > B₀
 - In the case of reverse or back scatter \rightarrow B < B₀



- Conservation of energy:
 - For hemispherical scatter, the product of the BSDF and the PSA must be less than or equal to one.
 - The total power contained in the incident beam is equal to the sum of the reflected, transmitted, scattered, and absorbed components:

$$P_{incident} = R_{specular} + R_{scatter} + T_{specular} + T_{scatter} + A$$

- Coating specifications on a surface apply only to specular rays.
- Allowable scatter directions are determined by the **Raytrace Controls**.



Examples Scatterers

Scatter Dia	logs: <u>Lar</u>	<u>nbertian</u>				
🕻 Scatter			<u>? ×</u>			
Name:	Scatter	1	OK			
Description:			Cancel			
Туре:	Lambert	ian (equal scatter in all directions)	▼ Help			
Va	alue	Description				
Refl 0	.04	Reflectivity (0>1) 0=black absorbing, 1=white reflecting				
Additional	data On Reflectio	n 🗖 Apply On Transmission 🔽	Halt Incident Ray			

Scatter Dialogs: <u>Harvey-Shack</u>

Scatt	er			?)
Name:	Scatte	er 1		OK
Descript	ion:			Cancel
Туре:	Harve	y-Shack (polished surface scatter)		Help
		BSDF(B,B0) = b0((1+(B-B0)^2/(L^2))^(S/2)	<u> </u>	
	Value	Description		
b0	0.1	Value of BRDF at B=B0 (0.001 <b0<10)< td=""><td></td><td></td></b0<10)<>		
L	0.01	Knee of the curve (0.001 <l<0.2)< td=""><td></td><td></td></l<0.2)<>		
s	-1.5	Slope for large B-B0 (-3 < S < -0.5)		
	onal data oply On Reflec	tion 🔲 Apply On Transmission	🔽 Halt Inc	ident Ray

Scatter	Dial	اممع	A Da
Scatter	Dia	lugs.	ADg.

🕻 Scatte	er		? ×
Name:	OK		
Descripti	on:		Cancel
Туре:	ABgis	catter (polished surface scatter)	Help
		BSDF(B,B0) = Acoef/(Bcoef+(B-B0)^G)	
	Value	Description	
Acoef	0.0025	Acoef	
Bcoef	0.001	Bcoef	
G	1.8	Slope for large B-B0	
	nal data ply On Reflec	tion 🗖 Apply On Transmission 🔽 Halt I	ncident Ray

Scatter Dialogs: Phong

🕻 Scatt	er		? >
Name:	Scatte	r 1	OK
Description:			Cancel
Туре:	Phone	; scatter (Cos^n from specular)	Help
		BSDF = d*T^n (T is cosine of angle between specula	r and scatter
	Value	Description	
d	0.1	d (0 <d<1)< td=""><td></td></d<1)<>	
n	16	n (1 <n)< td=""><td></td></n)<>	
	onal data oply On Reflec	tion 🗖 Apply On Transmission 🔽 Halt Ir	ncident Ray

Scatter Dialogs: Flat Black Paint

🕻 Scatt	er				? ×
Name:	5	Scatter 1			OK
Descrip	tion:				Cancel
Туре:		Flat Black Pa	aint		Help
	Value	Des	cription	N	
TIS	0.02	Refle	ectivity (0>1): 0=black absorbir	ig, 1=white reflecting	
	onal data pply On F		Apply On Transmission	🔽 Halt Ind	cident Ray

Scatter Dialogs: Surface Particle (Mie)

		?	
Scatter 1	OK		
		Cancel	
Surface Particle (Mie) Scatter	Help	
Value	Description		
0.5	Wavelength (um)		
1.5	Real part of particle refractive inde	x	
0	Imag part of particle refractive inde	ex	
Uniform	Particle density function		
400	Maximum particle diameter (um)		
1	Minimum particle diameter (um)		
0.1	Particle density (# per square um)		
	Surface Particle (Mie Value 0.5 1.5 0 Uniform 400 1	Surface Particle (Mie) Scatter Value Description 0.5 Wavelength (um) 1.5 Real part of particle refractive inde 0 Imag part of particle refractive inde Uniform Particle density function 400 Maximum particle diameter (um) 1 Minimum particle diameter (um)	

Scatter dialogs: Tabulated BSDF

Scatter			? >	
Name:	Scatter 1		ОК	
Description:			Cancel	
Гуре:	Tabulated BSDF (I	Reciprocity-obeying sampled BSDF)	Help	
	Value	Description		
File		Last accessed file		
Ang Thresh	0.001	Angular threshold (in radians) for distinct data points		
Dim	● Constant ● Varies w/angle	Dimensionality (constant for no spec angle variation)		
Min BSDF	0	Minimum BSDF data threshold		
Max BSDF	10000000000	Maximum BSDF data threshold		
	TIS	Integration Parameters (advanced)		
Main Samps	200	# of TIS integration samples across the dir cos u	nit circle	
Spec Samps	200	# of TIS integration samples across the specular subregion		
Spec Size	10	Size of specular subregion (semi-ape in degrees). Enter 0.0 to s	
•			F	
Additional da		Apply On Transmission 🔽 Halt In	cident Ray	

Scatter dialogs: Diffuse Polynomial

🔆 Scatt	er:		? ×		
Name:		Scatter 1	OK		
Descrip	tion:		Cancel		
Туре:		Diffuse Polynomial	Help		
Term	Value	Description			
n	0	maximum k counter (n>=0)			
m	0	diffuse component counter (m any positive or negative integer)			
1	0	maximum j counter (Lorentzian component)	maximum j counter (Lorentzian component)		
ľ	0	minimum j counter (Lorentzian component)			
d	0	Lorentzian coefficient (log [specular peak])			
0	0	C(0,0,0) diffuse			
	onal dai pply On	a Reflection 🗖 Apply On Transmission 🔽 Halt Inc	cident Ray		

	er		?		
Name:	ſ	Scatter 1	OK		
Description:			Cancel		
Гуре:	[Diffuse Binomial (plane symmetric polynomial)	Help		
Term	Value	Description			
n	0	maximum k counter (n>=0)			
m	0	diffuse component counter (m any positive or negative integer)			
I	0	maximum j counter (Lorentzian component)			
ľ	0	minimum j counter (Lorentzian component)			
d	0	Lorentzian coefficient (log [specular peak])			
0	0	C(0,0) diffuse			

Scatter dialogs: Diffuse Binomial

🕻 Scatter	? ×
Name: Scatter 1	OK
Description:	Cancel
Type: Scripted (BSDF given by user-script can also modify waveler	Help
Compile	
'Function: BSDF scatter function. 'Input: (g_Xinc, g_Yinc, g_Zinc) incident (g_Xspec, g_Yspec, g_Zspec) specula (g_Xscat, g_Yscat, g_Zscat) scatter g_ran is a uniform random number b Output: g_bsdf is the BSDF value that you c 'In/Out: g_w is the wavelength in microns. you must supply an output value if	r direct: directic etween 0 compute. If using
<pre>' Example: Harvey-Shack smooth surface scatter B0=0.1 'BSDF in specular direction S=-1.5 'Slope in log-log space L=0.01 'Sine of angle at shoulder delA=g_Xscat-g_Xspec delB=g_Yscat-g_Yspec arg=1.0+(delA*delA+delB*delB)/(L*L) g_bsdf=B0*arg^(S/2)</pre>	
	▶
Additional data Additional data Image: Apply On Reflection Image: Apply On Reflection	ncident Ray

Scatter dialogs: Scripted Scatter

Scatter dialogs: Tabulated PSD

atter 1		ОК
		Cancel
bulated Power Spectral	Density (PSD)	Help
e	Description (right mouse-click for pe	opup menu)
•	Reference wavelength (um) for TIS calcul	lation
	Refractive index difference across the su	irface (2 for ref
	Surface reflectance or transmission	
	Last accessed file	
	Number of data points read from file	
	Min spatial frequency (1/(um*um))	
	Max spatial frequency (1/(um*um))	
	PSD at min spatial frequency	
	PSD at max spatial frequency	
		•
	e	Reference wavelength (um) for TIS calcu Refractive index difference across the su Surface reflectance or transmission Last accessed file Number of data points read from file Min spatial frequency (1/(um*um)) Max spatial frequency (1/(um*um)) PSD at min spatial frequency

Scatter dialogs: K-correlation

🔆 Scatter			? ×
Name:	Scatter	1	OK
Description			Cancel
Туре:	K Correl	ation (K Correlation Power Spectral Density)	Help
	Value	Description	
Wavl(ref)	0.6328	Reference wavelength (um)	
Detta N	2	Refractive index difference across the surface (2 for refl	ection)
Refl/Tran	1	Surface reflectance or transmission	
Sigma	0.0015	RMS surf rough (um) measured at freqs from 0 to 1 //Vavl(ref)
в	200	2*pi times typical surface wavelength (um)	
S	2	Slope of the PSD at large spatial frequencies	
Additiona	l data • On Reflectio	on 🧖 Apply On Transmission 🔽 Halt In	cident Ray



See Also... Scatterers

The following links contain details about each of the scatter models. Lambertian for diffuse scatter Harvey-Shack for polished surface scatter ABg for polished surface scatter Phong scatter – cosⁿ from specular Flat Black Paint – specify Total Integrated Scatter (TIS) Surface Particle (Mie) – for particulate contamination Tabulated BSDF - measured BSDF Diffuse Polynomial - for painted surfaces Diffuse Binomial - for painted surfaces Scripted Scatter - general scatter model (allows ray wavelengths to be changed) Tabulated PSD - for measured power spectral density K-correlation -

Applying Scatter Properties

Description How Do I Get There? Dialog box and Controls

Description Applying Scatter Properties

This dialog page allows the user to select the **Scatter Properties** associated with a surface.

This dialog has two sections: **Scatter Properties** and **Scatter Ray Directions Properties**. Making a surface scatter requires both assigning **Scatter Properties** in the first section and defining a solid angle to scatter rays in the second section.

In the first section, one or more Scatter Properties currently defined in the FRED document can be assigned to the surface. Highlighting the desired property and pressing the assign button will assign **Scatter Properties** to the surface. The **Scatter Properties** settings can be edited/viewed and new **Scatter Properties** can be defined from this dialog. Please see the help for the **Create New Scatterer...** dialog for more information on how to edit and add new **Scatter Properties**.

Assigned Scatter Properties:		Available Scatter Prop	perties:
	< Assign	Name	Description
		Black Lambertian	4% Lambertia
	> Remove	White Lambertian	96% Lamberti
		Harvey Shack	Polished surfa
	Edit/View		
	Create New		

TIP More than one scatter property can be added to a surface.

Pressing the button, Add New..., will open a dialog for setting the scatter solid angle that rays scattered off this surface into. The solid angle may be described in a number of ways including the example below where 25 rays have been scattered into a 0.5 degree cone angle around the specular reflection.

Pressing OK will add this solid angle specification to the **Scattered Direction Region(s) of Interest** section.

Scatter Direction Region(s) of Interest	
✓ImpSamp 1	Remove
	Edit∕View
	Add New

Applying these **Scatter Properties** to the primary mirror of the Houghton sample and tracing rays will yield results like those shown below.



The important thing to note about the power of the rays scattered into the selected small solid angle is that they have same power as they would if they were scattered into a full hemisphere (2 steradians) and they happened to fall into this selected small solid angle. By selecting a smaller solid angle, the same radiometric transfer is achieved but with much better sampling of the solid

angle(s) of interest. The radiometric transfer is no longer valid if any of the solid angles overlap. In the overlap areas, the radiometric transfer would be approximately twice the expected value because in the overlap region rays for both selected solid angles carry the correct flux for that region of the total solid angle.

WARNING The radiometric transfer is no longer valid if any of the selected solid angles overlap.

How Do I Get There? Applying Scatter Properties

This page is in the <u>Create New Surface...</u> and Edit/View Surface... dialogs.



Dialog Box and Controls Applying Scatter Properties

(² (FRED1 *) Create a New Surface as Child of: "Elem 1"				
SURFACE Aperture Location/Orientation Scatter Visualization Glue Grating		ting/RayControl Modifiers	OK Cancel	
Note: Checked items are active, unchecked items are ignored Scatter Assigned Scatter Properties:	during the raytrace Available Scatter Propert	ies:	Apply Help	
Assigned Scatter Properties: Available Scatter Properties: Name Description Black Lambertian 4% Lambertian White Lambertian 96% Lambertian Harvey Shack Polished surfact Create New				
		Remove Edit/View Add New		

Control	Inputs	Defaults				
Scatter	Scatter					
Assigned Scatter Properties						
Assign	Assigns a highlighted Scatter Property in the Available Scatter Properties list to the surface.					
Remove	Removes a highlighted Scatter Property in the Assigned Scatter Properties list from the surface.					
Available Scatter properties:	List of the available defined Scatter Properties . The Scatter Properties listed here are the same as those listed in the Tree . The user may add additional Scatter Properties in this dialog or via the Tree directly using the right click pop-up menu.	Black Lambertian, White Lambertian, and a polished surface Harvey Shack Model.				

Edit/View	Edit/View existing Available Scatter Properties.	
Create New	Create new Scatter Properties and add to Available Scatter Properties list.	
Scatter Direction	Region(s) of Interest	
List	List of the scatter directions or regions assigned to this surface.	blank
Remove	Removes a highlighted scatterdesignation in the Scatter DirectionRegion of Interest list from the surface.	
Edit/View	Edit/View existing Scatter Direction Region of Interest.	
Add New	Add new Scatter Properties and add to Scatter Direction Region of Interest list.	
ОК	Accept Scatter changes and close dialog box.	
Cancel	Discard Scatter changes and close dialog box.	
Apply	Apply Scatter changes and keep dialog box open.	
Help	Access this Help page.	



Impo	ortan	ce Sampling Speci	ications (for Scat	ter)	? ×
Name:		ImpSamp 1			OK
Descrip	tion:				Cancel
Туре:		Scatter rays into a gi	en direction	•	Help
	Valu	e	Description		
Angle	90		Semi-Angle (deg)	of the solid angle	cone
Х	0		X component of d	irection vector	
Y	0		Y component of direction vector		
Z	1	Z component of direction vector			
Entity	y Global Coordinate Syste 💌 Coordinate system of the direction vector				
Other Data Active Reverse Ray Directions Number of Scatter Rays: 10 Solid Angle Scale Factor: 1 Fractional Hole in Solid Angle: 0					

Control	Inputs	Defaults
Name	Name of this scattering solid angle to be assigned to this surface	ImpSamp1
Description	Informative description of Importance Sampling Specification	Blank
Туре	 Drop down menu of the available solid angle descriptions. Available options include: 1. Scatter rays through a close curve 2. Scatter rays into given direction 3. Scatter rays toward an entity 4. Scatter rays toward a point 5. Scatter rays into the specular direction 6. Scatter rays toward an ellipsoidal volume NOTE: Each of these options is described in more detail below. 	Scatter rays into a given direction
Other Data		
Number of scatter rays	Sets the number of rays to be scattered into this solid angle per incident ray.	10
Solid angle scale factor	Sets the solid angle scale factor. This is useful when scattering towards an entity.	1
Reverse Ray Directions	This will reverse the direction of the scatter rays at the time of scatter event.	Not Selected

Fractional hole in Solid Angle	Allows a central hole in the solid angle to be defined, in effect making an annular solid angle region.	0
ОК	Accept Importance Sampling Specifications changes and close dialog box.	
Cancel	Discard Importance Sampling Specifications changes and close dialog box.	
Help	Access this Help page.	

Scatter rays into a given direction

Гуре:	Scatter rays into a giv	en direction 🗾 Help
	Value	Description
Angle	90	Semi-Angle (deg) of the solid angle cone
Х	0	X component of direction vector
Y	0	Y component of direction vector
Z	1	Z component of direction vector
Entity	Global Coordinate Syste 💌	Coordinate system of the direction vector

Control	Control Inputs	
Angle	The angle around the direction vector defined.	90
X	X component of the direction cosine.	0
Y	Y component of the direction cosine.	0
Ζ	Z component of the direction cosine, note that the relationship between these angles is: $X^2 + Y^2 + Z^2 = 1$.	1
Entity	Coordinate system of the direction vector.	Global Coordinate system

Scatter rays through a closed curve

Туре:	Scatter rays through a closed curve	Help	
	Selected Curve		
Curve			
Contro	ol Inputs	Defaults	
contro			
Curve	Pull down menu of all the curves defined in the FRED document. Only the closed curves will be listed in the pull down menu.	ed Blank	

Scatter rays toward an entity

Type: Scatter rays toward an entity Help				
Entity	Entity Houghton corrector (corrector lens)			
Contr	Control Inputs Defaults			
Entity		Pull down menu of all the objects defined in the FRED document.	Blank	

Scatter rays toward a point

Гуре:	Scatter rays toward a	point Help
	Value	Description
Angle	90	Semi-Angle (deg) of the solid angle cone
Х	0	X component of position vector
Y	0	Y component of position vector
Z	1	Z component of position vector
Entity	Global Coordinate Syste 📼	Coordinate system of the position vector

Control	Inputs	Defaults
Angle	The angle around the direction vector defined.	90
X	X component of the position vector to the point.	0
Y	Y component of the position vector to the point.	0
Ζ	Z component of the position vector to the point.	1
Entity	Coordinate system of the direction vector.	Global Coordinate system

Scatter rays into the specular direction

Descript Туре:	ion. Scatte	p	
	Value	Description	
Angle	45	Semi-Angle (deg) of the solid angle cone	
Contro	ol	Inputs	Defaults
Angle		Semi-angle around the specular direction of the reflected or refracted parent ray.	45

Scatter rays towards an ellipsoidal volume

Description.	1			Lanu	
Туре:	Scatter	ays toward	an ellipsoidal volu	ume 💌 Hel	P
	x	Y	Z	Description	
Center	0	0	1	Center of the ellipsoid	
X-dir	1	0	0	Vector along ellipsoid's X-	axis
Y-dir	0	1	0	Vector along ellipsoid's Y-	axis
Semi-Apes	0.1	0.1	0.1	Semi-apertures of the ellip	soid
Entity	Global Co	oordinate S	ystem	Coordinate system of the e	ellipsoi
	-			74	
Control	Control Inputs				Defaults
Center			X, Y, and Z center of the	coordinates of the ellipsoid.	0,0,1

X-dir	Vector along the ellipsoid's X-axis.	1,0,0
Y-dir	Vector along the ellipsoid's Y-axis.	0,1,0
Semi-Apes	Semi-apertures of the ellipsoid in the X, Y, and Z directions.	0.1, 0.1, 0.1
Entity	Coordinate system of the ellipsoid coordinates.	Global Coordinate system



Edit/Create New Scatter Model - ABg

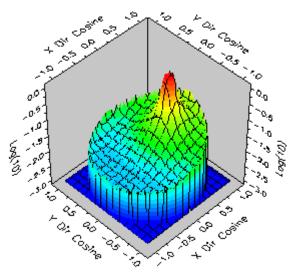
Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes Examples See Also...

Description Edit/Create New Scatter Model - ABg

Like the <u>Harvey-Shack</u> scatter model, the ABg scatter model describes a smooth surface BSDF. It has a logarithmic falloff from specular, with a slope parameter given by G. It can apply on both transmission and reflection if the Raytrace Controls allow it.

Visualization (example) Edit/Create New Scatter Model - ABg

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The ABg scatter parameters are Acoef = .0025, Bcoef = .001, G = 1.8. The specular angle is 30 degrees.





_

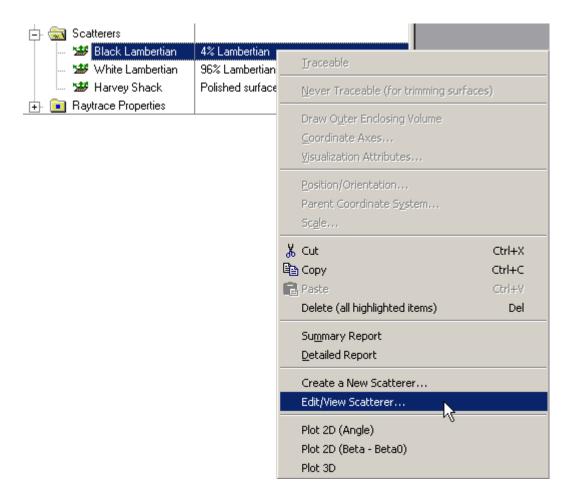
How Do I Get There? Edit/Create New Scatter Model - ABg

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'

Objects			Description	
	Coatings			
· 🕂 🐱	Scatterers Raytrace Pr	Traceable		
		Never Trace	able (for trimming sur	faces)
		Draw Outer F Coordinate A Visualization		
		Position/Orie Parent Coord Sc <u>a</u> le	ntation linate S <u>y</u> stem	
		X Cut		Ctrl+X
		Copy		Ctrl+C
		Delete (all hig	ghlighted items)	⊂trl+∀ Del
		Su <u>m</u> mary Rej <u>D</u> etailed Rep		
		Create a Nev Edit/View Sca	v Scatterer	J
		Plot 2D (Ang Plot 2D (Beta Plot 3D		

2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option 'Edit/View Scatterer...'.



3. Expand the Scatterers folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE	Aperture	Location	/Orientation	Materials	Coating/RayControl
Scatter		Visualization	1	Glue	Grating
Scatter Assigned Scatte	er Properties:			Available Scatte	er Properties:
Name		ription <	- Assign	Name	Description
				Black Lamberti	an 4% Lambertian
		3	> Remove	White Lamberti	
				Harvey Shack	Polished surfac
			Edit/View		
•		F	Create New		

When the Scatter dialog has been opened, select ABg scatter from the list of available models.



🕻 Scatter		<u>?×</u>
Name:	Scatter 1	ОК
Description:		Cancel
Туре:	ABg scatter (polished surface scatter)	Help

After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls Edit/Create New Scatter Model - ABg

	er		? ×
Name:	Scatte	er 1	ОК
Descrip	tion:		Cancel
Туре:	ABg s	scatter (polished surface scatter)	Help
	BSDF(B,B0) = Acoef/(Bcoef+(B-B0)^G)		
	Value	Description	
Acoef	0.0025	Acoef	
Bcoef	0.001	Bcoef	
G	1.8	Slope for large B-B0	
	onal data		
		tion Apply On Transmission Halt Inc	
		tion C Apply On Transmission I Halt Inc	ident Ray
ntrol		<u>Inputs</u>	<u>Defaults</u>
ntrol me		Inputs Name of the model (required). Alpha-numeric text describing the model	Defaults Scatter n

Bcoef

Value of the B coefficient.

.001

G	Slope of the BSDF at large B-B0.	1.8
	Additional data	
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

<u>Script Commands</u> Edit/Create New Scatter Model - ABg

Commands

Subroutines
 AddAbgScatter
 SetAbgScatter
 GetAbgScatter

YourScatter IndexInScatterList, YourScatter IndexInScatterList, YourScatter

• Functions None

Associated Data Type

- Type Name T_ABGSCATTER
- Type Members

Name - (string) holds the name of the model. Default is an empty string.Description - (string) holds the description of the model. Default is an empty string.

Acoef - (double) The value of the A coefficient. Default is 0.

Bcoef - (double) The value of the B coefficient. Default is 0.

G - (double) The value of the BSDF slope at large B-B0. Default is 0.

ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False.

ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False.

HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

This example adds an ABg Scatter model to the FRED file associated with this script.

```
Dim s As T_ABGSCATTER
s.Name = "Example ABg Scatter"
s.Description = "Sample from FRED documentation"
s.Acoef = 0.0002
s.Bcoef = 0.002
s.G = 3.0
s.ApplyRefl = true
s.ApplyTrans = true
s.HaltIncident = true
AddAbgScatter s
```

• This example sets the fourth Scatter model's name to "Example ABg Scatter 2", as long as that scatter model is an ABg scatter model. It fails if it is any other scatter type.

```
Dim s As T_ABGSCATTER
s.Name = "Example ABg Scatter 2"
SetAbgScatter4, s
```

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is an ABg scatter model. It fails if it is any other scatter type.

Dim s As T_ABGSCATTER GetAbgScatter4, s Print s.Name

Application Notes Edit/Create New Scatter Model - ABg

0

 The Bidirectional Scatter Distribution Function (BSDF) for the ABg model is defined as

$$BSDF = \frac{Acoef}{Rcoef + (|R - R0|)^G}$$

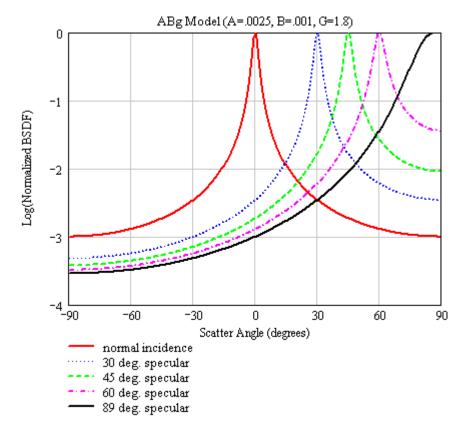
- The ABg model is linear shift invariant, which means that the BSDF depends only on the difference between the sine of the specular angle (B0) and the sine of the scattered angle (B). B and B0 are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction (B-B0 = 0) is Acoef/Bcoef multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The ABg model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

Examples Edit/Create New Scatter Model - ABg

The following examples show a series of line plots of the log(normalized ABg BSDF) as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees.

Example 1

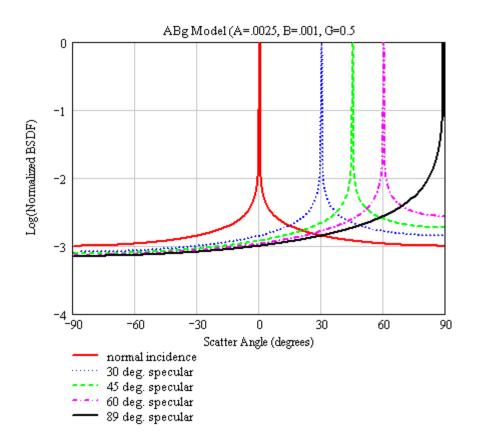
The ABg scatter parameters for the following plot are Acoef = .0025, Bcoef = .001, G = 1.8.



Example 2

The ABg scatter parameters for the following plot are Acoef = .0025, Bcoef = .001, G = 0.5, which has the effect of narrowing the distribution function so that the bulk of the scattered light more closely follows the specular path. A small value a G is more appropriate for a smooth specular surface.

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See Also.... Edit/Create New Scatter Model - ABg

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>Harvey-Shack</u> – for polished surface scatter <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Phong</u> scatter – cosⁿ from specular <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>Tabulated PSD</u> – measured PSD data <u>K-Correlation</u> – analytic PSD

Edit/Create New Scatter Model - Flat Black Paint

Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes See Also...

Description Edit/Create New Scatter Model - Flat Black Paint

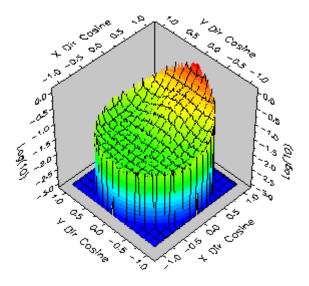
The generic Flat Black Paint BSDF is a parametric scatter model that has only one user input: the Total Integrated Scatter (TIS) at normal incidence. FRED takes the TIS value and scales the BSDF accordingly. The BSDF used in this model is a complex 3 dimensional polynomial fit to the scatter distribution from a flat surface treated with a generic flat black paint. It is near Lambertian at normal incidence. At large angles of incidence there is significant scatter in the (forward) specular direction, which is a characteristic of all flat black paints.

WARNING The TIS entry is for normal incidence. If this entry is greater than 0.25, the scattered power at high angles of incidence can exceed the incident power, which violates conservation of energy. Use with caution.

Visualization (example) Edit/Create New Scatter Model - Flat Black Paint

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Flat Black Paint scatter parameters are TIS = 0.02. The specular angle is 30 degrees.

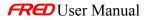




How Do I Get There? Edit/Create New Scatter Model - Flat Black Paint

There are four ways to open a Scatter model dialog.

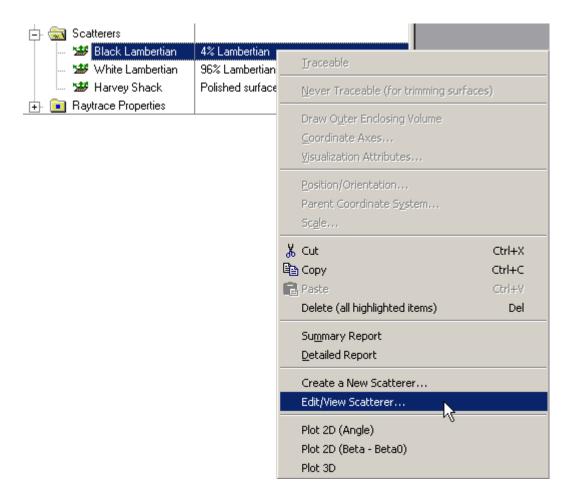
1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'



Objects		Description	
Optical Sou Optical Sou Optical Sou Analysis Sur Materials One Coatings			
+ 🔂 Scatterers	Iraceable		
	Never Trace	able (for trimming surf	aces)
	Draw Outer Coordinate A Visualization		
	Position/Orie Parent Coore Sc <u>a</u> le	ntation dinate S <u>v</u> stem	
	んんしょう Cut 自 Copy		Ctrl+X Ctrl+C
	Paste		⊂trl+∀ Del
	Summary Re		Dei
	Create a New Edit/View Sci	w Scatterer	ŝ
	Plot 2D (Ang Plot 2D (Beta Plot 3D		

2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.





3. Expand the Scatterers folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

Visualiza erties: Description		Glue	Grating Properties:
		Available Scatter	Properties:
	K Assign	Name	Description
		Black Lambertian	n 4% Lambertian
	> Remove	White Lambertian	n 96% Lambertia
		Harvey Shack	Polished surfac
		Edit View.	Edit View

When the Scatter dialog has been opened, select Flat Black Paint from the list of available models.



🕻 Scatter		<u>? ×</u>
Name:	Scatter 1	ОК
Description:		Cancel
Туре:	Flat Black Paint	Help

After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls

Edit/Create New Scatter Model - Flat Black Paint

Name:	Scat	ter 1	OK
Descript	tion:		Cancel
Туре:	Flat	3lack Paint	Help
	Value	Description	<u> </u>
	value	Description	
TIS	0.02	Reflectivity (0>1): 0=black absorbing, 1=white reflect	ing
			ing

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
<u>Name</u>	Name of the model (required).	Scatter <i>n</i>
Description	Alpha-numeric text describing the model (optional).	blank
Туре	Choose Flat Black Paint from the pull down menu.	Lambertian
TIS	Value of the Total Integrated Scatter (TIS) between 0 and 1.	0.02

Additional data				
Apply on Reflection	Checked			
Apply on Transmission	Apply the scatter model on transmission.	Unchecked		
Halt Incident Ray	Halt the incident ray.	Checked		
OK	Accept model or changes and close dialog box.			
Cancel	Discard model or changes and close dialog box.			
Help	Access this Help page.			

<u>Script Commands</u> Edit/Create New Scatter Model - Flat Black Paint

Commands

Subroutines
 AddBlackPaint
 SetBlackPaint
 GetBlackPaint

YourScatter IndexInScatterList, YourScatter IndexInScatterList, YourScatter

• Functions None

Associated Data Type

- Type Name T_BLACKPAINT
- Type Members

Name - (string) holds the name of the mode. Default is an empty string.
 Description - (string) holds the description of the model. Default is an empty string.

Refl - (double) The value of the Normal Incidence Reflectivity coefficient. Default is 0.

Vd - (double) holds the ABBE number at the 'd' wavelength. Default is 0.

ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False.

ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False. *HaltIncident* - (Boolean) Halts the incident ray. Default is False.

Examples

• This example adds a Black Paint Scatter model to the FRED file associated with this script.

Dim s As T_BLACKPAINT s.Name = "Black Paint Example" s.Description = "Sample from FRED documentation" s.Refl = 0.02 s.ApplyRefl = true s.ApplyTrans = true s.HaltIncident = true AddBlackPaint s

• This example sets the fourth Scatter model's name to "Black Paint Example 2", as long as that scatter model is a Black Paint model. It fails if it is any other scatter type.

```
Dim s As T_BLACKPAINT
s.Name = "Black Paint Example 2"
SetBlackPaint4, s
```

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Black Paint model. It fails if it is any other scatter type.

```
Dim s As T_BLACKPAINT
GetBlackPaint4, s
Print s.Name
```

Application Notes Edit/Create New Scatter Model - Flat Black Paint

- This model is intended to represent a generic black paint.
- The TIS entry is measured at normal incidence. FRED uses this entry as an offset to shift the magnitude of the BSDF up and down, but the functional form of the distribution is unchanged.
- The TIS scatter model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

See Also.... Edit/Create New Scatter Model - Flat Black Paint

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>Harvey-Shack</u> – for polished surface scatter <u>ABg</u> – for polished surface scatter <u>Phong</u> scatter – cosⁿ from specular <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>Tabulated PSD</u> – measured PSD data K-Correlation - analytic PSD

Edit/Create New Scatter Model - Harvey-Shack

Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes Examples See Also...

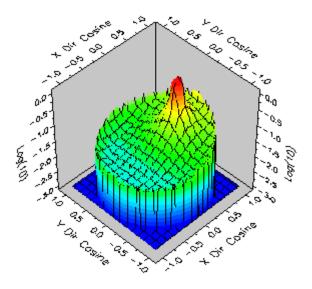
Description Edit/Create New Scatter Model - Harvey-Shack

The Harvey-Shack scatter model is generally applied to smooth optical surfaces. This model uses a rollover specification (L) that transitions the BSDF to a constant value (b0) at near-specular angles. Large angle scatter is linear in log space with a slope parameter S, which typically lies between -1 and -2.5. The model can be applied in both transmission and reflection if the Raytrace Controls allow it.

Visualization (example) Edit/Create New Scatter Model - Harvey-Shack

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -1.5. The specular angle is 30 degrees.

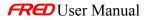




How Do I Get There? Edit/Create New Scatter Model - Harvey-Shack

There are four ways to open a Scatter model dialog.

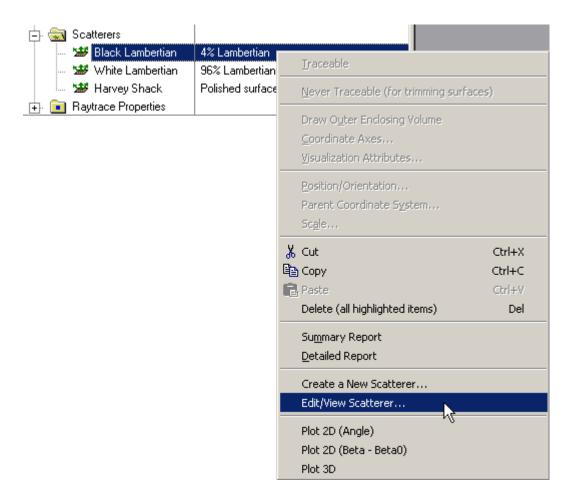
1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'



Objects		Description	
Optical Sou Optical Sou Optical Sou Analysis Sur Materials One Coatings			
+ 🔂 Scatterers	Iraceable		
	Never Trace	able (for trimming surf	aces)
	Draw Outer Coordinate A Visualization		
	Position/Orie Parent Coore Sc <u>a</u> le	ntation dinate S <u>v</u> stem	
	Cut 聞 Copy		Ctrl+X Ctrl+C
	Paste		⊂trl+∀ Del
	Summary Re		Dei
	Create a Nev Edit/View Sci	w Scatterer	ŝ
	Plot 2D (Ang Plot 2D (Beta Plot 3D		

2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.





3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE	Aperture	Loca	ation/Orientat	ion	Materials	Co	ating/RayControl
Scatter		Visualiza	tion		Glue		Grating
Scatter Assigned Scatt	ter Properties:				Available Scatte	er Prope	erties:
Name	Desc	ription	< Assign		Name		Description
				-	Black Lamberti	an	4% Lambertian
			> Remov	9	White Lamberti	ian	96% Lambertia
				_	Harvey Shack		Polished surfac
		Þ	E dit. Create	View New			
C							

When the Scatter dialog has been opened, select Harvey-Shack scatter from the list of available models.



	? ×
Scatter 1	ОК
	Cancel
Harvey-Shack (polished surface scatter)	Help
	Scatter 1 Harvey-Shack (polished surface scatter)

After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed

Dialog Box and Controls Edit/Create New Scatter Model - Harvey-Shack

.

	🕻 Scati	ter		? ×
	Name: Scatter 1			ОК
	Description:			Cancel
	Type: Harvey-Shack (polished surface scatter)			Help
			BSDF(B,B0) = b0((1+(B-B0)^2/(L^2))^(S/2)	
		Value	Description	
	bO	0.1	Value of BRDF at B=B0 (0.001 <b0<10)< td=""><td></td></b0<10)<>	
	L	0.01	Knee of the curve (0.001 <l<0.2)< td=""><td></td></l<0.2)<>	
	S	-1.5	Slope for large B-B0 (-3 < S < -0.5)	
	 ⊢Additi	onal data		
		onal data pply On Reflec	tion 🗖 Apply On Transmission 🔽 Halt Incid	dent Ray
ontr			tion	dent Ray
`ontr				
<u>ame</u>			<u>Inputs</u>	<u>Defaults</u>
l <u>ame</u>			Inputs Name of the model (required). Alpha-numeric text describing the model	Defaults Scatter n

L	Value of the near specular BSDF rollover point (L=B-B0).	
S	Slope of the BSDF at large B-B0.	-1.5
	Additional data	
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands Edit/Create New Scatter Model - Harvey-Shack

Commands

•	Subroutines		
	AddHarveyShackScatter	YourScatter	
	SetHarveyShackScatter	IndexInScatterList,	YourScatter
	GetHarveyShackScatter	IndexInScatterList,	YourScatter

• Functions None

Associated Data Type

- Type Name T_HARVEYSHACKSCATTER
- Type Members

Name - (string) Holds the name of the model. Default is an empty string.

Description - (string) Holds the description of the model. Default is an empty string.

 $\it BO$ - (double) Value of the BRDF when B=B0. Default is 0.

L - (double) Knee of the curve. Default is 0.

S- (double) Slope for large B-B0. Default is 0.

ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False.

ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False.

HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

• This example adds a Harvey-Shack Scatter model to the FRED file associated with this script.

Dim s As T_HARVEYSHACKSCATTER s.Name = Harvey-Shack Example" s.Description = "Sample from FRED documentation" s.b0 = 0.2 s.L = 0.02 s.S = -2 s.ApplyRefl = true s.ApplyTrans = true s.HaltIncident = true AddHarveyShackScatter s

 This example sets the fourth Scatter model's name to "Harvey-Shack Example 2", as long as that scatter model is a Harvey-Shack model. It fails if it is any other scatter type.

Dim s As T_HARVEYSHACKSCATTER s.Name = "Harvey-Shack Example 2" SetLambertianScatter4, s

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Harvey-Shack model. It fails if it is any other scatter type.

```
Dim s As T_HARVEYSHACKSCATTER
GetHarveyShackScatter4, s
Print s.Name
```

Application Notes Edit/Create New Scatter Model - Harvey-Shack

• The Bidirectional Scatter Distribution Function (BSDF) for the Harvey-Shack model is defined by the following function

$$BSDF = b_0 \left(1 + \frac{(B - B0)^2}{L^2}\right)^{S/2}$$

- The Harvey-Shack model is linear shift invariant, which means that the BSDF depends only on the difference between the sine of the specular angle (B0) and the sine of the scattered angle (B). B and B0 are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction (B-B0 = 0) is b0 multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The BSDF at large angles is linear in the log space of B-B0. The slope of the line is S with S < -1. A typical value for S is between -2.5 and -1.
- This form of the Harvey-Shack model has a near specular roll-off angle (or shoulder) located at B-B0 = L. The default setting is .01 radians (0.573 degrees), which represents a good quality (low RMS roughness) surface.
- The Harvey-Shack model is wavelength invariant.

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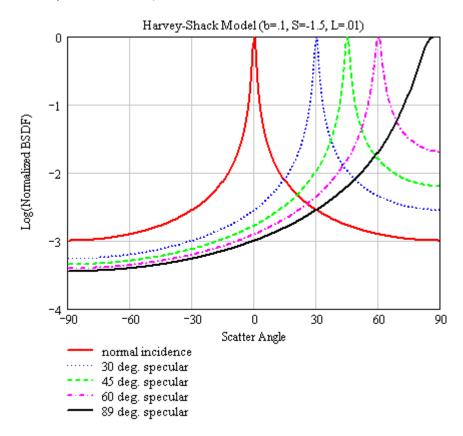
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

Examples Edit/Create New Scatter Model - Harvey-Shack

The following examples show a series of line plots of the Harvey-Shack BSDF as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees. To illustrate the effect that changing L and S have on the scatter distribution, it is helpful to look at the function in log space. Each pair of plots to follow will show the angle space plot (as above) and its corresponding large angle specular log space plot. The ordinate axes for the log space plots are BSDF on the Y-axis, and |B-B0| on the X-axis.

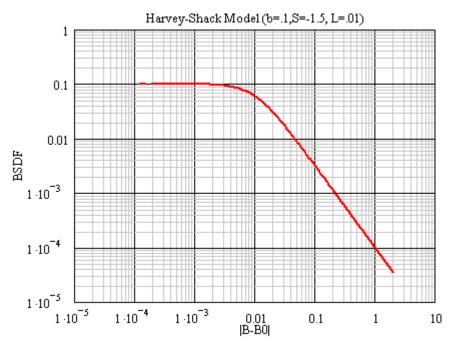
Example 1

The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -1.5.



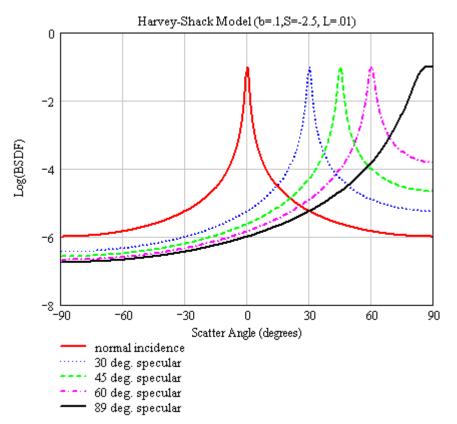
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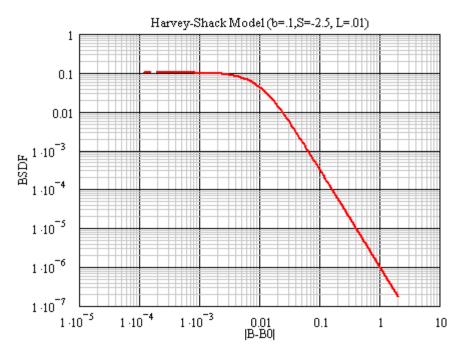
_



Example 2

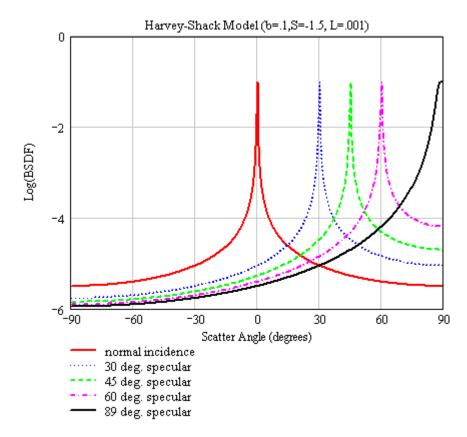
The Harvey-Shack scatter parameters are b0 = 0.1, L = .01, and S = -2.5. Changing the value of S from -1.5 to -2.5 causes the large angle scatter to fall off more rapidly.





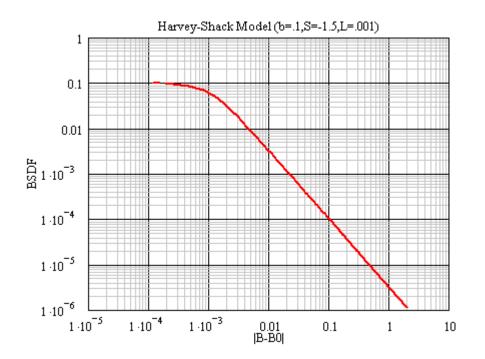
Example 3

The Harvey-Shack scatter parameters are b0 = 0.1, L = .001, and S = -1.5. Changing the value of L from .01 to .001 shifts the roll-off angle closer to specular, which has the effect of directing more of the scattered light into the specular direction. This also attenuates large angle scatter.



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See Also.... Edit/Create New Scatter Model - Harvey-Shack

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>ABg</u> – for polished surface scatter <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Phong</u> scatter – cosⁿ from specular <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>Tabulated PSD</u> – measured PSD data <u>K-Correlation</u> – analytic PSD



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Edit/Create New Scatter Model - Lambertian

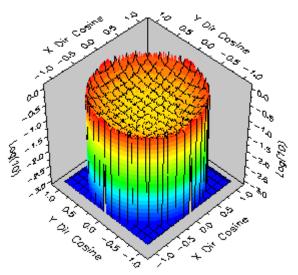
Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes See Also...

Description Edit/Create New Scatter Model - Lambertian

The Lambertian scatter model is typically used to simulate a perfect diffuser. Unlike other models, the BSDF does not depend on either the angle of incidence or the specular ray direction(s). The predefined models Black Lambertian and White Lambertian are both of this type.

<u>Visualization (example)</u> Edit/Create New Scatter Model - Lambertian

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Lambertian scatter parameter is reflectivity = 0.04. The specular angle is 30 degrees.



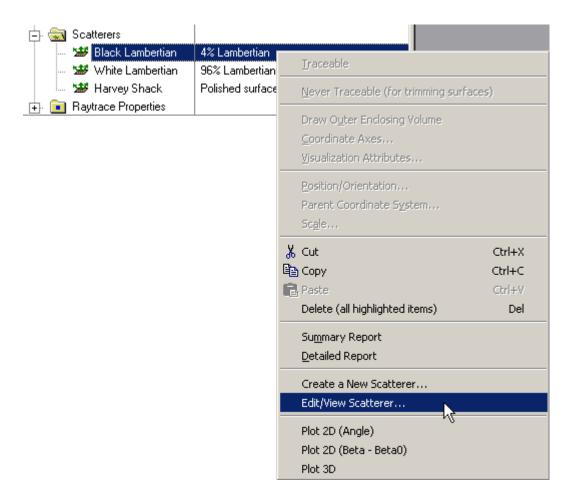
How Do I Get There? Edit/Create New Scatter Model - Lambertian There are four ways to open a Scatter model dialog.

1. Right click on the **Scatterers** folder to open a the pop-up menu and select the option 'Create a New Scatterer...'

Objec	ots				Description	
		Optical Sour Geometry Analysis Sur Materials Coatings		(s)		
		Scatterers Raytrace Pr		∐raceable		
				Never Tracea	able (for trimming surfac	es)
				Draw Outer B Coordinate A Visualization		
				<u>P</u> osition/Orie Parent Coorc Sc <u>a</u> le	ntation linate System	
				Cut		Ctrl+X
				Сору		Ctrl+C
			B	Paste		Ctrl+V
				Delete (all hiç	ghlighted items)	Del
				Summary Rep Detailed Rep		
			_			
				Create a Nev Edit/View Sca	v Scatterer 😽	
				Plot 2D (Angl Plot 2D (Beta Plot 3D		

2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.





3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

URFACE	Aperture	Loca	ation/Orientatio	n	Materials) Co	ating/RayControl
Scatter		Visualiza	tion		Glue		Grating
Scatter							
Assigned Scatte	er Properties:				Available Scatte	er Prope	erties:
Name	Desc	ription	k Assign		Name		Description
				- 1	Black Lamberti	an	4% Lambertian
			> Remove		White Lamberti	ian	96% Lambertia
				-	Harvey Shack		Polished surfac
			Edit,≰V	iew			
4		Þ	Create N	ĺew	•		

When the Scatter dialog has been opened, select Lambertian from the list of available models.



🕻 Scatter		? ×
Name:	Scatter 1	OK
Description:		Cancel
Туре:	Lambertian (equal scatter in all directions)	Help
Val		

After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls Edit/Create New Scatter Model - Lambertian

Name:	Sca	tter 1	<u> </u>
Descrip	otion:		Cancel
Туре:	Lam	bertian (equal scatter in all directions)	Help
	Value	Description	°
	value	Description	
Refl	0.04	Reflectivity (0>1) 0=black absorbing,	1=white reflecting
Refl			1=white reflecting

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>			
Name	Name of the model (required).	Scatter <i>n</i>			
Description	Alpha-numeric text describing the model (optional).	blank			
Туре	Choose Lambertian from the pull down menu.	Lambertian			
Refl	Diffuse reflectance of the scatter surface.	0.04			
Additional data					

Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands Edit/Create New Scatter Model - Lambertian

Commands

Subroutines • AddLambertianScatter YourScatter SetLambertianScatter IndexInScatterList, YourScatter GetLambertianScatter IndexInScatterList, YourScatter

Functions • None

Associated Data Type

- Type Name • T_LAMBERTIANSCATTER
- Type Members •

Name - (string) Holds the name of the model. Default is an empty string. Description - (string) Holds the description of the model. Default is an empty string.

Refl - (double) The value of the Reflectivity coefficient. Default is 0.

ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False. *ApplyTrans* - (Boolean) Applies the scatter model on transmission. Default is False. HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

This example adds a Lambertian Scatter model to the FRED file associated with this script.

Dim s As T LAMBERTIANSCATTER s.Name = "Lambertian Example" s.Description = "Sample from FRED documentation" s.Refl = 0.05

s.ApplyRefl = true s.ApplyTrans = true s.HaltIncident = true AddLambertianScatter s

• This example sets the fourth Scatter model's name to "Lambertian Example 2", as long as that scatter model is a Lambertian model. It fails if it is any other scatter type.

Dim s As T_LAMBERTIANSCATTER s.Name = "Lambertian Example 2" SetLambertianScatter4, s

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Lambertian model. It fails if it is any other scatter type.

Dim s As T_LAMBERTIANSCATTER GetLambertianScatter4, s Print s.Name

Application Notes Edit/Create New Scatter Model - Lambertian

- The Lambertian scatter model has no specular component. The scatter distribution function is completely independent of the angles of incidence, reflection, and transmission. It represents an ideal diffusing surface.
- Reflectivity must be between 0 and 1. This setting is independent of the Coating specification on the surface, which applies only to specular rays. Reflectivity near zero approximates a perfect absorber. Conversely, reflectivity approaching a value of 1 approximates a perfect diffuse reflecting surface as might be found in an integrating sphere. White paper is has a Lambertian reflectivity of about 0.8.
- The Lambertian scatter model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Forward (i.e. transmitted) and reverse (i.e., reflected) scatter can be modeled by specifying two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

See Also.... Edit/Create New Scatter Model - Lambertian

The following links contain details about each of the scatter models: <u>Harvey-Shack</u> – for polished surface scatter <u>ABg</u> – for polished surface scatter <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Phong</u> scatter – cosⁿ from specular <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>Tabulated PSD</u> – measured PSD data K-Correlation – analytic PSD

Edit/Create New Scatter Model - Mie

Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes Examples See Also...

Description Edit/Create New Scatter Model - Mie

The Surface Particle (Mie) Scatter model is used to calculate scatter from particulate contamination on otherwise smooth optical surfaces. Particulates are assumed to be spheres of varying size distributed uniformly on the surface. The size distribution of the particles can take one of several forms: Uniform, Gaussian, mil standard (MIL-1246C or IEST-STD-1246D) or Sampled. User inputs include the incident wavelength, the real and imaginary parts of the particle refractive index, the minimum and maximum particle diameters, and the particle density. The calculation relies on a numeric integration of the scatter distribution over the range of particle sizes. The BSDF for a uniform particle distribution is uniform in direction cosine space. The BSDF for both the Gaussian and the MIL-1246C distribution is peaked in the specular direction. Note that a large difference between the minimum and maximum particle sizes substantially increases the duration of the calculation. The model can be applied in both transmission and reflection if the Raytrace Controls allow it.

<u>Visualization (example)</u> Edit/Create New Scatter Model - Mie

See Examples.

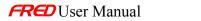
How Do I Get There? Edit/Create New Scatter Model - Mie

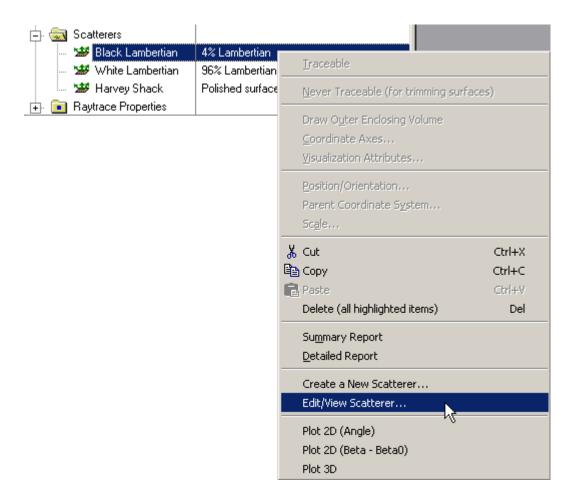
There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'

Objects		Description	
 Image: Image: Im	Iraceable		
		able (for trimming surfa	aces)
	Draw O <u>u</u> ter <u>C</u> oordinate A <u>V</u> isualization		
	Position/Orie Parent Coore Sc <u>a</u> le	ntation dinate System	
	人 Cut 聞 Copy 記 Paste		Ctrl+X Ctrl+C Ctrl+∀
		ghlighted items)	Del
	Su <u>m</u> mary Re <u>D</u> etailed Rep		
	Create a Nev Edit/View Sca	w Scatterer	ŝ
	Plot 2D (Ang Plot 2D (Beta Plot 3D		

2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.



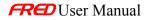


3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE	Aperture	Loca	ation/Orientat	ion	Materials	Co	ating/RayControl
Scatter		Visualiza	tion		Glue		Grating
Scatter Assigned Scatt	er Properties:				Available Scatte	er Prope	erties:
Name	Desc	ription	< Assign		Name		Description
				-	Black Lamberti	an	4% Lambertian
			> Remov	∍	White Lamberti	an	96% Lambertia
				_	Harvey Shack		Polished surfac
•		Þ		/iew New	•		

When the Scatter dialog has been opened, select Surface Particle (Mie) Scatter from the list of available models.



🕻 Scatter		<u>? ×</u>
Name:	Scatter 1	OK
Description:		Cancel
Туре:	Surface Particle (Mie) Scatter	Help

After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls Edit/Create New Scatter Model - Mie

The Surface Particle (Mie) Scatter dialog has four forms: <u>Uniform</u>, <u>Gaussian</u>, <u>MIL-standard</u>. and <u>Sampled</u>.

	Uniform	Particle	Size	Distribution
--	---------	----------	------	--------------

🗧 Scatter			? ×
Name:	Scatter 1	OK	
Description:			Cancel
Туре:	Surface Particl	e (Mie) Scatter	Help
	Value	Description	
Wavelen	0.5	Wavelength (microns)	
Ref Index	1.5	Real part of particle refractive index	
Imag Index	0	Imag part of particle refractive index	
Immerse Index	1	Real part of immersion refractive index	
Surf Refl	1	Surface reflection coefficient	
Surf Tran	1	Surface transmission coefficient	
Density Func	Uniform	Particle density function	
Max Dia	400	Maximum particle diameter (micron)	
Min Dia	1	Minimum particle diameter (micron)	
Density	0.1	Total particle density (# per square micron)	
Additional dat	-	Apply On Transmission 🔽 Halt Ir	ncident Ray

<u>Control</u>	Inputs	<u>Defaults</u>
Name	Name of the model (required)	Scatter <i>n</i>
Description	Alpha-numeric text describing the model (optional).	blank
Туре	Choose Surface Particle (Mie) Scatter from the pull down menu.	Lambertian
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1
Density Func	Particle size distribution function; choose Uniform .	Uniform
Max. Dia	Maximum particle diameter in microns	400
Min. Dia	Minimum particle diameter in microns.	1
Density	Particle density in particles per square micron.	0.1
	Additional data	
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
ОК	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

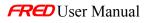
Gaussian Particle Size Distribution

Name:	Scatter 1	OK		
-	- -			
Description:			Cancel	
Туре:	Surface Particle	Mie) Scatter	Help	
	Value	Description		
Wavelen	0.5	Wavelength (microns)		
Ref Index	1.5	Real part of particle refractive index		
lmag Index	0			
Immerse Index	1			
Surf Refl	1 Surface reflection coefficient			
Surf Tran	1	Surface transmission coefficient		
Density Func	Gaussian	 Particle density function 		
Max Dia	400	Maximum particle diameter (micron)		
Min Dia	1	Minimum particle diameter (micron)		
Density	0.1	Total particle density (# per square micron)		
Mean	10	Gaussian mean particle diameter (micron)		
Standard Dev	1	Gaussian standard deviation (micron)		

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>			
Name	Name of the model (required).	Scatter <i>n</i>			
Description	Alpha-numeric text describing the model (optional).	blank			
Туре	Choose Surface Particle (Mie) Scatter from the pull down menu.	Lambertian			
Model Specification					
Wavelen	Wavelength in microns for the scatter calculation.	0.5			
Ref Index	Real part of the refractive index of the particles.	1.5			
Imag Index	Imaginary part of the refractive index of the particles.	0			
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1			

Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1
Density Func	Particle size distribution function; choose Gaussian .	Uniform
Max. Dia	Maximum particle diameter in microns.	400
Min. Dia	Minimum particle diameter in microns.	1
Density	Particle density in particles per square micron.	0.1
Mean	Mean particle diameter in microns.	10
Standard Deviation Standard deviation of particle sizes in microns.		1
	Additional data	
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

MIL-1246C or IEST-STD-1246D Particle Size Distributions



Name:	Scatter 1		OK			
Description:			Cancel			
Гуре:	Surface Particle	(Mie) Scatter	Help			
	Value	Description				
Wavelen	0.5	Wavelength (microns)				
Ref Index	1.5	Real part of particle refractive index				
lmag Index	0 Imag part of particle refractive index					
Immerse Index	1 Real part of immersion refractive index					
Surf Refl	1	Surface reflection coefficient				
Surf Tran	1	Surface transmission coefficient				
Density Func	MIL-1246C	Particle density function				
Max Dia	400	Maximum particle diameter (micron)				
Slope	0.926	Slope of distribution function				
CLevel	400	Cleanliness level				
-Additional dat						

<u>Control</u>	Inputs	<u>Defaults</u>
Name	Name of the model (required)	Scatter <i>n</i>
Description	Alpha-numeric text describing the model (optional).	blank
Туре	Choose Surface Particle (Mie) Scatter from the pull down menu.	Lambertian
	Model Specification	
Wavelen	Wavelength in microns for the scatter calculation.	0.5
Ref Index	Real part of the refractive index of the particles.	1.5
Imag Index	Imaginary part of the refractive index of the particles.	0
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1

Density Func	Particle size distribution function; choose MIL-1246C or IEST-STD-1246D.Uni			
Max. Dia	Maximum particle diameter in microns.	400		
	Additional data			
Apply on Reflection	Apply the scatter model on reflection.	Checked		
Apply on Transmission	Apply the scatter model on transmission.	Unchecked		
Halt Incident Ray	t Ray Halt the incident ray.			
OK	Accept model or changes and close dialog box.			
Cancel	Discard model or changes and close dialog box.			
Help	Access this Help page.			

Sampled Particle Size Distribution

Scatter		?
Name:	Scatter 1	OK
Description:		Cancel
Type:	Surface Particle (Mie	e) Scatter Help
	Value	Description
Wavelen	0.5	Wavelength (microns)
Ref Index	1.5	Real part of particle refractive index
lmag Index	0	Imag part of particle refractive index
Immerse Index	1	Real part of immersion refractive index
Surf Refl	1	Surface reflection coefficient
Surf Tran	1	Surface transmission coefficient
Density Func	Sampled	Particle density function
Particle	Diam (um)	Density (particles per square um)
		Delete Highlighted Rows Replace With Data From File

<u>Control</u>	Inputs	<u>Defaults</u>	
Name	Name of the model (required)	Scatter <i>n</i>	
Description	Alpha-numeric text describing the model (optional).	blank	
Туре	Choose Surface Particle (Mie) Scatter from the pull down menu.	Lambertian	
Wavelen	Wavelength in microns for the scatter calculation.	0.5	
Ref Index	Real part of the refractive index of the particles.	1.5	
Imag Index	Imaginary part of the refractive index of the particles.	0	
Immerse Index	Refractive index of material in which particles are immersed (usually air).	1	
Surf Refl	Reflectance of surface to which particles are attached. (see App Notes below)	1	
Surf Tran	Transmittance of surface to which particles are attached. (see App Notes below)	1	
Density Func	Particle size distribution function; choose Sampled .	Uniform	
Data	DataParticle diameter, Particle density (number per μm^2). Data can be read from a file or entered manually.		
	Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked	
Apply on Transmission	Apply the scatter model on transmission.	Unchecked	
Halt Incident Ray	Halt the incident ray.	Checked	
ОК	Accept model or changes and close dialog box.		
Cancel	Discard model or changes and close dialog box.		
Help	Access this Help page.		

Commands

Subroutines
 AddMieScatter
 SetMieScatter
 GetMieScatter

YourScatter IndexInScatterList, YourScatter IndexInScatterList, YourScatter

• Functions None

Associated Data Type

- Type Name T_MIESCATTER
- Type Members

Name - (string) Holds the name of the model. Default is an empty string.Description - (string) Holds the description of the model. Default is an empty string.

Wavelen - (double) Wavelength used for the scatter calculation. Default is 0. *RefIndex* - (double) Real part of the particle refractive index. Default is 0.

ImagIndex - (double) Imaginary part of the particle refractive index. Default is 0.

MaxDia - (double) Maximum particle diameter, in microns. Default is 0.

MinDia - (double) Minimum particle diameter, in microns. Default is 0.

Density - (double) Particle density, in number per square micron. Default is 0.

Function - (String) Specifies the density function to use when calculating the scatter. Default is an empty string. Possible values are "MIL-1246C", "Uniform", or "Gaussian". Compilation and calculation fail if any other string is specified.

ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False. *ApplyTrans* - (Boolean) Applies the scatter model on transmission. Default is False. HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

• This example adds a Mie Scatter model to the FRED file associated with this script.

Dim s As T_MIESCATTER s.Name = "Mie Scatter Example" s.Description = "Sample from FRED documentation" s.Wavelen = 0.6 s.RefIndex = 1.6 s.ImagIndex = 0 s.MaxDia = 300 s.MinDia = 1 s.Density = 0.2 s.Function = "Gaussian" s.ApplyRefl = true s.ApplyTrans = true s.HaltIncident = true AddMieScatter s



• This example sets the fourth Scatter model's name to "Mie Example 2", as long as that scatter model is a Mie model. It fails if it is any other scatter type.

Dim s As T_MIESCATTER s.Name = "Mie Example 2" SetMieScatter4, s

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Mie model. It fails if it is any other scatter type.

Dim s As T_MIESCATTER GetScatter4, s Print s.Name

<u>Application Notes</u> Edit/Create New Scatter Model - Mie

- The Mie scatter model is not linear shift invariant, which means that the BSDF depends the angle of incidence of the specular ray.
- The scatter distribution function for the Uniform particle size distribution is uniform in direction cosine space.
- The scatter distribution functions for the Gaussian and the MIL-1246C particle size distributions have a strong component in the specular direction, and a smaller reverse component in the opposite direction as the incident ray.
- The Mie model is weakly wavelength dependent. It is not generally necessary to enter additional Mie scatter models for all of the system wavelengths unless they span a large range.
- The maximum particle size for the MIL-1246C model is equivalent to the contamination (or cleanliness level). Level 200 or lower is a pristine surface. Level 600 is typical for visibly clean optics. Level 1000 or higher is appropriate for visibly dirty optics.
- The integration time for the calculation is directly proportional to the range of particle sizes.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.
- The Mie model now allows a constant reflectance and transmittance to be specified for the surface to which the model is attached. In the past, this model assumed R=1 when used in reflection.

Examples

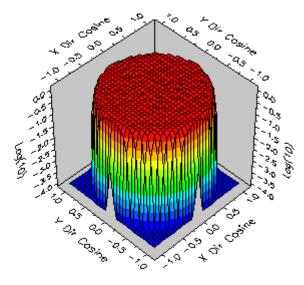
Edit/Create New Scatter Model - Mie

The following examples show a series of 3-dimensional surface log plots of the normalized reflected BSDF (BRDF) as a function of scatter angle for 30 degrees angle of incidence.



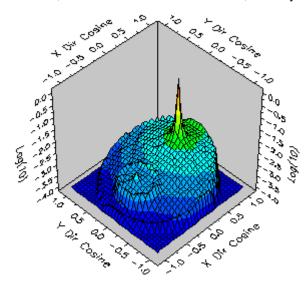
Example 1 – Uniform Particle Size Distribution

The Mie scatter parameters are: Wavelen = 0.5 microns, Ref Index = 1.5, Imag Index = 0, Maximum Particle Size = 400 microns, Minimum Particle Size = 1 micron, Density = 0.1 particles per square micron. For a large range of particle sizes, this scatter model is close to Lambertian.

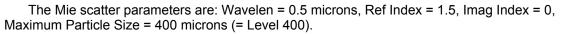


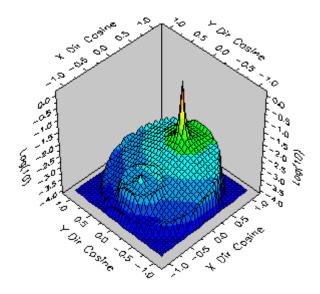
Example 2 - Gaussian Particle Size Distribution

The Mie scatter parameters are: Wavelen = 0.5 microns, Ref Index = 1.5, Imag Index = 0, Maximum Particle Size = 400 microns, Minimum Particle Size = 1 micron, Mean Particle Size = 10 microns, Standard Deviation = 1 micron, Density = 0.1 particles per square micron.



Example 3 – MIL-1246C Particle Size Distribution





<u>See Also....</u> Edit/Create New Scatter Model - Mie

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>Harvey-Shack</u> – for polished surface scatter <u>ABg</u> – for polished surface scatter <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Phong</u> scatter – cosⁿ from specular <u>Tabulated BSDF</u> – measured BSDF data

Tabulated PSD – measured PSD data

K-Correlation - analytic PSD

Edit/Create New Scatter Model - Tabulated Data

Description How Do I Get There? Dialog box and Controls Script Commands Application Notes See Also...

Description - Edit/Create New Scatter Model - Tabulated Data

Model is based upon tabulated data given in polar coordinates. It can apply on both transmission and reflection if the Raytrace Controls allow it. Data can be read from a text file in column format.

How Do I Get There? - Edit/Create New Scatter Model - Tabulated Data

	click on the		catter model dialo older to open a th		u and selec	t the option ' <i>Crea</i>	te a
Objects			Description				
	Dptical Source Reometry Analysis Surfa Naterials Coatings						
	catterers laytrace Pr	Iraceable					
		Never Tracea	able (for trimming sur	faces)			
		Draw Outer E ⊆oordinate A ⊻isualization /					
		<u>P</u> osition/Orier Parent Coord Sc <u>a</u> le,	ntation linate S <u>y</u> stem				
	[X Cut Copy Paste Delete (all hig	phlighted items)	Ctrl+X Ctrl+C Ctrl+∀ Del			
	_	Su <u>m</u> mary Rep Detailed Repo					
		Create a New Edit/View Sca		~			
		Plot 2D (Angl Plot 2D (Beta Plot 3D					

2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a popup menu and select the option '*Edit/View Scatterer...*'.

🕂 🗟 Scatterers			
- 🐸 Black Lambertian	4% Lambertian	Traceable	
- 😕 White Lambertian	96% Lambertian	Пассавіс	
🔤 🌌 Harvey Shack	Polished surface	Never Traceable (for trimming surfa	ices)
🕂 🔳 Raytrace Properties		Draw O <u>u</u> ter Enclosing Volume <u>C</u> oordinate Axes <u>V</u> isualization Attributes	
		Position/Orientation Parent Coordinate System St <u>a</u> le	
		🔏 Cut	Ctrl+X
		B Copy	Ctrl+C
		🔒 Paste	⊂trl+∀
		Delete (all highlighted items)	Del
		Su <u>m</u> mary Report Detailed Report	
		Create a New Scatterer	
		Edit/View Scatterer	
		Plot 2D (Angle)	
		Plot 2D (Beta - Beta0)	
		Plot 3D	

Expand the Scatterers folder and double left mouse click on the scatter model name.
 From the Scatter tab in the Surface dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE	Aperture	Loca	ation/Orientation		Materials	Co	ating/RayControl
Scatter		Visualization			Glue		Grating
– Scatter –							
Assigned Scatte	er Properties:				Available Scatter	Prope	rties:
Name	Desc	ription	< Assign		Name		Description
					Black Lambertia	n	4% Lambertian
			> Remove		White Lambertia	n	96% Lambertia
					Harvey Shack		Polished surfac
			Edit	-			
		•	Create Nev	₩	•		▶

When the Scatter dialog has been opened, select Tabulated scatter from the list of available models.

侯 Scatter		<u>? ×</u>
Name:	Scatter 1	OK
Description:		Cancel
Туре:	Tabulated BSDF (Reciprocity-obeying sampled BSDF)	Help

After a new Scatter model has been created, the model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls - Edit/Create New Scatter Model - Tabulated Data

Scatter		<u>_</u>	
Name:	Scatter 1	ОК	
Description:		Cancel	
Туре:	Tabulated BSDF	(Reciprocity-obeying sampled BSDF)	
	Value	Description	
File		Last accessed file	_
Ang Thresh	0.001	Angular threshold (in radians) for distinct data points	
Dim	● Constant ○ Varies w/angle	Dimensionality (constant for no spec angle variation)	
Min BSDF	0	Minimum BSDF data threshold	
Max BSDF	10000000000	Maximum BSDF data threshold	
	TIS	Integration Parameters (advanced)	
Main Samps	200	# of TIS integration samples across the dir cos unit circle	
Spec Samps	200	# of TIS integration samples across the specular subregion	
Spec Size	10	Size of specular subregion (semi-ape in degrees). Enter 0.0 t	os
		Apply On Transmission 🔽 Halt Incident Ray	
Control	.	T (
Name		Inputs	Defaults
		Inputs Name of the model (required).	DefaultsScatter n
Descriptio	n	•	
Descriptio Type	n	Name of the model (required). Alpha-numeric text describing the model	Scatter <i>n</i>
•	n	Name of the model (required). Alpha-numeric text describing the model (optional). Choose Tabulated BSDF from the pull down	Scatter <i>n</i>
Туре	n [Name of the model (required). Alpha-numeric text describing the model (optional). Choose Tabulated BSDF from the pull down menu. Last file accessed by "Replace with Data from	Scatter n blank Lambertian

Min/Max BSDF	Slope of the BSDF at large B-B0.	0, 1e+11
Additional data		
Apply on Reflection	Apply the scatter model on reflection.	Checked
Apply on Transmission	Apply the scatter model on transmission.	Unchecked
Halt Incident Ray	Halt the incident ray.	Checked
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Script Commands - Edit/Create New Scatter Model - Tabulated Data

Commands

Associated Subroutines AddTabulatedScatter InitTabulatedScatter SetTabulatedScatter GetTabulatedScatter

Associated Data Type

Type Name T TABULATEDSCATTER

Type Members

Name – (string) holds the name of the model. Default is an empty string. Description – (string) holds the description of the model. Default is an empty string. Filename – (string) File name.

Type - (long) Type.

CollapseTol - (double) The value of the BSDF slope at large B-B0. Default is 0.

MinBSDF - (double) Minimum allows BSDF value. default=0

MaxBSDF - (double) Maximum allowed BSDF value. default=1000000000

ApplyRefl – (Boolean) Applies the scatter model on reflection. Default is False.

ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False.

HaltIncident - (Boolean) Halts the incident ray. Default is False.

Example

This example adds a Tabulated Scatter model to the FRED file from data in a script: Dim tab3 As T_TABULATEDSCATTER ' scripted tabulated scatter InitTabulatedScatter tab3 tab3.Name="scripted tabulated scatter" tab3.Description="Reciprocity-obeying sampled BSDF" tab3.FileName="myScripted"

Dim A03(10) As Double Dim B03(10) As Double Dim A3(10) As Double

Dim B3(10) As Double

```
Dim BSDF3(10) As Double

A03(0)=10 : B03(0)=0 : A3(0)=-80 : B3(0)=0 : BSDF3(0)=0.105

A03(1)=10 : B03(1)=0 : A3(1)=-64 : B3(1)=0 : BSDF3(1)=0.104

A03(2)=10 : B03(2)=0 : A3(2)=-48 : B3(2)=0 : BSDF3(2)=0.103

A03(3)=10 : B03(3)=0 : A3(3)=-32 : B3(3)=0 : BSDF3(3)=0.102

A03(4)=10 : B03(4)=0 : A3(4)=-16 : B3(4)=0 : BSDF3(4)=0.101

A03(5)=10 : B03(5)=0 : A3(5)=0 : B3(5)=0 : BSDF3(5)=0.1

A03(6)=10 : B03(6)=0 : A3(6)=16 : B3(6)=0 : BSDF3(6)=0.099

A03(7)=10 : B03(7)=0 : A3(7)=32 : B3(7)=0 : BSDF3(7)=0.098

A03(8)=10 : B03(8)=0 : A3(8)=48 : B3(8)=0 : BSDF3(8)=0.097

A03(9)=10 : B03(9)=0 : A3(9)=64 : B3(9)=0 : BSDF3(10)=0.095
```

s3=AddTabulatedScatter(tab3, A03, B03, A3, B3, BSDF3)

Application Notes - Edit/Create New Scatter Model - Tabulated Data

• Data can be read from a text file in column format. Load the file by right-clicking in the spreadsheet area. The file name will be shown as "Last accessed file" :

Scatter			? >
Name:	Scatter 1		ОК
Description:			Cancel
Туре:	Tabulated BSDF	(Reciprocity-obeying sampled BSDF)	Help
	Value	Description	
File		I ast accessed file	
Ang Thresh	0. Replace Wil	th Data From a File dians) for distinct data po	ints
Dim		Accessed File Name, 🦄 for no spec angle variati	ion)
	O Varies w/angli	e	
Min BSDF	0	Minimum BSDF data threshold	
Max BSDF	10000000000	Maximum BSDF data threshold	
	TI	IS Integration Parameters (advanced)	
Main Samps	200	# of TIS integration samples across the dir cos ur	nit circle
Spec Samps	200	# of TIS integration samples across the specular	subregion
Spec Size	10	Size of specular subregion (semi-ape in degrees)). Enter 0.0 to s
•			•
Additional da		Size of specular subregion (semi-ape in degrees). Enter 0.0
Apply Or		Apply On Transmission 🔽 Halt Inc	cident Ray

File format is shown here and is the standard format also used for binomial/polynomial datasets:

📕 bsdf_3	_fred.txt	- Notepad			
File Edit	Format	View Help			
type be	df_dat		ue scale=1		
•					

• The Tabulated Scatter model is wavelength invariant.

• All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the **Surface Dialog**.

• Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

See Also - Edit/Create New Scatter Model - Tabulated Data

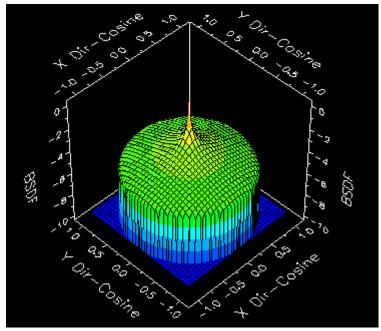
The following links contain details about each of the scatter models. <u>ABg</u> for smooth surface scatter <u>Lambertian</u> for diffuse scatter <u>Harvey-Shack</u> for polished surface scatter <u>Phong</u> scatter – \cos^n from specular <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Surface Particle (Mie)</u> – for particulate contamination

Edit/Create New Scatter Model - K-Correlation

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description K-Correlation Scatter Model

The K-correlation scatter model is used to represent Power Spectral Density (PSD) measurements which can be fit to a specific algebraic form, namely a straight line on a log-log plot of PSD versus frequency.

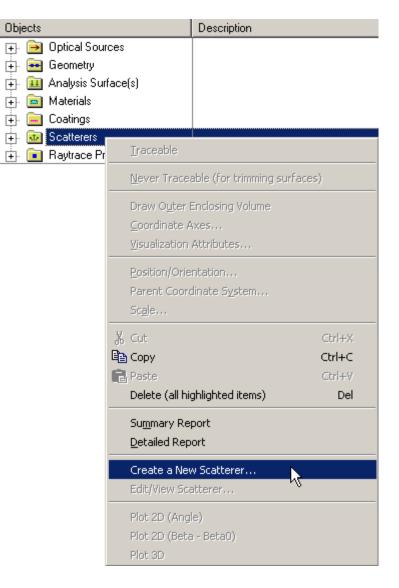


How Do I Get There? K-Correlation Scatter Model

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'





2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.



Objects		Description	
Optical Sources Geometry Analysis Surface(s) Materials Coatings Scatterers Scatterers Seatterers Seatter		4% Lambertian 96% Lambertian Polished surface scatter	
→ 😕 K-correlation mode → 🖬 Raytrace Properties	Iraceable		
	Never Tracea	able (for trimming surfaces)	
	Coordinate A Visualization / Position/Orier Parent Coord	Attributes	
_	Sc <u>a</u> le		
E	X Cut Copy Paste Delete (all hig	Ctrl+X Ctrl+C Ctrl+V ghlighted items) Del	
	Summary Rep Detailed Repo		
	Create a New Edit/View Sca		
	Plot 2D (Angli Plot 2D (Beta Plot 3D		

3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE Ape	rture Loca	ation/Orientation	Materials	Coating/RayControl
Scatter	Visualiza	ition	Glue	Grating
Scatter Assigned Scatter Prop	erties:		Available Scatte	r Properties:
Name	Description	< Assign	Name	Description
			Black Lambertia	an 4% Lambertian
		> Remove	White Lambertia	an 96% Lambertia
			Harvey Shack	Polished surfac
		Edit Vie Create Ne		

Dialog Box and Controls K-Correlation Scatter Model

<u> Scatter</u>			<u>?</u> ×
Name:	Scatte	r1	OK
Description	: [Cancel
Туре:	K Corr	elation (K Correlation Power Spectral Density)	Help
	Value	Description	
Wavl(ref)	0.6328	 Reference wavelength (um) 	
Detta N	2	Refractive index difference across the surface (2 for reflecti	ion)
Refl/Tran	1	Surface reflectance or transmission	
Sigma	0.0015	RMS surf rough (um) measured at freqs from 0 to 1 ///avl(ref)
В	200	2*pi times typical surface wavelength (um)	
S	2	2*pi times typical surface wavelength (um) Slope of the PSD at large spatial frequencies	
Additiona	2	Slope of the PSD at large spatial frequencies	ent Ray
S Additiona	2	Slope of the PSD at large spatial frequencies	ent Ray
Additiona	2	Slope of the PSD at large spatial frequencies	
Additiona	2	Slope of the PSD at large spatial frequencies ion Apply On Transmission I Halt Incide Inputs / Description	<u>Defaults</u>

Wavl(ref)	Reference wavelength.	default wavelength
Delta N	Refractive index difference between incident and substrate material. For reflection, Delta N = 2 .	2
Refl/Tran	Reflectance/transmittance of surface.	1
Sigma	RMS surface roughness (um) measured at frequencies from 0 to 1/Wavl(ref).	0.0015
В	2π time typical surface wavelength (um).	200
S	Slope of PSD at large spatial frequencies.	2
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Application Notes K-Correlation Scatter Model

• The K-Correlation scatter model is defined by

$$\mathcal{S}(f) = \frac{A'}{\left[1 + (Bf)^2\right]^{(\sigma+1)/2}}$$

where

$$A' = \frac{\Gamma[(c+1)/2]}{2\sqrt{\pi}\Gamma(c/2)}$$

• The value of A is determined by low-frequency behavior. The parameter B is related to correlation length. C determines the rate of fallof or slope of the PSD at high frequencies.

• Reference material for this model can be found in Chapter 4 of *Optical Scattering Measurement and Analysis* by John Stover (<u>references</u>).

See Also.... K-Correlation Scatter Model

The following links contain details about each of the scatter models:

Lambertian – for diffuse scatter Harvey-Shack – for polished surface scatter ABg – for polished surface scatter Flat Black Paint – specify Total Integrated Scatter (TIS) Phong scatter – cosⁿ from specular Surface Particle (Mie) – for particulate contamination Tabulated BSDF – measured BSDF data Tabulated PSD – measured PSD data



Edit/Create New Scatter Model - Phong

Description Visualization (example) How Do I Get There? Dialog box and Controls Script Commands Application Notes Examples See Also...

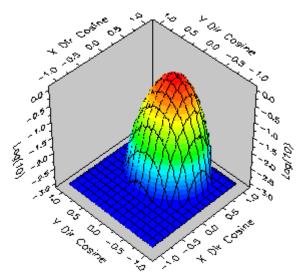
Description Edit/Create New Scatter Model - Phong

The Phong scatter model simulates a quasi-Gaussian scatter distribution function in which the BSDF is proportional to Tⁿ where T is the cosine of the angle between the specular and scattered rays. It can apply on both transmission and reflection if the Raytrace Controls allow it.

WARNING: Use of the Phong scatter model can result in non-physical effects for specular angles near grazing incidence (see Examples below). Use with caution.

Visualization (example) Edit/Create New Scatter Model - Phong

The following picture shows a normalized log space plot of the reflected hemispherical scatter intensity distribution in direction cosine space. The Phong scatter parameters are d = 0.1 and n = 16. The specular angle is 30 degrees.





How Do I Get There? Edit/Create New Scatter Model - Phong

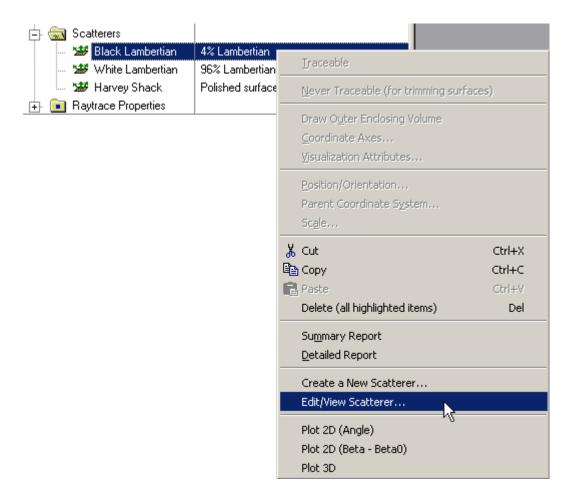
There are four ways to open a Scatter model dialog.

1. Right click on the **Scatterers** folder to open a the pop-up menu and select the option 'Create a New Scatterer...'

Objects		Description	
	Traceable		
	Never Trace	able (for trimming sur	faces)
	Draw Outer I ⊆oordinate A Visualization		
	Position/Orie Parent Coord Sc <u>a</u> le	ntation linate S <u>y</u> stem	
	从 Cut 国語 Copy		Ctrl+X Ctrl+C
	R Paste		Ctrl+V
		ghlighted items)	Del
	Su <u>m</u> mary Rej <u>D</u> etailed Rep		
	Create a Nev Edit/View Sca	v Scatterer atterer	<u>.</u>
	Plot 2D (Ang Plot 2D (Beta Plot 3D		

2. Expand the **Scatterers** folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer...*'.





3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.

SURFACE	Aperture	Loca	ation/Orientation		Materials	C	Coating/RayControl
Scatter		Visualiza	tion	6	âlue		Grating
Scatter Assigned Scatt	er Properties:			A١	vailable Sca	atter Pro	nerties:
Name		ription	< Assign		lame		Description
				В	lack Lambe	ertian	4% Lambertian
			> Remove	W	/hite Lambe	ertian	96% Lambertia
				H	arvey Shac	sk	Polished surfac
			Edit				
•		Þ	Create Nev	· 🔳			I

When the Scatter dialog has been opened, select Phong scatter from the list of available models.



🔇 Scatter		? ×
Name:	Scatter 1	OK
Description:		Cancel
Туре:	Phong scatter (Cos^n from specular)	Help
	لمح BSDF = d*T^n (T is cosine of angle between specular	r and scatter

After a new Scatter model has been created, its model Type cannot be changed. Only the input parameters can be changed.

Dialog Box and Controls Edit/Create New Scatter Model - Phong

代 Sca	tter		? ×
Name	c Sca	tter 1	ок
Desc	iption:		Cancel
Туре:	Pho	ng scatter (Cos^n from specular)	Help
		BSDF = d*T^n (T is cosine of angle between specular ar	nd scatter
d	0.1	d (0 <d<1)< th=""><th></th></d<1)<>	
	16	n (1 <n)< td=""><td></td></n)<>	
	itional data Apply On Refl		
ontrol		<u>Inputs</u>	Defaults
ontrol	Apply On Refl	<u>Inputs</u>	<u>Defaults</u>
ontrol ame	Apply On Refl	Inputs Name of the model (required). Alpha-numeric text describing the model	Defaults Scatter n

n	Value of the exponent greater than 1.					
	Additional data					
Apply on Reflection	Apply on Reflection Apply the scatter model on reflection.					
Apply on Transmission	Apply the scatter model on transmission.	Unchecked				
Halt Incident Ray Halt the incident ray.		Checked				
OK	Accept model or changes and close dialog box.					
Cancel	Discard model or changes and close dialog box.					
Help	Access this Help page.					

<u>Script Commands</u> Edit/Create New Scatter Model - Phong

Commands

•	Subroutines	
	AddPhongScatter	YourScatter
	SetPhongScatter	IndexInScatterList, YourScatter
	GetPhongScatter	IndexInScatterList, YourScatter

• Functions None

Associated Data Type

- Type Name T_PHONGSCATTER
- Type Members

Name - (string) Holds the name of the model. Default is an empty string.Description - (string) Holds the description of the model. Default is an empty string.

d - (double) Holds the d parameter as shown in the above dialog. Default is 0. n - (double) Holds the n parameter as shown in the above dialog. Default is 0. ApplyRefl - (Boolean) Applies the scatter model on reflection. Default is False. ApplyTrans - (Boolean) Applies the scatter model on transmission. Default is False. HaltIncident - (Boolean) Halts the incident ray. Default is False.

Examples

This example adds a Phong Scatter model to the FRED file associated with this script.

Dim s As T_PHONGSCATTER s.Name = "Phong Example" s.Description = "Sample from FRED documentation" s.d = 0.05 s.n = s.ApplyRefl = true s.ApplyTrans = true s.HaltIncident = true AddPhongScatter s

• This example sets the fourth Scatter model's name to "Phong Example 2", as long as that scatter model is a Phong model. It fails if it is any other scatter type.

```
Dim s As T_PHONGSCATTER
s.Name = "Phong Example 2"
SetPhongScatter4, s
```

• This example gets the fourth Scatter model and prints its name, as long as that scatter model is a Phong model. It fails if it is any other scatter type.

```
Dim s As T_PHONGSCATTER
GetPhongScatter4, s
Print s.Name
```

<u>Application Notes</u> Edit/Create New Scatter Model - Phong

0

 The Bidirectional Scatter Distribution Function (BSDF) for the Phong model is defined by the following function

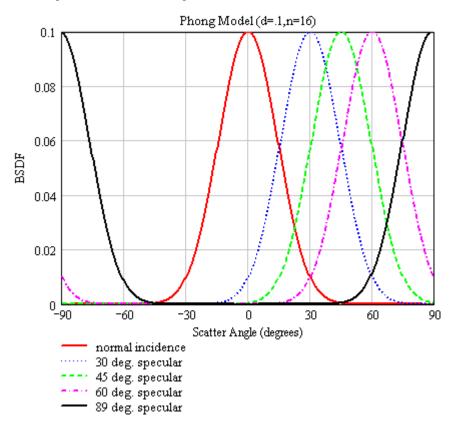
$$BSDF = d \cdot \cos(\theta_{scatter} - \theta_{specular})^n$$

- The Phong model is linear shift invariant, which means that the BSDF depends only on the cosine of the difference between the specular angle and the scattered angle). The scattered and specular angles are always taken in the plane of the incident ray. Angles are measured relative to the surface normal.
- The relative scattered ray power in the specular direction is d multiplied by the projected solid angle in the specular direction. This product cannot exceed 1 for a 100% scattering surface or the relative ray power contained in the specular ray(s). Failure to satisfy this restriction violates conservation of energy.
- The BSDF for the Phong model at large specular angles can result in a split distribution in angle space that is the result of the distribution wrapping across the scatter angle boundary from 90 to –90 degrees.
- The Phong model is wavelength invariant.
- All scatter models describe the BSDF as measured over a maximum of 2π steradians. Both transmitted and reflected scatter can be modeled by specifying the two scatter directions simultaneously with the appropriate direction controls found under the Scatter tab in the Surface Dialog.
- Multiple scatter models can be attached to the same surface. The scatter direction controls are then imposed on every attached model.

Examples Edit/Create New Scatter Model - Phong

The following examples show line plots of the Phong BSDF as a function of scatter angle for specular angles of 0, 30, 45, 60, and 89 degrees for n=16 and n=24. Notice that the distribution wraps across the scatter angle boundary from 90 degrees to –90 degrees for large specular angles.

Example 1

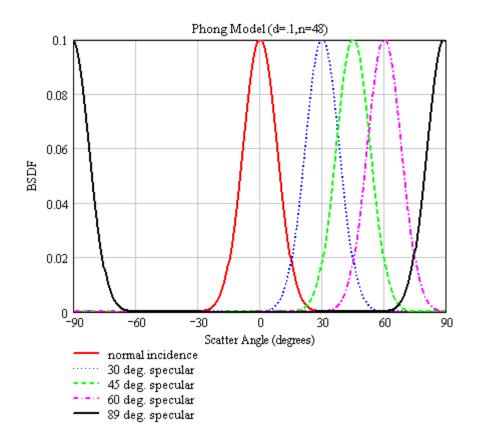


The Phong scatter model settings are d = 0.1 and n = 16.

Example 2

The Phong scatter model settings are d = 0.1 and n = 48. Increasing the value of n has the effect of narrowing the linewidth of the distribution function so that more light is scattered near the specular angle.

_



See Also.... Edit/Create New Scatter Model - Phong

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>Harvey-Shack</u> – for polished surface scatter <u>ABg</u> – for polished surface scatter <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>Tabulated PSD</u> – measured PSD data <u>K-Correlation</u> – analytic PSD



Edit/Create New Scatter Model - Tabulated PSD

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Tabulated PSD

The Tabulated Power Spectral Density (PSD) scatter model accepts measured PSD data and creates an interpolated BSDF model.

How Do I Get There? Tabulated PSD

There are four ways to open a Scatter model dialog.

1. Right click on the Scatterers folder to open a the pop-up menu and select the option 'Create a New Scatterer...'



Objects		Description			
🕂 🛄 Raytrace Pr	Traceable				
	Never Trace	Never Traceable (for trimming surfaces)			
	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes				
	Position/Orie Parent Coore Sc <u>a</u> le	ntation dinate System			
	X Cut Copy Paste Delete (all hi	ghlighted items)	Ctrl+X Ctrl+C Ctrl+V Del		
	Su <u>m</u> mary Report Detailed Report				
	Create a Nev Edit/View Sc	w Scatterer	5		
	Plot 2D (Ang Plot 2D (Beta Plot 3D				

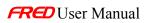
2. Expand the Scatterers folder and right mouse click on a specific scatter model to open a pop-up menu and select the option '*Edit/View Scatterer*...'.



Objects		Description	
- 🔁 Optical Sources			
📻 Geometry 🛄 Analysis Surface(s)			
🕂 🔜 Materials			
Free Coatings			
🔁 🔙 Scatterers			
😕 Black Lambertian		4% Lambertian	
😕 White Lambertian		96% Lambertian	
- 😾 Harvey Shack		Polished surface scatter	
- 🥗 K-correlation model			
Tabulated PSD model Agyrace Properties	Traceab	le	
	Never T	raceable (for trimming surf	aces)
	Draw O	Iter Enclosing Volume	
	⊆oordin	ate Axes,	
	⊻isualiza	tion Attributes	
	Position,	Orientation	
	Parent (Coordinate S <u>y</u> stem	
	Sc <u>a</u> le		
	🔏 Cut		Ctrl+X
	🖺 Copy		Ctrl+C
	📳 Paste		Ctrl+∀
	Delete (all highlighted items)	Del
	Summar	y Report	
	<u>D</u> etailed	Report	
	Create a	a New Scatterer	
	Edit/Viev	w Scatterer	
	Plot 2D	(Angle)	

3. Expand the **Scatterers** folder and double left mouse click on the scatter model name.

4. From the Scatter tab in the **Surface** dialog, left mouse click on either the '*Edit/View...*' or '*Create New...*' coating buttons.



SURFACE A	Aperture Loc	ation/Orientation	Materials	Coating/RayContro
Scatter	Visualiza	ition	Glue	Grating
Scatter				
Assigned Scatter Pr	roperties:		Available Scatter	Properties:
Name	Description	< Assign	Name	Description
			Black Lambertia	n 4% Lambertiar
		> Remove	White Lambertia	n 96% Lamberti
			Harvey Shack	Polished surfa
L		Edit _e View.		
-				
4		Create New		•

Dialog Box and Controls Tabulated PSD

)escription:			Cancel
Гуре:	Tabulated Power Spectral	Density (PSD)	Help
	Value	Description (right mouse-click for p	opup menu)
Wavl(ref)	0.587 💌	Reference wavelength (um) for TIS calc	ulation
Delta N	2	Refractive index difference across the s	urface (2 for refl
Refl/Tran	1	Surface reflectance or transmission	
File		Last accessed file	
# Points	0	Number of data points read from file	
Freq(min)	0	Min spatial frequency (1/(um*um))	
Freq(max)	0	Max spatial frequency (1/(um*um))	
PSD at min	0	PSD at min spatial frequency	
PSD at max	0	PSD at max spatial frequency	
•			Þ

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Name	Name of the model (required).	Scatter <i>n</i>
Description	Alpha-numeric text describing the model (optional).	blank
Туре	Choose Tabulated Power Spectral Density from the pull down menu.	Lambertian

Wavl(ref)	Reference wavelength	0.587
Delta N	Refractive index difference between incident and substrate material. For reflection, Delta N = 2.	2
Refl/Tran	Reflectance/transmittance of surface.	1
File	Full path to file containing measured data.	blank
# Points	Number of data points in file.	0
Freq(min/max)	Minimum and maximum frequency represented in file data.	0,0
PSD at min	PSD value at minimum.	0
PSD at max	PSD value at maximum.	0
OK	Accept model or changes and close dialog box.	
Cancel	Discard model or changes and close dialog box.	
Help	Access this Help page.	

Application Notes Tabulated PSD

The file format for Tabulated PSD data is shown below. There is a two line header followed by data in two columns (freq PSD). Entries in [] are optional.

📕 ti	abpsd	lformat.	txt - N	otepad				_1	
		Format							
for 0 1 2 3 4 5	e ta mat 0.02 0.3 0.84 1.7 0.45 2.3 0.7		edpsc og lc	g10]	[scalefreq	<value>]</value>	[scalepsd	<value>]</value>	< I

See Also.... Tabulated PSD

FRED User Manual

The following links contain details about each of the scatter models: <u>Lambertian</u> – for diffuse scatter <u>Harvey-Shack</u> – for polished surface scatter <u>ABg</u> – for polished surface scatter <u>Phong</u> scatter – cosⁿ from specular <u>Flat Black Paint</u> – specify Total Integrated Scatter (TIS) <u>Surface Particle (Mie)</u> – for particulate contamination <u>Tabulated BSDF</u> – measured BSDF data <u>K-Correlation</u> – analytic PSD



Chapter 11 - Raytrace Properties

Raytrace Control

Description Visualization (example) How Do I Get There? Dialog box and Controls Application Notes Examples See Also...

Description Raytrace Control

The **Raytrace Properties** folder contains the default and optional user entered raytrace control settings that are applied to every surface in FRED. Raytrace Properties tell FRED how to propagate every ray that intersects a surface. The default controls are <u>Halt All</u>, <u>Transmit</u> <u>Specular</u>, <u>Reflect Specular</u>, and <u>Allow All</u>. The user can edit any one of these or create additional controls.

WARNING Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

visualization (example) Raytrace Control

The Raytrace Properties folder is at the bottom of the tree.

Objects	Description
🕂 📄 Optical Sources	
🕂 📻 Geometry	
💷 Analysis Surface(s)	
🕂 💼 Materials	
🕂 🧰 Coatings	
🕂 💼 Scatterers	
🕂 💼 Raytrace Properties	



How Do I Get There? Raytrace Control

A left click on the 🗄 symbol ne	xt to the folder name will expand the tree.
🕂 间 Raytrace Properties	
1 45	
	······································
🔁 🔂 Raytrace Properties	
🚝 Halt All	Halt all ray components
- 🚝 Transmit Specular	Allow transmitted specular ray only
- 🚝 Reflect Specular	Allow reflected specular ray only
ZZ Allow All	Allow all ray components

A left click on the \Box symbol next to an open folder will collapse the tree. Existing Raytrace Controls can be edited via a right mouse click.

Dialog Box and Controls Raytrace Control

÷ —	ace	Properties folder pops up the fo	llowing menu.
🔃 💼 Raytrace Properties		Iraceable	
		Never Traceable (for trimming surface	s)
		Draw Outer Enclosing Volume Coordinate Axes, Visualization Attributes,	
		Position/Orientation Parent Coordinate System Sc <u>a</u> le	
	Å	Cut	Ctrl+X
	Ē	Сору	Ctrl+C
	B	Paste	⊂trl+∀
		Delete (all highlighted items)	Del
		Su <u>m</u> mary Report Detailed Report	
		Create a New Raytrace Control Set Edit a Raytrace Control Set	

The first option available on the right click menu is a Summary Report.



Summary Report
Detailed Report
Create a New Raytrace Control Set
Edit a Raytrace Control Set

When this option is selected, FRED prints a list of all the Raytrace Property controls in the model as well as any descriptive text associated with each.

RAYTRACE CONTROLS	
Halt All	Halt All Ray Components
Transmit Specular	Allow Transmitted Specular Ray Only
Reflect Specular	Allow Reflected Specular Ray Only
Allow All	Allow Reflected and Transmitted Specular Rays

The second option available on the right click menu is a Detailed Report.

Summary Report
Detailed Report
الريمين Create a New Raytrace Control Set
Edit a Raytrace Control Set,

When this option is selected, FRED prints a detailed summary of all of the Raytrace Property controls.

RAYTRACE (CONTROLS					
<u>Allow Tran</u>	Parent	<u>Max spec Ivl</u>	<u>Max total</u>	<u>Rel trans pwr</u>	<u>Abs trans pwr</u>	<u>Name</u>
<u>Allow Refl</u>	Allow TIR	<u>Max scat Ivl</u>	Max consec	<u>Rel refl pwr</u>	<u>Abs refl pwr</u>	
N	Largest Incoherent Power	2	1000	1e-9	1e-14	Halt All
N	N	1	10	1e-9	1e-14	
Y	Largest Incoherent Power	2	1000	1e-9	1e-14	Transmit Specular
N	N	1	10	1e-9	1e-14	
N	Largest Incoherent Power	2	1000	1e-9	1e-14	Reflect Specular
Y	N	1	10	1e-9	1e-14	
Y	Largest Incoherent Power	2	1000	1e-9	1e-14	Allow All
Y	Y	1	10	1e-9	le-14	

The third option available is to Create a New Raytrace Control Set...

Su <u>m</u> mary Report <u>D</u> etailed Report	
Create a New Partness Control Cat	
Create a New Raytrace Control Set	
Edit a Raytrace Control Set 🙌	

Selecting this option opens the Raytrace Control Dialog. This is one of 3 ways to access this dialog.

🕻 (FRED1 *) Create a New Raytrace Control Set	? _ 🗆 🗙
Name	
Raytrace Control 1	OK.
Description	Close
	Apply
	Help
Specular Ray Power Cutoff Thresholds	Intersection Count Cutoff
Absolute power Relative power Reflected Ray: 1e-014 1e-009	Total: 1000 🗧
Transmitted Ray: 1e-014 1e-009	Consecutive: 100 +
Scatter Ray Power Cutoff Thresholds	Ancestry Level Cutoff
Absolute power Relative power	Specular: 2 🛨
Reflected Ray: 0 0	Scatter: 1 🗧
Transmitted Ray: 0	Spec+Scat: 10 ਦ
Allowed Specular Operations Allowed Scatter Operations	Parent Ray Specifier
Allow reflected ray	 Largest incoherent power Transmitted
Allow transmitted ray	C Reflected
Allow Total Internal Refl	C Monte-Carlo (1 ray only)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>		
Name	Name of the Raytrace Control.	Raytrace Control <i>n</i>		
Description	Alpha-numeric description of the Raytrace Control.	blank		
Specular Ray Power Cutoff Thresholds				
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014		
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009		
Scatter Ray Power Cutoff Thresholds				

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0		
Reflected/Transmitted Ray Relative Power	power of the reflected/transmitted ray			
	Intersection Count Cutoff			
Total	This value sets the maximum number of surface intersections for each ray.	1000		
Consecutive	This value sets the number of			
	Ancestry Level Cutoff			
Specular	This value sets the maximum number of Specular generations that can be split.	2		
ScatterThis value sets the maximum number of Scatter generations that can be split.		1		
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)		
	Allowed Specular Operations			
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Checked		
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked		
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked		
Allowed Scatter Operations				
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked		
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked		
Parent Ray Specifier				
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected		
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected		

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

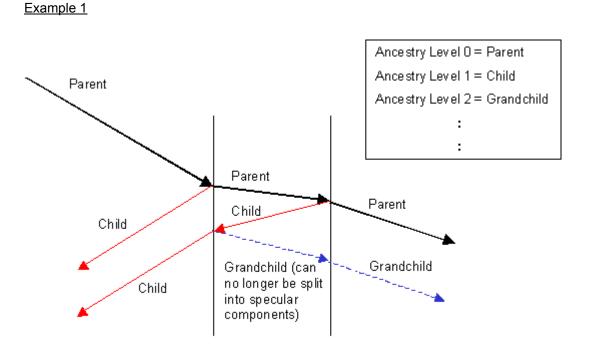
Application Notes

Raytrace Control

- Raytrace Controls are applied before **Coatings**.
- Coatings are use in conjunction with the Raytrace Controls to determine ray propagation.
 - To continue propagating a reflected ray, both the Raytrace Control and the Coating must allow the reflection
 - To continue propagating a transmitted ray, both the Raytrace Control and the Coating must allow the transmission
- Scattered rays are subject to the same limitations.
- Relative and Absolute power cutoffs apply to both coherent and incoherent rays
- With the exception of Lens, Mirror, and Prism components, the Raytrace Control for every surface created in FRED is <u>Halt All</u>, which stops ray propagation.
- The Ancestry levels in FRED are used to determine whether or not a ray can be split at an interface. On creation, the Ancestry Level is automatically set to 0. That is to say, every ray is a Parent ray. When a propagated ray intersects a surface, if allowed, the ray can be split into reflected and transmitted specular components and 1 scatter component. The Parent ray specifier tells FRED which component maintains the Ancestry Level of the incident ray. The Ancestry level for any split ray that is not the Parent is incremented by 1. If the Ancestry level exceeds the cutoff, then the ray is halted. Otherwise, the ray continues to propagate.
 - Ancestry levels for specular and scatter components are completely independent of one another.
 - If the Parent Ray Specifier is set to 'Largest Incoherent Power' and both the reflected and transmitted components have equal power, then FRED automatically makes the transmitted ray the Parent

Examples Raytrace Control

The following examples illustrate Parentage and Ancestry Level splitting. In the first 2 examples, the Specular Ancestry Cutoff has been set to Level 2, which means that Grandchildren rays can no longer be split into specular components. Because the Scatter Ancestry Level has been set to 0, the Raytrace Control will not allow any ray to scatter, even if a **Scatter Property** has been assigned to the surface. The third example shows a scattering surface. Note that since the reflected specular ray is the Parent, all of the scattered rays will maintain the Specular Ancestry Level of the incident ray.

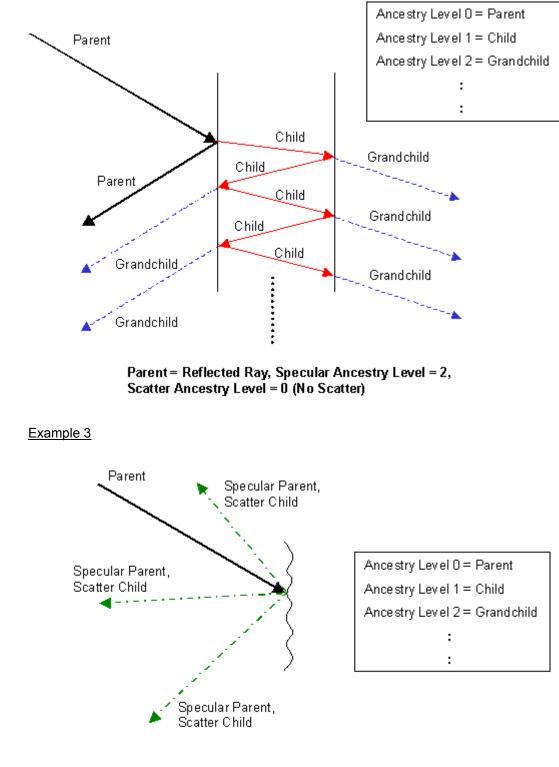


Parent = Trans mitted Ray, Specular Ancestry Level = 2, Scatter Ancestry Level = 0 (No Scatter)

Example 2



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Parent = Reflected Ray, Specular Ancestry Level = 2, Scatter Ancestry Level = 1

See Also.... Raytrace Control

To view the default Raytrace Control settings select the following links <u>Halt All</u> <u>Transmit Specular</u> <u>Reflect Specular</u> Allow All

Default Raytrace Controls - Allow All

Description How Do I Get There? Dialog box and Controls

Description Default Raytrace Controls – Allow All

The Reflect Specular raytrace control allows both reflected and transmitted rays to propagate if the flux (power) exceeds the specified thresholds. This control also allows Total Internal Reflection.

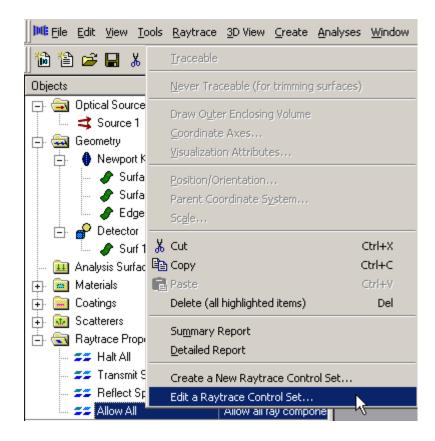
WARNING: Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

<u>How Do I Get There?</u> Default Raytrace Controls – Allow All

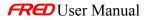
The dialog can be reached with a right click on the Allow All control under the <u>Raytrace</u> <u>Properties</u> folder.



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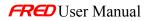


The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



<mark>(</mark> (FRED1 *) Crea	ite a New Surl	ace as Child of: "E	ilem 1"		_ 🗆 🗙
Scatter SURFACE	Visualiza Aperture	tion Glue Location/Orient		Auxiliary Data Coating/RayControl	OK Cancel
Ray Colors Change color	Coating Assigned:	Absorb	100% Absor	bing Coating	Apply
of rays that intersect this surface:	List of Available	Name Absorb Reflect	Description 100% Absorbing Coating 100% Reflective Coating	Assign	Help
Transmit	Coatings:	Transmit Standard Coating	100% Transmissive Coatin 96% Transmitting, 4% Ref		
Reflect	– Raytrace C Assigned:		Halt all ray o	components	
Diffract	List of Available Raytrace	Name Halt All Transmit Specular Reflect Specular	Description Halt all ray components Allow transmitted specular Allow reflected specular ra		
Scatter	Controls:	Allow All	Allow all ray components	v or <u>Edit/View</u> Create New	

<u>Dialog Box and Controls</u> Default Raytrace Controls – Allow All



🗲 (FRED1 *) Edit Raytrace Control Set	? <u> </u>
Name	
Allow All	OK.
Description	Close
Allow all ray components	é == 1 :
	Apply
	Help
Specular Ray Power Cutoff Thresholds	ount Cutoff
Absolute power Relative power Reflected Ray: 1e-014 1e-009 Total:	1000 🗧
Transmitted Ray: 1e-014 Te-009 Consecutive:	10 🗧
Scatter Ray Power Cutoff Thresholds	al Cutoff
Specular:	
Absolute power Relative power	
Reflected Ray: 0 Scatter:	1 🚍
Transmitted Ray: 0 0 Spec+Sc	at: 10 📩
Allowed Specular Operations Allowed Scatter Operations Parent Ray S	pecifier
	coherent power
Allow transmitted ray	-
Allow Total Internal Refl C Monte-Ca	rlo (1 ray only)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>			
Name	Name of the Raytrace Control.	Allow All			
Description	Alpha-numeric description of the Raytrace Control.	Allow reflected and transmitted specular rays			
Sp	Specular Ray Power Cutoff Thresholds				
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014			
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009			
Scatter Ray Power Cutoff Thresholds					

Reflected/Transmitted Ray Absolute Power	te Power discrete laboration of the reflected/transmitted ray drops below this level.						
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0					
	Intersection Count Cutoff						
Total	This value sets the maximum number of surface intersections for each ray.	1000					
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10					
	Ancestry Level Cutoff						
Specular	SpecularThis value sets the maximum number of Specular generations that can be split.						
Scatter	This value sets the maximum number of Scatter generations that can be split.						
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)					
	Allowed Specular Operations						
Allow reflected ray	Allow reflected ray Check this box to allow propagation of the reflected ray component.						
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked					
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked					
	Allowed Scatter Operations						
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked					
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked					
	Parent Ray Specifier						
Largest incoherent power	erent Check this radio button to allow FRED to determine the Parent ray following a surface intersection.						
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected					

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also....</u> Default Raytrace Controls – Allow All

For a detailed explanation of Raytrace Controls, select the following link <u>Raytrace Controls</u> To view the remaining default Raytrace Control settings select the following links <u>Halt All</u> <u>Transmit Specular</u> <u>Reflect Specular</u>

Default Raytrace Controls - Halt All

Description How Do I Get There? Dialog box and Controls See Also...

Description Default Raytrace Controls – Halt All

The Halt All raytrace control stops all rays incident on the surface.

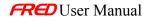
WARNING Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is required.

<u>How Do I Get There?</u> Default Raytrace Controls – Halt All

The dialog can be reached with a right click on the Halt All control under the <u>Raytrace</u> <u>Properties</u> folder.

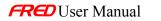
14		144	
Objects		Description	
🕞 🔄 Optical Source	es		
💷 🚅 Source 1			
🕂 🔤 Geometry			
📃 🛄 Analysis Surfa	ce(s)		
🕂 🧰 Materials			
🕂 🧰 Coatings			
🕂 应 Scatterers	ortion		
	Jerues	 _ , _	
= = = Transmit	∐raceable		
E Reflect S	Never Trac	eable (for trimming sur	faces)
Allow All	Draw Oute	r Enclosing Volume	
	 ⊆oordinate		
	⊻isualizatio	n Attributes	
	 Position/Or	ientation	
		rdinate System	
	Sc <u>a</u> le	~	
	👗 Cut		Ctrl+X
	🖺 Сору		Ctrl+C
	🕞 Paste		⊂trl+∀
	Delete (all l	highlighted items)	Del
	Su <u>m</u> mary R	leport	
	<u>D</u> etailed Re		
	Create a N	ew Raytrace Control Se	et
	Edit a Rayt	race Control Set	

The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



🔆 (FRED2 *) Crea	te a New Surf	ace as Child of:	"Elem 1"					_ 🗆 ×
Scatter	Visualizat	ion 📔 G	lue	Grating	1	Auxiliary Data	- L	ОК
SURFACE	Aperture	Location/Ori	entation	Materials	С	oating/RayControl		Cancel
Ray Colors	Coating						1	
Change color	Assigned:	Absorb		100% Abs	orbing (Coating		Apply
of rays that intersect this		Name	Descriptio	on		Assign		Help
surface:	List of Available	Absorb Reflect		orbing Coating	_			
🗖 Transmit	Coatings:	Transmit Standard Coating	100% Tra	nsmissive Coa smitting, 4% R	ating	Edit/View		
 *			g 30% Han	sinikang, 478 m	ene ↓	Create New		
E Reflect	Raytrace C	ontrol					$\frac{1}{2}$	
v	Assigned:	Halt All		Halt all ray	y compo	onents		
🔲 Diffract		Name	Descriptio	n		Assign		
T	List of	Halt All		y components		Assign		
	Available Raytrace	Transmit Specula Reflect Specular		smitted specul acted specular				
C Scatter	Controls:	Allow All		ay component:		Edit/View		
		•			▶	Create New		

<u>Dialog Box and Controls</u> Default Raytrace Controls – Halt All



(Carlos (FRED1 *) Edit Raytrace Control Set	? _ 🗆 🗙
Name	
Halt All	OK.
Description	Close
Halt all ray components	
	Apply
	Help
Specular Ray Power Cutoff Thresholds	
Absolute power Relative power	
Reflected Ray: 1e-014 Total:	1000 🗧
Transmitted Ray: 1e-014 Te-009 Consecutive:	10 🗧
Scatter Ray Power Cutoff Thresholds	Cutoff
Specular:	2 🕂
Absolute power Relative power Reflected Ray: 0 0 Scatter:	
helieuteu hay. ju scatter:	1 🕂
Transmitted Ray: 0 0 Spec+Scat:	10 🛬
Allowed Specular Operations Allowed Scatter Operations Parent Ray Spec	cifier
Allow reflected ray	herent power
Allow transmitted ray	
Allow Total Internal Refl	(1 and and a)
C Monte-Carlo	(Tray only)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>					
Name	Name of the Raytrace Control.	Halt All					
Description	Alpha-numeric description of the Raytrace Control.	Halt All ray components					
Sp	Specular Ray Power Cutoff Thresholds						
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014					
Reflected/Transmitted Ray Relative PowerFRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.		1e-009					
S	Scatter Ray Power Cutoff Thresholds						

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0				
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0				
	Intersection Count Cutoff					
Total	This value sets the maximum number of surface intersections for each ray.	1000				
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10				
	Ancestry Level Cutoff					
Specular	SpecularThis value sets the maximum number of Specular generations that can be split.					
Scatter	ScatterThis value sets the maximum number of Scatter generations that can be split.					
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)				
	Allowed Specular Operations					
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Unchecked				
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Unchecked				
Allow Total Internal Reflection	row that undergood lotal Internal					
	Allowed Scatter Operations					
Allow reflected ray	Allow reflected ray Check this box to allow propagation of the reflected scatter component.					
Allow transmitted ray	Allow transmitted ray Check this box to allow propagation of the transmitted scatter component.					
Parent Ray Specifier						
Largest incoherent power	Selected					

Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected
Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
ОК	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also....</u> Default Raytrace Controls – Halt All

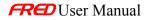
For a detailed explanation of Raytrace Controls, select the following link
Raytrace Controls
To view the remaining default Raytrace Control settings select the following links
Transmit Specular
Reflect Specular
Allow All

Default Raytrace Controls - Reflect Specular

Description How Do I Get There? Dialog box and Controls

<u>Description</u> Default Raytrace Controls – Reflect Specular

The Reflect Specular raytrace control allows only reflected rays to propagate if the flux (power) exceeds the specified thresholds. This control does not allow Total Internal Reflection.



WARNING	Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is
	required.

<u>How Do I Get There?</u> Default Raytrace Controls – Reflect Specular

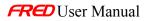
The dialog can be reached with a right click on the Reflect Specular control under the Raytrace Properties folder.

 ☐.	Halt all ray components Allow transmitted specular ray only	
	Iraceable	
	Never Traceable (for trimming surface	s)
	Draw O <u>u</u> ter Enclosing Volume <u>C</u> oordinate Axes Visualization Attributes	
	Position/Orientation Parent Coordinate S <u>v</u> stem Sc <u>a</u> le	
	🐰 Cut	Ctrl+X
	Copy	Ctrl+C
	💼 Paste	Ctrl+∀
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report Detailed Report	
	Create a New Raytrace Control Set	
	Edit a Raytrace Control Set	

The Dialog can also be reached using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.

(illuminator.frd	l) Edit Surface	: "mirror"				
Scatter	Visualizat	ion	Glue	Grating	Auxiliary Data	ОК
SURFACE	Aperture	Location/	Orientation	Materials	Coating/RayControl	Cancel
- Ray Colors	Coating					
Change color	Assigned:	Reflect		100% Refl	ective Coating	Apply
of rays that intersect this		Name	Descrip	otion	▲ Assign	Help
surface:	List of Available	Absorb Reflect		bsorbing Coating Reflective Coating		
🔲 Transmit	Coatings:	Transmit Standard Coa	100% 1	ransmissive Coa ansmitting, 4% R	ting Edit/View	
 *				instructing, 4% fr	Create New	
Reflect	Raytrace C	ontrol				
	-	Reflect Specu	lar	Allow refle	cted specular ray only	
Diffract		Name	Descrip	ition	Assign	
v	List of	Halt All		ray components		
	Available	Transmit Spec		ansmitted specul		
Scatter	Raytrace Controls:	Reflect Specu Allow All		eflected specular Il ray components		
 *		Allow All	Allow a	in ay components	Create New	

<u>Dialog Box and Controls</u> Default Raytrace Controls – Reflect Specular



🧳 (FRED1 *) Edit Raytrace Control Set	? _ 🗆 ×
Name	
Reflect Specular	0K.
Description	Close
Allow reflected specular ray only	/ nelv
	Apply
	Help
Specular Ray Power Cutoff Thresholds	ount Cutoff
Absolute power Relative power Reflected Ray: 1e-014 1e-009 Total:	1000 🛨
Transmitted Ray: 1e-014 1e-009 Consecutive:	10 📫
Scatter Ray Power Cutoff Thresholds	l Cutoff
Absolute power Relative power Specular:	2 🕂
Reflected Ray: 0 0 Scatter:	1.
Transmitted Ray: 0 0 G Spec+Sca	it 10 📻
Allowed Specular Operations Allowed Scatter Operations Parent Ray Sp	ecifier
	oherent power
Allow transmitted ray Allow transmitted ray O Beflected	3
Allow Total Internal Refi O Monte-Carl	o (1 ray only)

<u>Control</u>	Inputs	<u>Defaults</u>	
Name	Name of the Raytrace Control.	Reflect Specular	
Description	Alpha-numeric description of the Raytrace Control.	Allow reflected specular ray only	
Sp	ecular Ray Power Cutoff Thresholds		
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014	
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009	
Se	catter Ray Power Cutoff Thresholds		

Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	0	
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0	
	Intersection Count Cutoff		
Total	This value sets the maximum number of surface intersections for each ray.	1000	
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10	
	Ancestry Level Cutoff		
Specular	This value sets the maximum number of Specular generations that can be split.	2	
Scatter	This value sets the maximum number of Scatter generations that can be split.	1	
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)	
	Allowed Specular Operations		
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Checked	
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Unchecked	
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Checked	
	Allowed Scatter Operations		
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked	
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked	
	Parent Ray Specifier		
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected	
Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected	

Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
ОК	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also....</u> Default Raytrace Controls – Reflect Specular

For a detailed explanation of Raytrace Controls, select the following link
Raytrace Controls
To view the remaining default Raytrace Control settings select the following links
Halt All
Transmit Specular

Allow All

Default Raytrace Controls - Transmit Specular

Description How Do I Get There? Dialog box and Controls See Also...

Description Default Raytrace Controls – Transmit Specular

The Transmit Specular raytrace control allows only transmitted rays to propagate if the transmitted flux (power) exceeds the specified thresholds. This control does not allow Total Internal Reflection.



WARNING	Changing the default raytrace controls can have unexpected consequences. It is recommended that the user create a new control if different functionality is
	required.

<u>How Do I Get There?</u> Default Raytrace Controls – Transmit Specular

The dialog can be reached either by a right click on the Transmit All control under the <u>Raytrace Properties</u> folder...

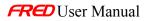
Objects		Description	
- Dptical Source:	s		
🕂 🔤 Geometry			
- 🛄 Analysis Surfac	e(s)		
🕂 🧰 Materials			
🕂 📃 Coatings			
🕂 📃 Coatings 🕂 🝻 Scatterers			
🗄 🔄 Raytrace Prope	erties		
🚽 🗾 🖉 Halt All		Halt all ray components	
🚽 🛫 Transmit S	pecular	Allow transmitted specular ray	
- 🛫 Reflect	Iracea	able	
Allow Al	\underline{N} ever Traceable (for trimming surfaces)		
	Draw (Outer Enclosing Volume	
	⊆oord	inate Axes	
— ⊻isuali		zation Attributes	
	Positio	n/Orientation	
•	Parent	t Coordinate S <u>v</u> stem	
	Sc <u>a</u> le,		
	Su <u>m</u> ma	ary Report	
	<u>D</u> etaile	ed Report	
	Create	e a New Raytrace Control Set	
	Edit a	Raytrace Control Set	

... or by using the Edit/View button under the Coating/Raytrace Control tab in the Edit/View Surface or Create a New Surface Dialogs.



FRED2 *) Crea	ite a New Surf	ace as Child o	of: "Elem 1"			
Scatter	Visualizat	tion	Glue	Grating	Auxiliary Data) ok
SURFACE	Aperture	Location/(Drientation	Materials	Coating/RayControl	Cancel
Ray Colors	Coating —					
Change color	Assigned:	Absorb		100% Abs	orbing Coating	Apply
of rays that intersect this		Name	Descript	ion	Assign	Help
surface:	List of Available	Absorb Reflect		sorbing Coating eflective Coatin		
Coatings:	Cuatings.	Transmit 100% Transmissive Coating Edit/ Standard Coating 96% Transmitting, 4% Refle				
<u>▼</u>					Create New	
Reflect	Raytrace C	ontrol				
	Assigned:	Halt All		Halt all raj	y components	
Diffract		Name	Descripti	on	Assign	
v	List of	Halt All		ay components		
	Available Raytrace	Transmit Spec		nsmitted specu		
🔲 Scatter	Controls:	Reflect Specu Allow All		lected specular ray component		
.		▲	Allow di		Create New	

<u>Dialog Box and Controls</u> Default Raytrace Controls – Transmit Specular



C (FRED1 *) Edit Raytrace Control Set	? <u>-</u>
Name	
Transmit Specular	0K.
Description	Close
Allow transmitted specular ray only	
	Apply
	Help
Specular Ray Power Cutoff Thresholds	ount Cutoff
Absolute power Relative power Reflected Ray: 1e-014	1000 🛨
Transmitted Ray: 1e-014 Te-009 Consecutive:	10 🛨
Scatter Ray Power Cutoff Thresholds	I Cutoff
Absolute power Relative power Specular:	2 -
Reflected Ray: 0 0 Scatter:	1÷
Transmitted Ray: 0 0 Spec+Sca	at: 10 🛫
Allowed Specular Operations Allowed Scatter Operations Parent Ray Sp	ecifier
	oherent power
Allow transmitted ray Allow transmitted ray C Transmitted C Reflected	d
Allow Total Internal Refl	lo (1 ray only)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Name of the Raytrace Control.	Transmit Specular
Description	Alpha-numeric description of the Raytrace Control.	Allow transmitted specular ray only
Sp	ecular Ray Power Cutoff Thresholds	
Reflected/Transmitted Ray Absolute Power	FRED halts ray propagation when the absolute power of the reflected/transmitted ray drops below this level.	1e-014
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	1e-009

S	catter Ray Power Cutoff Thresholds	
Reflected/Transmitted Ray Absolute Power	absolute power of the reflected/transmitted ray drops below	
Reflected/Transmitted Ray Relative Power	FRED halts ray propagation when the power of the reflected/transmitted ray relative to the incident ray drops below this level.	0
	Intersection Count Cutoff	
Total	This value sets the maximum number of surface intersections for each ray.	1000
Consecutive	This value sets the number of consecutive intersections each ray can have with a single surface.	10
	Ancestry Level Cutoff	
Specular	This value sets the maximum number of Specular generations that can be split.	2
Scatter	This value sets the maximum number of Scatter generations that can be split.	1
Spec+Scat	Sum of specular and scatter ancestries.	Unchecked (10)
	Allowed Specular Operations	
Allow reflected ray	Check this box to allow propagation of the reflected ray component.	Unchecked
Allow transmitted ray	Check this box to allow propagation of the transmitted ray component.	Checked
Allow Total Internal Reflection	Check this box to allow propagation a ray that undergoes Total Internal Reflection.	Unchecked
	Allowed Scatter Operations	
Allow reflected ray	Check this box to allow propagation of the reflected scatter component.	Checked
Allow transmitted ray	Check this box to allow propagation of the transmitted scatter component.	Checked
	Parent Ray Specifier	
Largest incoherent power	Check this radio button to allow FRED to determine the Parent ray following a surface intersection.	Selected

Transmitted	Check this radio button to always make the transmitted ray the Parent ray.	Not selected
Reflected	Check this radio button to always make the reflected ray the Parent ray.	Not selected
Monte-Carlo (1 ray only)	Check this radio button to invoke Monte-Carlo raytracing. Chooses either the transmitted, reflected or scattered ray based upon probability.	Not selected
OK	Accept Raytrace Control changes and close dialog box.	
Close	Discard Raytrace Control changes and close dialog box.	
Apply	Apply Raytrace Control changes and keep dialog box open.	
Help	Access this Help page.	

<u>See Also....</u> Default Raytrace Controls – Transmit Specular

For a detailed explanation of Raytrace Controls, select the following link <u>Raytrace Controls</u> To view the remaining default Raytrace Control settings select the following links <u>Halt All</u> <u>Reflect Specular</u> <u>Allow All</u>



Chapter 12 - New Coatings and Materials Digitization Tool

Description How Do I Get There? Dialog box and Controls

Description New Coatings and Materials Digitization Tool

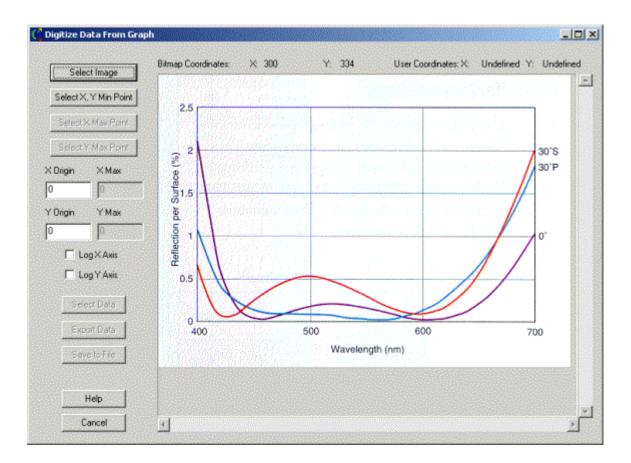
The Digitization Tool (or Digitizer) is a tool unique to FRED in the optical engineering software market. This tool allows the user to digitize data points from a graph, plot, lens drawing, etc in an image file. The user can import an image file in a number of different image file formats including BMP bitmap, PC Paintbrush, JPEG, Targa, or TIFF image file. The user then uses the mouse to identify the graph origin, the X-axis scale, and the Y-axis scale. The user can then acquire data from the image by using the mouse to point and click on the image.

These data points are then exported as different types of data, depending on how the Digitization Tool is started. For example, you can call the Digitizer from the Sampled Materials Edit dialog and display a graph of refractive indices versus wavelength. The data you select is then interpreted as wavelength-refractive index pairs.

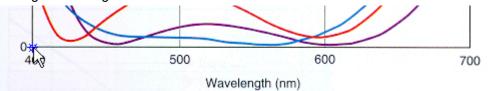
Follow this process for digitizing New Coating or New Material data from an image file:

- a) The option to digitize data is available in the Sampled Coating and Generalized Coating option in the New Coating dialog and the Sampled Material option in the New Material dialog. To access this tool, right mouse click in the sampled data area and select the appropriate Digitize data option in the right mouse click pop-up menu.
- b) Press the Select Image button and select the image file to digitize. The graph image will be displayed in the Digitization Tool Dialog. In the example below, a reflectivity graph for a single layer anti-reflection (AR) coating is being digitized.

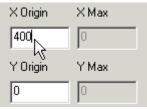




a) Press the Select X,Y Min Point button and then left mouse click on the point where the X and Y axes cross. The point clicked on with the mouse will be marked with this symbol:
 . The X Y minimum point selection can be changed as long as the Select X Max Point button is not pushed, once the Select X Max Point button has been pushed, this point can no longer be changed.

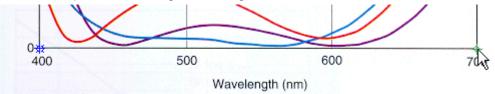


1. Enter the graph or plot coordinates where the X and Y axes cross, in this example the axes cross at X = 400 and Y = 0.

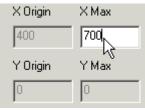


2. Press the Select X Max Point button and then left mouse click on the max coordinate on the X axis. This point will be marked with this symbol: +. Note that the point does not have to be the max value on the X axis, it just needs to be a point that can be numerically identified on the graph. The X maximum point selection can be changed as long as the

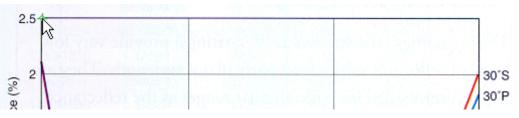
Select Y Max Point button is not pushed, once the Select Y Max Point button has been pushed, this point can no longer be changed.



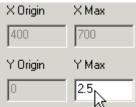
• Enter the graph coordinate for the point selected on the X-axis. In this example the selected X value is 700.



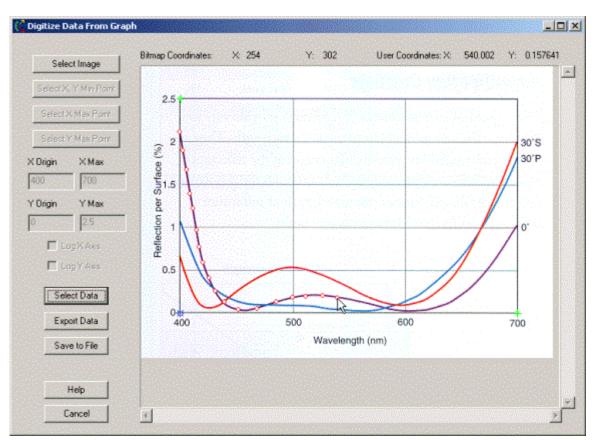
 Press the Select Y Max Point button and then left mouse click on the max coordinate on the Y axis. This point will be marked with this symbol: +. Note that the point does not have to be the max value on the Y axis, it just needs to be a point that can be numerically identified on the graph. The Y maximum point selection can be changed as long as the Select Data button is not pushed, once the Select Data button has been pushed, this point can no longer be changed. This point should be located above the previously selected X Min point.



• Enter the graph coordinates for the point selected on the Y-axis. In this example, the selected Y value is 2.5.



Press the Select Data button and start acquiring data by left mouse clicking on the appropriate data points in the graph. Each selected point will be marked with this symbol:
 The data points will not be sorted prior to loading them into the New Coating dialog so select the data points in ascending or descending wavelength order.



- In addition, the current image pixel and graph coordinates are listed at the top of the window.
- If you would like to save the acquired data to a ASCII text file press the Save To File button.
- After acquiring the data by selecting points on the graph, the data can be loaded into the into the dialog which generated the Digitizer by pressing the Export Data button. This will close the Digitizer and load the acquired data into the previous dialog.

How do I get there? New Coatings and Materials Digitization Tool

The Digitizer is available as a right mouse click pop-up menu option for entering sampled data into the New Materials and New Coatings dialogs.



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Coating					?
ame:	Coating 1				ОК
escription:					Cancel
	·				
ype:	Sampled Coating	(reflection/transm	ission for discrete wave	elengths) 💌	Help
Wau	elength (um)	Reflectio	n Coefficient	Tran	smission C
	75618 v 0	Power	Phase (deg)	Powe	er
<u>د </u>		Dele Appr Digit Digit	rt Wavelength te Wavelength end All <u>S</u> ource Wavelen <mark>ize <u>R</u>eflection Curve ize <u>T</u>ransmission Curve ort Data To a File</mark>		
🛟 New Ma				<u>?</u> ×	
Name:	Material 1			OK	
Descriptio	n:			Cancel	
				Help	
Туре:	Sampled Mater	rial (refraction indic	es for discrete waveler	athe)	
.,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	Loguipied indici	nai (rondonorrinaio			
	Wavelength (um)	Refractive l	ndex Imaginary	Refractive	
1	0.5875618	• 1	<u>i</u> n		
		Insert	'avelength Wavelength Wavelength		
		Appen	d All Source Waveleng	ths	
			e With Data From a Fil	e	

Dialog Box and Controls New Coatings and Materials Digitization Tool

0

Gradient Index Material Common P

Step Size Max # Steps X

1000

0.1

Digitize Material Index...

Export Data To a File ...

🧲 Digitize Data From Grapi	ı					
Select Image	Bitmap Coordinates:	X: 0	Y: 0	User Coordinates: X:	Undefined Y:	Undefined
Select X, Y Min Point						<u> </u>
Select X Max Point						
Select Y Max Point						
×Origin ×Max						
0 0						
Y Origin Y Max						
E Log X Axis						
🗖 Log Y Axis						
Select Data						
Export Data						
Save to File						
Help						T
Cancel	4					Þ

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Select Image	Allows selection of image file (*.bmp only).	
Select X, Y Min Point	Sets the origin of the X- and Y-axes on the image.	
Select X Max Point	Sets the maximum point on the X scale.	
Select Y Max Point	Sets the maximum point on the Y scale.	
X Origin	Sets the value of the origin point on the X scale.	0
Y Origin	Sets the value of the origin point on the Y scale.	0
X Max	Sets the value of the max point on the X scale.	0
Y Max	Sets the value of the max point on the Y scale.	0
Log X Axis	Defines the X-axis as a logarithmic axis. Values for the X Origin and X Max are limited to positive, nonzero values.	Unchecked
Log Y Axis	Defines the Y-axis as a logarithmic axis. Values for the Y Origin and Y Max are limited to positive, nonzero values.	Unchecked

Image Coordinates	Specifies the location of the cursor in bitmap coordinates, relative to the point X=0, Y=0 at the upper left corner of the image.	(0, 0) is at the upper left corner
User Coordinates	Specifies the location of the cursor in the coordinate system you define. Shown as undefined until Data Selection Mode chosen.	Undefined
Image	Displays the image selected for Digitization.	
Select Data	Toggles Data Selection Mode if all requisite parameters have been specified correctly.	
Export Data	Exports data selected to the dialog that brought up the Digitization Tool (for example, the sampled materials edit dialog).	[
Save to File	Saves selected data in a text file in x, y format, one point per line.	
Help	Brings up this help article.	
Cancel	Dismisses the dialog without exporting any data to the coating or material.	



Chapter 13 - The Modulation Transfer Function Calculation in FRED

Description - The Modulation Transfer Function Calculation in FRED

FRED can calculate the Modulation Transfer Function (MTF) for a given system. This help article explains how to do so.

Building The System - The Modulation Transfer Function Calculation in FRED

The system we will use for this article is a simple lens, focusing a source's light onto an analysis surface attached to a geometric surface. The lens is a simple biconvex BK7 singlet, with parameters r1=60 mm, r2=-300 mm, ct=4 mm, x semi-aperture=10, y semi-aperture=10. The lens has its image plane located at the paraxial focus.

🌾 (mtflens.frd) Edit Len	5			? _ 🗆 ×
Name: Lens 1				0K.
Description: simple BK7 s	inglet: r1=60 mm, rå	2=-300 mm, ct=4 mm		Close
Basic Parameters Parameter Type: F	Front Radius:	Back Radius:	Thickness:	Apply
	60	-300	4	Help
Lens Aperture Specification	on	_ Materials		
X Semi-ape: Y	Semi-ape:	Name:	Catalog:	Select:
10 10		N-BK7	Current	Glass
Advanced		Air	Current	Immersion
Location of the Lens (from	nt surface vertex)—			
Parent 1	Гуре Рага	meters		
1 Geometry. ▼	Make coin 👻			
		÷	÷÷	F
Derived Properties (comp	uted from the basic	parameters)		
Focal: 97.1303972707	Front Prin: 0.441	2128517 Wavlen(um)	: 0.5892938 💌	
Bend: 0.66666666666	Back Prin: -2.20	6064258 Edge Thick:	2.99408484229	Update

The geometric surface where the rays focus is a simple plane whose location specification is coincident with the second surface of the lens and shifted in the Z direction 94.591622 mm.

FRED User Manual

	Parent	Туре	Parameters
1	Geometry.Subassenbly 1.Lens 1.Surface 2 💌	Make coincident wit 💌	
	Geonetry.Subassenbly 1.Lens 1.Surface 2 💌	Shift in T direction	Z 94.591622

The source is a 41 x 41 grid of coherent rays pointed in a single, planar direction, with wavelength 0.55 $\mu m,$ and unit power.

(menensaro)	Edit Optical So	urce: "So	urce 1"			>
Polar	ization		Wavelengths	Vis	ualization	0K
Source	Positions/Dire	otions	Location/Orientation	Power	Coherence	Cancel
Logical Parent	Optical Sources	3				Apply
Name:	Source 1					Help
Description:	0.55 um cohere	ent source				<u>·</u>
	,					
-Immersion M	aterial		- Additional Phas	e to Add to the s	Source	
Name:	Catalog:	Selec	t Phase: 0	waves		
Air	Current	Selec		arter wave, 0.5	= half wave, etc.)	
	n Ray Propagation					
💌 No Extra	Propagation (do r	iothing)	C Propagate To P		7 0	
O Propaga	te by: 🔀 🖯		×: 0	Y:]0	Z: 0	
🔿 Propaga	teto: 🔀 🗐 🛛		C Propagate To S		7 0	
	te to optical		X: [0	Y: 0	Z: 0	
O Propaga	path length:		Most neg dis	the second se	tius: 1	

Polar	ization	_ I	Wavelengths	Visualization	0K
Source	Positions/D	irections	Location/Orientation	Power Coherence	Cance
Ray Position:	s				
Туре:	Grid Plane (re	ctangular array	of points arranged on a plane)		Apply
Parameters:		Parameter	Description		Help
	X Num Rays	41	Number of rays across X		
	YNum Rays	41	Number of rays across Y		
	X Semi-Ape	5	X Semi-aperture		
	Y Semi-Ape	5	Y Semi-aperture		
	Aperture	Elliptical 📘	The aperture shape		
	,			Y	
Ray Direction	ns				
Туре:	Single Directi	on (plane wave	e)		
Parameters:		Parameter	Description		
	X Component	0	X component of ray direction		
	Y Component	0	Y component of ray direction		
	Z Component	1	Z component of ray direction		



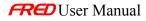
<u>(</u> (mtflens.frd) Edit Optical Sou	rce: "Source 1"		_ 🗆 🗙
Source Positions/Direc Polarization	tions Location/Orientation Wavelengths	Power Coherence Visualization	OK Cancel
Wavelength List Wavlens (um) Wei 1 0.55 1 2 1	ights Ray Color Type:		Apply Help

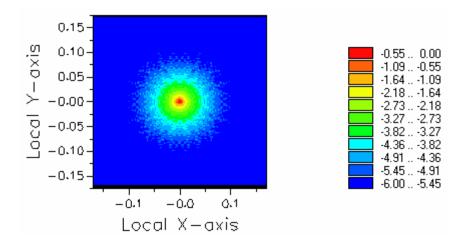


📢 (mtflens.frd) Edit Optical Sou	ırce: "Sa	urce 1'	•			
Pola	rization		Wavelengths		Visu	alization) ок
Source	Positions/Direc	tions	Loc	ation/Orientation	Power	Coherence	Cancel
Coherer	nt 🔿 Not	Coherent					Apply
Countier D	D ((Help
Gaussian Be	eam Properties (for (conerent d	oniyj				
	eams Overlap Facto	or:		The featies of event		-6	
1.5			<	The fractional overl Gaussian beams wh	nen created in a	grid.	
				Typically this has a	value between	1.4 and 1.6.	
	Secondary Rays:			The		- i - t - dith	
8	<u> </u>		<	The number of seco each Gaussian bea			
				value 4 or 8.			
	Ray Scale Factor:	_	<	Advanced feature.	Tunicallu this ha	as the value	
1				1.0. Changing this			

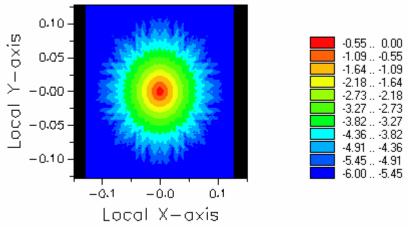
Analysis - The Modulation Transfer Function Calculation in FRED

The point spread function for this system with Log (Normal PSF) $\lambda = 0.55$ mm 0.32 waves 3rd order spherical EPD = 10 mm f/# = 9.68 Gives this point spread function:





The point spread function for this system with Log (Normal PSF) $\lambda = 0.55$ mm 1 wave 3rd order spherical EPD = 13.31 mm f/# = 7.27 Gives this point spread function:



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<u>Setting Up The Calculation - The Modulation Transfer Function Calculation in</u> <u>FRED</u>

In order to fully sample the spatial frequency out to the lens cutoff, the minimum half width of the analysis plane must be at least the following (I, F, D in lens units):

$$w_{\min} = \frac{N_x^2 \lambda F}{4N_f D} = \frac{N_x^2}{4N_f} \cdot \lambda(f/\#)$$

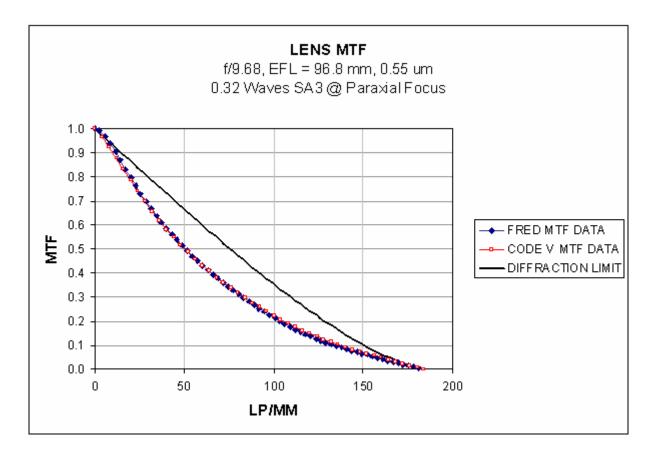
In this equation the variables are defined as follows:

- $N_x ==$ number of pixels in the analysis plane for the irradiance spread function (PSF)
- w == half width of the analysis plane for the irradiance spread function (PSF)
- $\Delta_x == pixel size in lens units = 2w/Nx$
- N_f == number of pixels in the transform grid;
 - a. the transform grid must have 2n x 2n pixels (i.e. ...16, 32 , 64, 128, 256, 512, ...)
 - b. FRED automatically sizes the transform grid so that it is 2n x 2n. Its size is the smallest grid for which Nf is greater than or equal to Nx
 - if N_x = 127, then FRED makes N_f = 128
 - if $N_x = 128$, then FRED makes $N_f = 128$
 - if N_x = 129, then FRED makes N_f = 256
- $\Delta f == pixel size in 1/lens units = 1/(Nf*Dx)$
- $\lambda ==$ wavelength in lens units
- F == focal length
- D == entrance pupil diameter

Comparison - The Modulation Transfer Function Calculation in FRED

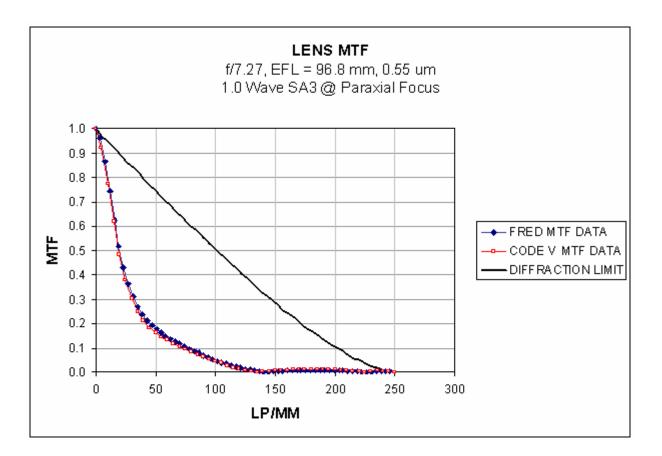
For the following graph, Lens EPD = 10 mm Cutoff frequency = 184 lp/mm Image plane grid: 128x128 pixels, 0.348 mm x 0.348 mm full width in X and Y





For the following graph, Lens EPD = 13.31 mm Cutoff frequency = 250 lp/mm Image plane grid: 128x128 pixels, 0.256 mm x 0.256 mm full width in X and Y







Description - Chart Axes Labels Dialog

This dialog sets the label text for the axes of a 3-D plot.

How Do I Get There? - Chart Axes Labels Dialog

From a 3-D plot, right-click and choose "Axes Labels...".

Dialog Box and Controls - Chart Axes Labels Dialog

📢 Charl	Axes Labels	<u>?×</u>
X-axis	Local X-axis	OK I
Y-axis	Local Y-axis	Cancel
Z-axis	Irradiance	Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
X-axis	Displays the label applied to the X axis	Local X-axis
Y-axis	Displays the label applied to the Y axis	Local Y-axis
Z-axis	Displays the label applied to the Z axis	(Analysis dependent)
OK	Applies the changes and dismisses the dialog	
Cancel	Discards the changes and dismisses the dialog	
Help	Displays this help article	

Application Notes - Chart Axes Labels Dialog

This dialog is modal and not resizable.

See Also - Chart Axes Labels Dialog

Plot Color Dialog

FRED User Manual

Adjust Image Brightness

Description - Adjust Image Brightness

How Do I Get There? - Adjust Image Brightness

There are three different ways to execute this command: Menu Keyboard Accelerator Toolbar Button Include Images

Dialog Box and Controls - Adjust Image Brightness

Adjust Image Brightness	×
Brightness less than 1 to dim 1 greater than 1 to t	prighten
Report number of out-of-gamut colors	Update
OK Cancel	Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>

Application Notes - Adjust Image Brightness

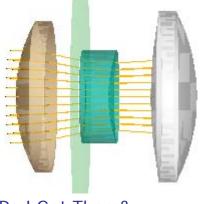


Chapter 15 - Advanced Raytrace

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

Description Advanced Raytrace

The Advanced Raytrace is a user-customized raytrace and is the most flexible of all raytrace methods. The user has the option to 1) choose sequential, non-sequential or specific paths to be traced, 2) specify the number of intersections to be traced, 3) start and/or stop rays on specified surfaces, 4) prevent or allow reflect/transmit operations, 5) create and trace source rays or simply trace existing rays, 6) select which rays are to be traced, 7) save path and history information pertaining to the current raytrace, 8) control which traced rays are drawn to the screen, and 9) temporarily supress scattering and summary printout.



How Do I Get There? Advanced Raytrace

There are three different ways to execute this command:

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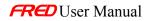
1. Select Advanced Trace in the Raytrace Menu,



<u>R</u> aytrace <u>3</u> D View <u>C</u> reate	<u>A</u> nalyses <u>W</u> indow <u>H</u> elp
🎬 <u>T</u> race All Sources	Ctrl+Shift+F5
🗳 Trace and <u>R</u> ender	Ctrl+Shift+F7
🤐 Create All Source Rays	Ctrl+Shift+F8
🔆 Delete Existing Rays	Ctrl+Shift+F9
Trace Existing Rays	Ctrl+Shift+F10
→ Trace Existing and Render	Ctrl+Shift+F11
1→ Trace Single Ray	Ctrl+Shift+1
+ Trace Targeted Ray	Ctrl+Shift+2
Ray Manipulation Utilities.	
#Puser-defined Ray Paths	. Ctrl+Shift+U
Coherent <u>F</u> ield Synthesis.	
A→ <u>A</u> dvanced Raytrace	Ctrl+Shift+A
or press the keyboard ac	celerator keys: Ctrl+Sh

- 3. or press the toolbar button: $A \rightarrow$

Dialog Box and Controls Advanced Raytrace



(FRED1) Advanced Raytr	ace		
Raytrace Method			
Non-sequential with hiera	irchical search		
O Non-sequential with linea	r search		Cancel
${f C}$ Sequential using raytrace	: path #; 🛛 🛛 🛛 🛛 🛛 🛛 🖉	-	Apply/Trace
${f C}$ Sequential using a user-d	lefined path:		
No paths defined		*	Help
Ray Start/Stop Surfaces			- 199 1
C Specify number of surface	e intersections	1	
Specify start/stop surface	es explicitly:	×.	
Start: Do not care			-
Stop: Do not care			
otop. [Do not cale			10000
SU - 92.			
What to do after the ray inter			
Perform the transmit/r	reflect operatio	n	
	reflect operatio	n	
 Perform the transmit/r Do not perform the transmit/r 	reflect operatio	n operation	
Perform the transmit/r Do not perform the tra Starting Rayset F	reflect operatio ansmit/reflect o	n operation aced	to 2147483647
 Perform the transmit/r Do not perform the tra Starting Rayset Traceable sources 	reflect operatio ansmit/reflect o Rays To Be Tra	n operation aced	to 2147483647 tep 1 📑
 Perform the transmit/r Do not perform the tra Starting Rayset Traceable sources 	reflect operatio ansmit/reflect o Rays To Be Tra Rays from	n operation aced	1
 Perform the transmit/r Do not perform the tra Starting Rayset Traceable sources Existing rays only 	reflect operatio ansmit/reflect o Rays To Be Tra Rays from	n operation aced 0 s	1
Perform the transmit/r Do not perform the tra Starting Rayset Traceable sources Existing rays only Miscellaneous	reflect operatio ansmit/reflect o Rays To Be Tra Rays from All Rays All Rays	n operation aced 0 s raytraced	1

<u>Control</u>	<u>Description</u>	<u>Defaults</u>				
	Raytrace Method					
Non-sequential with hierarchical search	Default ray-tracing mode. See application notes below for an explanation of the search process.	Selected				
Non-sequential with linear search	See application notes below for an explanation of the search process.	Not selected				
Sequential raytrace using raytrace path #	If selected, rays will only be traced for selected user-defined path.	Not selected				
Sequential using a user- defined path:	Opens a pop-up menu showing the user defined paths.	No paths defined				
Ray Start/Stop Surfaces						
Specify number of surface intersections:	Number of intersections before raytrace terminates.	1				



Specify start/stop surfaces explicitly: What to do after the ray	Specifies at which surfaces the raytrace will start and stop. Determines if the ray will transmit, reflect,	Start: Do not care Stop: Do not care Perform the			
intersects the stop surface:	or do nothing after it encounters the stop surface.	transmit/reflect operation			
	Starting Rayset				
Traceable sources	Trace all sources.	Selected			
Existing rays only	Trace only existing rays.	Not selected			
	Rays To Be Traced				
Rays from	Rays numbers (inclusive)	All active rays			
All rays	Use all rays.	All active sources			
	Miscellaneous				
Draw every	Determines if the rays will be rendered when traced.	Render			
Create/use ray history file	Generates history file for later use.	Unchecked			
Determine paths	Add each path traced to the list of paths as the paths are found.	Unchecked			
Suppress raytrace summary	Do not print raytrace summary to output window.	Unchecked			
Suppress ray scattering	Temporarily turns off all scattering for this trace.	Unchecked			
OK	Trace rays and close dialog box.				
Cancel	Discard tracing anymore rays and close dialog box.				
Apply / Trace	Trace rays with current selections and keep dialog open.				
Help	Access this Help page.				

Application Notes Advanced Raytrace

• The Advanced Raytrace uses the same buffer as all other trace options with the exception of the single raytrace, which has its own temporary

buffer. Therefore, the raytrace results from an Advanced Trace are available to the analysis planes, spot diagrams, and spread functions.

• Upon completion of a raytrace, *FRED* prints a Raytrace Summary to the Output Window. The user is encouraged to examine this print-out for timing information and as a diagnostic tool.

<u>RAYTRACE SUMMARY:</u>	<u>:</u> (ghost.frd)
	07/30/07 10:16:29
81	Num rays at start
1566	Num rays at end
1566	Num rays traced
4936	Num ray-surface intersections
0.319 sec	Elapsed ray trace time
0.28125	Total ray trace CPU time (seconds)
0.882280	Ratio of Cpu time to elapsed time
4912.536	Rays traced per elapsed second
4912.536	Rays processed per elapsed second
15484.21	Intersections per elapsed second
2	Num processors/cores detected
1	Num threads used during the raytrace
No	Ray buffer interlaced during trace

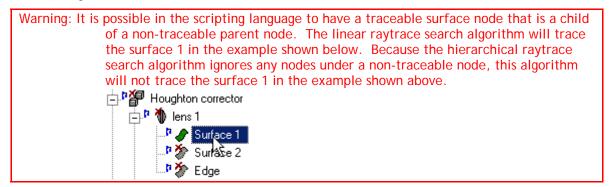
- The Trace Advanced command has the following options:
- 1. Trace using one of the following three methods:
 - 2. Hierarchical surface search algorithm,
 - 3. Linear surface search,
 - 4. Or trace a previously set user defined ray path. Note that the ray paths are defined with <u>User Defined Ray Paths</u> command.
- 5. Trace the existing <u>ray set</u> using one of the three methods above.
- 6. Trace all new rays using one of the three methods above. This option deletes the existing ray set and creates a new ray set from the currently traceable sources.
- 7. Render the rays during the trace.

The user-defined ray path can pause the rays at any surface in the path with the ray path ray controls. The rays can then be continued on the path by selecting the Trace Existing Rays option in the Advanced Trace dialog and pressing the apply button in the dialog box. If after the rays have hit a paused surface the "Delete existing rays and recreate all sources" option is used, then the rays will be traced from the source(s) to the same paused surface. It will appear as if nothing has changed.

Note If the rays have been traced along a sequential or mixed sequential and nonsequential path with a pause in the path, then the rays can be traced beyond the surface marked with a pause in the path by selecting "Existing Rays Only" in the Advanced Trace dialog and pressing Apply (or OK).

1. The linear raytrace search algorithm systematically checks every traceable surface node to determine if the ray interests the bounding surface. If the ray intersects the bounding surface, then the algorithm checks to see if the ray intersects the surface. After the algorithm has determined all the surfaces that the ray intersects, the closest

surface is chosen as the next surface intersection. The process then repeats. This algorithm does not consider and non-surface nodes.



The hierarchical raytrace search algorithm searched the FRED geometry nodes starting with a parent node and then working down through the children, grandchildren, etc. until the all progeny nodes have been searched. At each node (parent, child, grandchild, etc.), the algorithm first checks to see if the node is traceable. If the node is not traceable, then skips that node and all of its children and grandchildren. If the node is traceable, then it checks to see if the ray intersects the bounding box for that node. If the ray intersects the bounding box, then the algorithm checks to see if the ray intersects the surface. If the node is a surface, then the algorithm checks to see if the ray intersects the surface. If the node is not a surface, and it has child nodes then it systematically follows the same process for the child nodes. This process continues until all of the node under a parent node have been checked. Then the algorithm moves on to the next parent node. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

1. FRED and FRED Turbo

The multi-core usage feature is active at the time of a raytrace unless:

- 1. the user invokes a "Trace and Render" or "Trace Existing and Render"
- 2. the Advanced Raytrace "Determine raypaths" check-box is checked,
- 3. the Advanced Raytrace "Create/use ray history file" check-box is checked.

See Also.... Advanced Raytrace

<u>Trace and Render</u> <u>Trace All Sources</u> <u>Trace Existing Rays</u> <u>Trace Existing and Render</u> <u>Trace Single Ray</u> <u>Delete Existing Rays</u> <u>Create All Source Rays</u> <u>User Defined Ray Paths</u> <u>User Defined Ray Paths</u>

How Do I Get There? - Analyze Scatter Importance Sampling Dialog

After a Scatter Direction has been assigned to a surface, select the Tools menu, then select "Analyze Scatter Importance Sampling...".

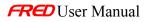
Eile Edit View	Tools Raytrace 3D View Create Analyses Window	Help
]™ ≌ ₽ ≊] ~ #	Preferences User Defined Scripting Tools Units and Scaling	•
FRED1 *	Edit/View GRIN Material Position/Orientation	
Objects	<u>R</u> eports	•
🕂 🔁 Optical	Determine Scatter Importance Sampling	
📄 🚍 Geomet	Analyze Scatter Importance Sampling	
En La Fol	Force Immediate Document Undate	



Dialog Box and Controls - Analyze Scatter Importance Sampling Dialog

🔆 (FRED:	1 *) A	nalyze	Scatter In	nportanc	e Samplii	ng	
"Detector" Surface to Scatter Toward:							
.Detecto	or (Pla	inar Surfa	ace)				•
Importan	it Samp	oled Surfa	aces (analyz	e all checi	ked):		
	Test	#Rays	Material		Surface		
1		10	Air (Air)	-	.Detector	(Planar S	Surface)
Wavelen	-	ang (111)) Weights	Pay Col	Prin	t efficienc	v results
1	0.5892		/ Weights			ne text win	
2	0.000		1		🗖 Dra	w the rays	used to
-	e and i					npute the e	
Analyze	s anu t	1036	CIUSE		andiyze		help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
"Detector" Surface to Scatter Toward	Identifies which surface will be used to perform the scatter analysis.	The first surface found in the tree that has a Scatter Direction assigned.
Important Sampled Surfaces (analyze all checked):	Contains the list of surfaces that have importance samplings assigned.	
Wavelengths:	Lists the wavelengths assigned to the importance sampling.	One wavelength (0.5892938 um) with weight 1 and white color



Print efficiency results to the text window	When checked, prints the results in the output window.	Checked
Draw the rays used to compute the efficiency	When checked, draws the rays used in the calculation in the Visualization Window.	Unchecked
Analyze and Close	Performs an analysis and closes the dialog.	
Close	Closes the dialog without performing an analysis.	
Analyze	Performs an analysis and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Analyze Scatter Importance Sampling Dialog

This dialog is both resizable and modeless.

See Also.... - Analyze Scatter Importance Sampling Dialog

Auto-Compute Scatter Importance Sampling Dialog



Chapter 16 – Importance Sampling and how to Auto-Compute Scatter Importance Sampling

Importance Sampling

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Importance Sampling

Importance Sampling defines a direction or region of interest towards which scattered rays are allowed to propagate. This method significantly increases the efficiency of the raytracing task. **FRED** handles the radiometry such that the proper amount of power is scattered into the given solid angle according to the specified scatter model.

How Do I Get There? Importance Sampling

An Importance Sampling is specified as a *Scatter Direction Region(s)* of *Interest* entry on the Scatter Tab of any Surface entity.



_

SURFACE Aperture Location/Drientation Materials Coating/RayControl OK Scatter Visualization Glue Grating Auxiliary Data Modifiers Cance Note: Checked items are active, unchecked items are ignored during the raytrace Available Scatter Properties: Appl Scatter Assigned Scatter Properties: Available Scatter Properties: Hell Image: Image	FRED2 *) Create a New !	_	
Note: Checked items are active, unchecked items are ignored during the raytrace Scatter Available Scatter Properties: Assigned Scatter Properties: Available Scatter Properties: Harvey Shack (Polished surface sca Edit/View Black Lambertian Kharvey Shack Polished surface Edit/View Create New Scatter Direction Region(s) of Interest			К
Scatter Available Scatter Properties: Appl Assigned Scatter Properties: Name Description Harvey Shack (Polished surface sca > Remove Name Description Black Lambertian 4% Lambertian 96% Lambertian Harvey Shack Polished surface Edit/View Edit/View Create New Image: Create New Scatter Direction Region(s) of Interest Image: Create New Image: Create New			ncel
Assigned Scatter Properties: Assigned Scatter Properties: Harvey Shack (Polished surface sca < Assign Hell Assigned Scatter Properties: Name Black Lambertian White Lambertian Harvey Shack Polished surface Edit/View Create New		Apr	ply
Assign Name Description Black Lambertian White Lambertian White Lambertian Harvey Shack Polished surface Create New Create New Scatter Direction Region(s) of Interest	Assigned Scatter Propertie	He	aln
Image: Scatter Direction Region(s) of Interest	✓Harvey Shack (Polishe)	ition	;ih
Edit/View			
Edit/View Create New Scatter Direction Region(s) of Interest			
Scatter Direction Region(s) of Interest		a surrac	
Scatter Direction Region(s) of Interest			
Scatter Direction Region(s) of Interest			
	J		
ImpSamp1Remove			
	✓ImpSamp1	ove	
Edit/View		Iew	
Add New		ew	
	1		

Dialog Box and Controls

Importance Sampling

The following Importance Sampling Types are available:

Through a closed curve

	Туре:	Type: Scatter rays through a closed curve		
	Selected Curve			
Curve Elem 1.Curve 1 ()				
<u>Control</u>	Inputs /	nputs / Description		
Curve	An existin aimed.	First available curve		

In a given direction

Type: Scatter rays into a given direction Help					
	Value	Description			
Angle	90	Semi-Angle (deg) of the solid angle cone			
Х	0	X component of direction vector			
Y	0	Y component of direction vector			
Z	1	Z component of direction vector			
Entity	Global Coordinate S	yste 💌 Coordinate system of the direction vector			

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Angle	Semi-angle (deg) of a cone centered about the Direction vector.	90
XYZ	Direction vector.	0,0,1
Entity	Coordinate system in which the XYZ vector is specified.	Global Coordinate System

Towards an entity

	Туре:	Scatter rays toward an entity	Help	
	Entity	Selected Entity		
<u>Control</u>			<u>Defaults</u>	
Entity	Entity Entity towards which rays are to be scattered.			

Towards a point

Туре:	Scatter rays toward a p	ooint Help
	Value	Description
Angle	90	Semi-Angle (deg) of the solid angle cone
Х	0	X component of position vector
Y	0	Y component of position vector
Z	1	Z component of position vector
Entity	Global Coordinate Syste 💌	Coordinate system of the position vector

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Angle	Semi-angle (deg) of a cone centered about the Position vector.	90
XYZ	X,Y,Z position of point to scatter towards.	0,0,1

Entity Coordinate system in which the XYZ vector is specified.	Global Coordinate System
--	--------------------------------

Into the specular direction

	Тур	Type: Scatter rays into the specular direction			Help
		Value Description			
	Angle 45 Semi-Angle (deg) of the solid angle cone				
<u>Control</u>	<u>Inputs</u>	Inputs / Description			
Angle		Semi-angle of solid angle cone centered on the specular direction.			

Towards an ellipsoidal volume

Туре:	Scatter rays toward an ellipsoidal volume Help				
	х	Υ	Z	Description	
Center	0	0	1	Center of the ellipsoid	
X-dir	1	0	0	Vector along ellipsoid's X-axis	
Y-dir	0	1	0	Vector along ellipsoid's Y-axis	
Semi-Apes	0.1	0.1	0.1	Semi-apertures of the ellipsoid	
Entity	Global Coordinate System 📃			Coordinate system of the ellipso	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Center	Center location of ellipsoid.	0,0,1
X-dir	Vector direction specifying ellipsoid's X-axis	1,0,0
Y-dir	Vector direction specifying ellipsoid's Y-axis	0,1,0
Semi- Apes	Ellipsoid semi-dimensions in X, Y & Z.	0.1, 0.1, 0.1
Entity	Coordinate system in which the ellipsoid is specified.	Global Coordinate System

Application Notes Importance Sampling

• Assignment of a scatter model MUST be accompanied by the specification of at least one Importance Sampling Region of Interest.

- Multiple Importance Sampling specifications can be assigned to any given surface.
- Each Importance Sampling specification is applied to every Scatter model assigned.
- New As of version 6.100, surfaces are now created with a default scatter importance sampling into the hemisphere. The user can now quickly add useful scattering to a surface by simply assigning the desired scatter model to the surface without bothering to explicitly assign an importance specification. Keep in mind that the default importance sampling is a general one that scatters into the whole hemisphere and is not optimized for efficiently generating scatter ray directions specific to any particular geometry.

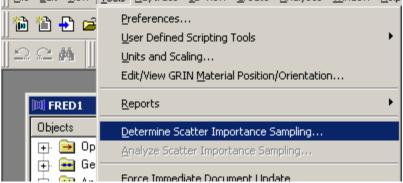
<u>See Also....</u> Importance Sampling

> Determine Importance Sampling Analyze Importance Sampling

Auto-Compute Scatter Importance Sampling

How Do I Get There? - Auto-Compute Scatter Importance Sampling Dialog

On the Tools menu, then select "Determine Scatter Importance Sampling...".



FRED User Manual

Dialog Box and Controls - Auto-Compute Scatter Importance Sampling Dialog

🔇 (FRED1) Auto-Compute Scatter I	mportance Sampling						
Scatter to the Specified Detector "Detector" Surface to Scatter Toward							
.Detector.Flat surface (Planar Surfac	•						
Immersion Material:	Wavelengths:						
Air (Air)	▼ Wavlens (um) Wei	ghts Ray Colo					
# of Rays to Emit per surface: I Emit Rays For 5000							
Scatter from the Specified Surfaces Compute importance sampling for all checked surfaces (right mouse-click for pop-up menu) Image: Surface Image: Su							
<u>Control</u>	Inputs / Description	<u>Defaults</u>					
"Detector" Surface to Scatter Toward:		The first surface found in the tree that has a Scatter Direction assigned.					
Immersion Material:		Air					
# of Rays to Emit per surface:		5000					
Emit Rays Forward		Checked					
Emit Rays Backward		Checked					
Wavelengths:		0.5892938					
Scatter from the Specified							
Surfaces		None Selected					

Print Computed Information		
also print ray paths		
Draw the rays used to compute the importance sampling		
Replace old importance samples with the new ones		
Compute and Close	Closes the dialog and computes the Scatter Importance Sampling.	
Close	Closes the dialog and does not compute the Scatter Importance Sampling.	
Compute	Computes the Scatter Importance Sampling and does not close the dialog.	
Help	Displays this help article	

Application Notes - Auto-Compute Scatter Importance Sampling Dialog

This dialog is both resizable and modeless.

See Also.... - Auto-Compute Scatter Importance Sampling Dialog



Chapter 17 - Background Grid Dialog

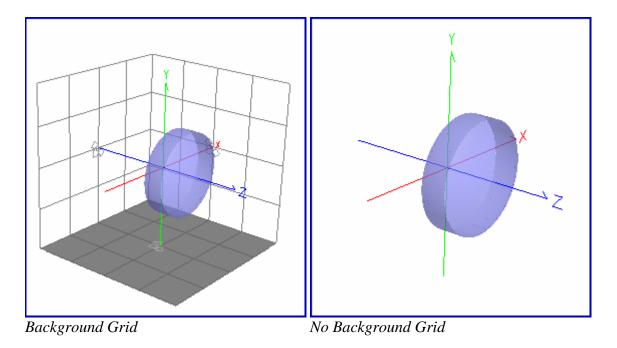
Description - Background Grid Dialog

This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

		×			
Units of Measurement	Warnings Miscellaneous Visualization	File Locations			
Draw local trimming volume when creating a new surface Draw surface trimming volumes instead of surfaces (for large models)					
Printing Mode • Auto C MetaFile C Bitmap	Background Grid	in new systems			
Default Visualization View	Screen Dackground Internet	recommended) πer Background			

Visualization (example) - Background Grid Dialog

An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.





🔆 (FRED1 *) Bac	:kgrour	d Grid Settin	gs		? _ 🗆 ×
Gobal Cube Dim	nensions				OK I
×min <mark>-</mark> 1	Xn	hax 1	X Divi	isions 🛛 🛨	Cancel
Ymin -1	Yn	nax 1	Y Divi	isions 🛛 🗧	Apply
Z min .1	Zn	nax 1	Z Divi	isions 4 📫	Help
Drawing Attribut	es of Ea	ch Cube Face-			
	Draw Face	Face Color	Draw Axis	Axis Color	Display As
Front (XY +z)					Grid Lines 💌
Back (XY -z)			▼	──	Grid Lines 💌
Left (ZY -x)					Grid Lines 💌
Right (ZY +x)			▼	□	Grid Lines 💌
Top (ZX +y)		-			Grid Lines 💌
Bottom (ZX -y)				□	Filled Grid 💌

Background Grid settings for the example shown above.

How Do I Get There? - Background Grid Dialog

There are three different ways to execute this command:

1. Select Edit Background Grid in the 3D View Menu,



2. or press the keyboard accelerator keys: Ctrl+Shift+F12,



3. or press the toolbar button:

Dialog Box and Controls - Background Grid Dialog

((FRED1 *) Ba	ckground	Grid Settin	gs		? <u>- </u> ×
Gobal Cube Din X min -1 Y min -1 Z min -1	nensions Xma Yma Zma	x 1	Y Div	isions 4 = isions 4 = isions 4 =	Cancel Apply Help
Drawing Attribut Front (XY +z) Back (XY -z) Left (ZY -x) Right (ZY +x) Top (ZX +y) Bottom (ZX -y)	Draw	ace Color	Draw Axis V V V	Axis Color	Display As Grid Lines I Grid Lines I Grid Lines I Grid Lines I Filled Grid I

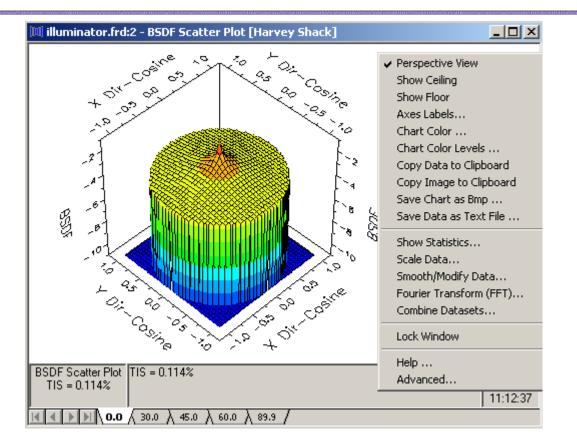


<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Global Cube Dimensions, X min, Max	Lists the minimum and maximum extent of the background grid on the X axis	-1, 1
Global Cube Dimensions, Y min and max	Lists the minimum and maximum extent of the background grid on the Y axis	-1, 1
Global Cube Dimensions, Z min and max	Lists the minimum and maximum extent of the background grid on the Z axis	-1, 1
Global Cube Dimensions, X Divisions	Lists the number of divisions in the X direction of the background grid	4
Global Cube Dimensions, Y Divisions	Lists the number of divisions in the Y direction of the background grid	4
Global Cube Dimensions, Z Divisions	Lists the number of divisions in the Z direction of the background grid	4
Drawing Attributes of Each Cube Face, Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences)	Unchecked
Drawing Attributes of Each Cube Face, Face Color	Selects the color of the given grid face	Dark gray
Drawing Attributes of Each Cube Face, Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox	Checked
Drawing Attributes of Each Cube Face, Axis Color	Selects the color of the axis labels	Light gray
Drawing Attributes of Each Cube Face, Display As	Selects the drawing style for the background grid faces. Options are Filled Grid, Grid Lines, and Grid Points.	Grid lines
ОК	Changes the Background Grid, dismisses the dialog.	
Cancel	Dismisses the dialog without changing the Background Grid.	
Help	Brings up this help article.	
Apply	Changes the Background Grid and does not dismiss the dialog.	

Description - BSDF 3D Plot Setup Dialog

Provides a 3D plot of an existing scatter model at selected angles of incidence.

Visualization (example) - BSDF 3D Plot Setup Dialog

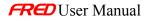


FRED User Manual

How Do I Get There? - BSDF 3D Plot Setup Dialog

Right-click on the scatter model you want to create a plot for and choose "Plot 3D".

Objects	Description		
en in the second	Description		
- 📻 Geometry			
- 🛄 Analysis Surface(s)			
+ 💼 Materials			
🕂 🛄 Coatings			
🕒 🧫 Scatterers			
📕 📜 🛩 Black Lambertian	4% Lambertian		
😕 😕 White Lambertian	96% Lambertian		
🔤 🖅 Harvey S 🛛 🔤 🖉	rceable		
🕂 💼 Raytrace Prop			
<u></u>	ver Traceable (for trimming surfaces)		
Dra	aw Outer Enclosing Volume		
Ωo	ordinate Axes		
∢ <u>V</u> is	ualization Attributes		
	sition/Orientation		
	rent Coordinate System		
	_		
	<u>a</u> le		
Su	mmary Report		
De	tailed Report		
 	eate a New Scatterer		
	Edit/View Scatterer		
	· · · · · · · · · · · · · · · · · · ·		
	t 2D (Angle)		
	t 2D (Beta - Beta0)		
Plo	t 3D		



Dialog Box and Controls - BSDF 3D Plot Setup Dialog

SDF 3D Plot Setup	? ×
Specular Angles 0 30 45 60 89.9 degrees	OK Cancel
Enter list of angles from 0 to 89.9 degrees	Help
Number of Plot Samples X: 101 Y: 101	
BSDF Scale © Logarithmic floor is 10 📑 decade C Linear	es below peak

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Specular Angles	List incident angles for which scatter data is plotted. Entered in ascending order.	0, 30, 45, 60, 89.9				
	Number of Plot Samples					
Х, Ү	Number of evenly spaced angular samples used to evaluate scatter model for plotting.	101, 101				
BSDF Scale						
Logarithmic	Display BSDF values as logarithmic.	Selected				
Linear	Display BSDF values as linear.	Not selected				
Floor is	Minimum value displayed below peak in decades.	10				
OK	Accept plot settings and close dialog box.					
Cancel	Discard plot settings and close dialog box.					
Help	Access this Help page.					

Application Notes - BSDF 3D Plot Setup Dialog

See Also - BSDF 3D Plot Setup Dialog

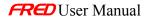
Plot 2D

Chapter 19 - Insert Lens from Catalog

Description - Insert Lens from Catalog

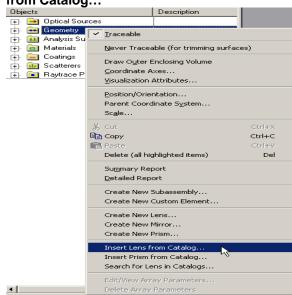
This dialog allows the selection and entry of a lens into your system from a vendor catalog. The lens is inserted with the location and orientation specified in the dialog.

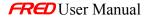
Note	FRED inserts the lens using the units provided by the vendor. Currently, in all cases, the units are millimeters. If this is not the unit of measure for your system, the lens is scaled by the appropriate factor for your system.
	For example, if your system uses centimeters and you import a singlet whose semi-aperture measures 10 mm by 10 mm, the Edit Lens dialog will show the singlet as having a 1.0 cm by 1.0 cm semi-aperture.



How Do I Get There? - Insert Lens from Catalog

To execute this command, right click on the **Geometry** folder and choose **Insert Lens** from Catalog...





Dialog Box and Controls - Insert Lens from Catalog

Serial Number	Туре		Diameter	Length	Effective Focal Length	Back Fo
15588	PCX		1		0.6	0.17
15589	PCX		1		1	0.57
13394	PCX		1.5		1	0.57
13395	PCX		1.5		1.5	1.07
13396	PCX		2		1.5	1.07
13397	PCX		2		2	1.57
13398	PCX		2.5		2	1.57
13399	PCX		2.5		2.5	2.07
15590	PCX		2.5		3	2.57
15118	PCX		3		3	1.88
15142	PCX		3		4.5	3.5
32953	PCX		3		6	4.81
32955	PCX		3		9	8.01
15070			2		10	11.20
ens Location a	nd Orientation.					
Refer	ence Coordinate Acti	ion Para	meters (right mou	se-click	for popup menu)	OK
Chartin	iq Coordinate System					

<u>Control</u>	Inputs	<u>Defaults</u>				
Lens Catalog	Shows selected vendor catalog.	Edmund Industrial Optics				
Lens List	Shows lenses available from vendor selected in the Lens Catalog list.	Edmund Industrial Optics lenses				
Lens Location and Orientation	Shows Location and Orientation modifiers that will apply to lens when placed in the FRED document.	Parent = Geometry Type = Make coincident with another coordinate system				
OK	Insert Catalog lens and close dialog box.					

Cancel	Close dialog without inserting Catalog lens.	
Apply	Inserts Catalog lens and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Insert Lens from Catalog

- This dialog is modeless, so you can have this window open while working on other things in your system.
- You may bring up more than one of these dialogs for a single system at a time.

See Also ... - Insert Lens from Catalog

Select Prism from Catalog



Chapter 20 - Insert Prism from Catalog

Description - Insert Prism from Catalog

This dialog allows the selection and entry of a prism into your system from a vendor catalog. The prism is inserted with the location and orientation specified in the dialog.

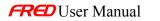
Note	FRED inserts the prism using the units provided by the vendor. Currently, in all cases, the units are millimeters. If this is not the unit of measure for your system, the prism is scaled by the appropriate factor for your system.
	For example, if your system uses centimeters and you import a right-angle prism whose input face measures 10 mm by 10 mm, the Edit Prism dialog will show the prism as having a 1.0 cm by 1.0 cm input face.



How Do I Get There? - Insert Prism from Catalog

To execute this command, right click on the **Geometry** folder and choose **Insert Prism** from Catalog...

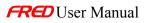
Objects	[Description	
🕀 🦻 Optical Sou	ırces		
🗗 📻 Geometry 🕂 🏛 Analysis St	✓ <u>T</u> raceable		
🕂 💼 Materials	<u>N</u> ever Traceable	e (for trimming surface	es)
🕂 🚺 Scatterers	Draw O <u>u</u> ter End		
🕂 直 Raytrace F	<u>C</u> oordinate Axe: <u>V</u> isualization Att		
	Position/Orienta	tion	
	Parent Coordina	ate S <u>v</u> stem	
	Sc <u>a</u> le		
	X Cut		Ctrl+X
	Copy		Ctrl+C
	🔁 Paste		Ctrl+∀
	Delete (all highli	ghted items)	Del
	Summary Report	t	
	Detailed Report		
	Create New Sub	bassembly	
	Create New Cus	stom Element	
	Create New Len	is	
	Create New Mirr	or	
	Create New Pris	m	
	Insert Lens from	n Catalog	
	Insert Prism from		
	Search for Lens	in Catalogs ん	



Dialog Box and Controls - Insert Prism from Catalog

Serial Number		Description		Material		Uncoated
\32998	Dove	Tech Spec D		BK7		
\32999	Dove	Tech Spec D		BK7	1 8 M	2.
132553	Dove	Tech Spec D		BK7	1/2	V.
\31055	Dove	Tech Spec D		BK7		-1
132554	Dove	Tech Spec D		BK7		VLX.
45403	Dove	Tech Spec D		BK7	Coated	N II
45815	Dove	Tech Spec D		BK7	1 AN	1 2 m
45816	Dove	Tech Spec D		BK7	RTN.	
45112	Penta	Tech Spec Pe		BK7		STIL.
\32030	Penta	Tech Spec Pe		BK7		N. K.O
43502	Penta	Tech Spec Pe		BK7	18	
\31051	Penta	Tech Spec Pe		BK7	121	
42779	Penta	Tech Spec Pe		BK7	· 1	1 T
15072	Donto	L Look Cooo Di	ooto Brom	•	-	S.
ism Location (and Orientatio	on				
Refer	ence Coord	dinate Action	Parameters (ri	ght mouse-click for p	opup menu)	OK
				3		

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Prism Catalog	Shows the vendor whose catalog is listed in the Prism List.	Edmund Industrial Optics
Prism List	Shows the prisms available from the vendor selected in the Prism Catalog list.	Edmund Industrial Optics prisms
Prism Diagram	Shows a diagram of the prism, listing various dimensions specified in the Prism List.	Click on a prism to see its dimensions
Prism Location and Orientation	Shows the Location and Orientation Modifiers that will apply to the prism when it is placed in the FRED document.	Parent = Geometry Type = Make coincident with another coordinate system



OK	Inserts prism and close dialog box.	
Cancel	Discard prism and close dialog box.	
Apply	Inserts prism and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Insert Prism from Catalog

- This dialog is modeless, so you can have this window open while working on other things in your system.
- You may bring up more than one of these dialogs for a single system at a time.

See Also - Insert Prism from Catalog

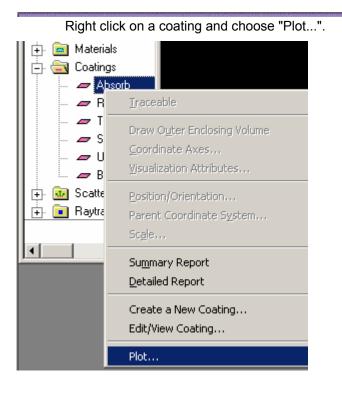
Select Lens from Catalog



Chapter 21 - Coating Plot Setup Dialog

Description - Coating Plot Setup Dialog

How Do I Get There? - Coating Plot Setup Dialog





Dialog Box and Controls - Coating Plot Setup Dialog

Coating Plot Setup	X
Vary © Wavelength © Angle	OK
Media Incident Material	Cancel
Air (Air)	Help
Substrate Material Standard Glass (Schott BK 💌	
Plot Parameters At incident angle 0.0000000 de	g
Min Wave (um) Max Wave (um) 0.587562 0.587562	Num Steps 101
Plot Trans/Refl C Phase	
Transmission: 🔽 Average 🔲 S-F Reflection: 🔲 Average 🗔 S-F	_

Control	Inputs / Description	Defaults
Wavelength		Selected
Angle		Not Selected
Incident Material		Air
Substrate Material		Standard Glass (Schott BK7)
Incident Angle		
Minimum Wavelength		
Maximum Wavelength		
Number of Steps		
Transmit/Reflect		Selected
Phase		Not Selected
Average Transmission		Checked
S-Pol Transmission		Unchecked

P-Pol Transmission		Unchecked
Average Reflection		Unchecked
S-Pol Reflection		Unchecked
P-Pol Reflection		Unchecked
OK	Closes the dialog and draws the plot	
Cancel	Closes the dialog and does not draw the plot	
Help	Displays this help article	

Application Notes - Coating Plot Setup Dialog

This dialog is modal and not resizable.

See Also - Coating Plot Setup Dialog



Chapter 22 - Changing *FRED's* Plots, Axes, and Visualization Attributes

Plot Color Levels

Description How Do I Get There? Dialog box and Controls

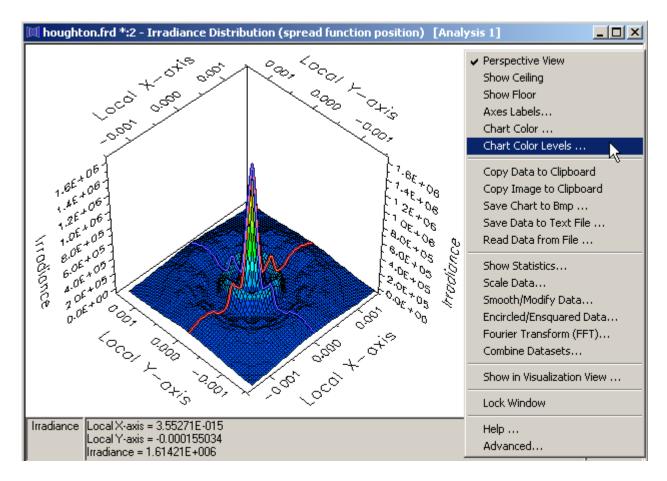
Description Plot Color Levels Dialog

The Plot Color Levels Dialog allows you to select the style and number of levels for the color scale of 3-D plots. These styles are specified in .sty files, located by default in <FRED Installation Directory>\Resources\Charts. Each chart type has its own default style, which is what is loaded into the chart when it is brought up for the first time. FRED will automatically adjust the number of levels and range of each level when you press the OK button.

How Do I Get There? Plot Color Levels Dialog

From a 3-D plot, right-click and choose "Chart Color Levels"





Dialog Box and Controls Plot Color Levels Dialog

(Color Levels	_ 🗆 🗙
Color Level Style Select	Cancel
Number of Levels 10	Apply
	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Color Level Style	Selects the chart style definition file.	
Number of Levels	A number from 1 to 100	10



OK	Accept Color Level changes and close dialog box.	
Cancel	Discard Color Level changes and close dialog box.	
Apply	Apply Color Level changes and keep dialog box open.	
Help	Access this Help page.	



Description - Color Similarity

How Do I Get There? - Color Similarity

There are three different ways to execute this command:

- 2. Menu
- 3. Keyboard Accelerator
- 4. Toolbar Button

Include Images

Dialog Box and Controls - Color Similarity

Color Similarity ? 🗙		
Your chart's background color is this:		
At least one of your ray colors is this: You may change the background color with this button, or you may click "Keep Color" button to keep the color scheme as it is:		
Make this change permanent: 🔲		
Change Color Keep Color		

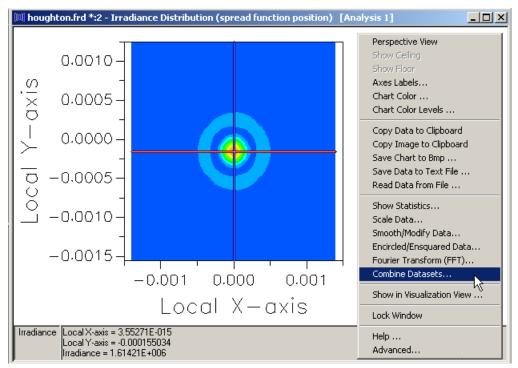
<u>Control</u>	Inputs / Description	<u>Defaults</u>

See Also.... - Color Similarity

Combine Datasets

This command, available in the right mouse click pop-up menu, brings up the Combine Datasets dialog box. This dialog provides an environment where the current dataset can be combined with saved datasets with the same number of grid points in X and Y, the same grid spacing, and the same analysis plane size.

Warning Once a combination has been applied to the dataset, there is no trivial way to recover the original dataset without recalculating the spread function from the filtered rays.



Irradiance spread function contour

_

	(FRED1 *) Combine With A Chart Data File			<u>? ×</u>
Data File To Cor	mbine With T	his Chart		>>>
🔲 Restore Origin	al Data File B	Before Performing th	ne Selected Operat	ion
Operation	Current C	hart Parameters —	Maximum	Chan Cine
Add	XValue	Minimum -3210.35	3267.93	Step Size 101.223
C Subtract	Y Value	-418.596	6059.68	101.223
C Multiply	Z Value	0	8.24702e-005	
< Malapiy	Row	1	64	1
	Column	1	64	1
OK		Close]	Apply	Help

The Combine Datasets dialog

The Combine Date dialog is broken up into four sections: the file to combine with this dataset, restore original data set, the operation, and current chart parameters.

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Data File To Combine With This Chart	File name of a previously saved data file with the same grid size, grid location, and grid spacing as the current dataset.	Blank
>>>	Equivalent to Open or Browse. Brings up an Open File dialog.	
Restore Original Data File Before Performing the Selected Operation	If checked, the original dataset will be restored prior to performing the next combining operation.	Unchecked
Operation		
Add	Adds the two data sets pixel by pixel.	Selected
Subtract	Subtracts the two data sets pixel by pixel.	Not Selected
Multiply	Multiplies the two data sets pixel by pixel.	Not Selected
Current Chart Parameters		
X,Y Value, Min/Max	The current dataset min and max values in the X,Y direction. This is set by the analysis plane parameters.	

X,Y Value, Step Size	The step size between grid points in the X,Y direction. This is set by the analysis plane parameters.	
Z Value, Min and Max	The min and max Z values in the current dataset.	
Row: Min/Max	The number of pixels in the "X" direction.	
Row: Step Size	Always 1	
Column: Min/Max	The number of pixels in the "Y" direction.	
Column: Step Size	Always 1	
OK	Accept indicated combinations and close dialog box.	
Close	Closes the dialog without any further combinations but does not cancel already applied combinations.	
Apply	Apply indicated combinations and keep dialog box open.	
Help	Access this Help page.	

Coordinate Axes...

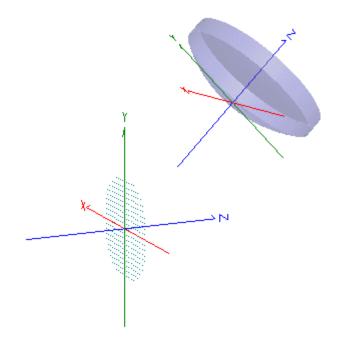
Description - Coordinate Axes...

The Coordinate Axes visualization dialog is accessed via the right mouse click context menu. It is functionally identical to the Coordinate Axes control found under the Visualization tab on the Surface dialog.

Visualization (example) - Coordinate Axes...

The following image shows Coordinate axes rendering for a source and at tilted and decentered catalog lens.





How Do I Get There? - Coordinate Axes...

The Coordinate Axes dialog is accessed via the right mouse click pop-up context menu.

Objects	Description
🚎 📄 Optical Sources	
占 🚘 Geometry	
🕂 🌗 Newport KPX313 # 1 👖	Mouroat Plana Conuc
🕂 🗬 detector	✓ <u>T</u> raceable
💷 Analysis Surface(s)	Never Traceable (for trimming surfaces)
🕂 🧰 Materials	
🕂 📻 Coatings	Draw O <u>u</u> ter Enclosing Volume
🕂 🖬 Scatterers	Coordinate Axes
🕂 间 Raytrace Properties	Visualization Attributes
	Position/Orientation



候 (FRED3) Coordinate	e Axes Visualization	ו	? <u>- </u> ×
Draw: Geometry	0		
Direct Specification-			
Origin	Neg Axis Length	Pos Axis Length	Axis Color
	1	1	
X: 0	<u>li</u>	1	
Y: 0	1	1	
Z: 0	1	1	
Absolute origin	Absolute length	Relative values a	
C Relative origin	C Relative length	as fraction of trim	iming volume
- Scale		al Length	
		Set to same length	1
			,
	Course 1		
	Cancel	Apply H	lelp

Dialog Box and Controls - Coordinate Axes...

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Draw	Check this box to render the coordinate axes for the displayed node.	Unchecked
	Direct Specification	
Origin	Enter the X, Y, and Z offsets of the coordinate axes from the local origin.	(0,0,0) absolute origin
Neg Axis Length	Enter the absolute or relative X, Y, and Z negative axes lengths.	(1.2,1.2,1.2) rel length
Pos Axis Length	Enter the absolute or relative X, Y, and Z positive axes lengths.	(1.2,1.2,1.2) rel length
Axis color	Change the axis color using the standard Windows color palette.	X=Red Y=Green Z=Blue
Absolute origin	Select this option to orient the coordinate axes relative to the local origin of the displayed node.	Selected
Relative origin	Select this option to orient the coordinate axes relative to the origin of the local (surfaces only) or global bounding volume.	Not selected
Absolute Length	Select this option to fix the axis lengths in system units.	Selected

Relative Length	Select this option to size the axes lengths based on the local (surfaces only) or global bounding volume.	Not selected
	Scale	
Scale lengths by	Scale axes lengths.	Unchecked (1)
	Equal Length	
Set to same length	Make all axes of same length.	Unchecked (1)
ОК	Accept Coordinate Axes Visualization changes and close dialog box.	
Cancel	Discard Coordinate Axes Visualization changes and close dialog box.	
Apply	Apply Coordinate Axes Visualization changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Coordinate Axes...

- The default settings for the dialog are to draw the coordinate axes at the local origin of the selected node with axis lengths that are scaled relative to the size of the bounding volume. If the bounding volume is not symmetric in three dimensions, the axes are rendered with different lengths.
- Selecting the relative position option is useful if the bounding volume is not centered at the local origin.
 - Only surfaces have a local bounding volume that may be both shifted and rotated
 - All other entities have a global bounding volume that may be decentered, but is never rotated
 - FRED always shows the local or global bounding volume in the Visualization window whenever a node is selected.
- Coordinate axes can be rendered for any Optical Sources, Geometry, or Analysis Surface(s) node.

Examples - Coordinate Axes...

Example 1 – Change the rendered color

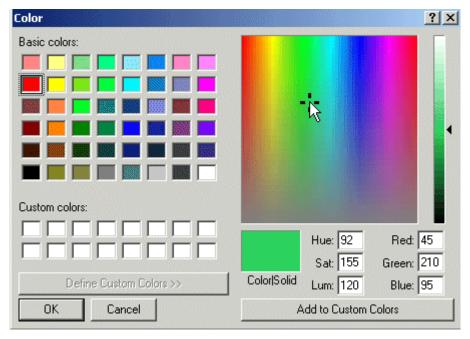
The axis rendering colors are edited via a standard Windows color palette, as shown in the following example. Any one of the displayed colors can be selected.



To expand the list of available colors, left mouse click on the 'Other...' button.

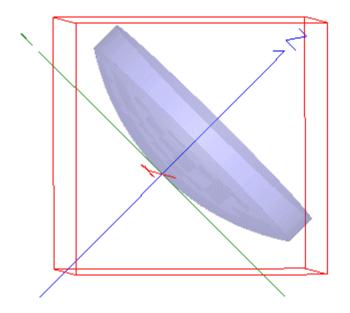


Now choose a color from the Windows palette and 'Add to Custom Colors' to save it, if so desired. Left mouse click on the OK or Cancel buttons to close the dialog. Note that the list of available colors may differ from that shown in the figure if a different color resolution is being used.



Example 2 – The difference between absolute and relative coordinate axis origins Absolute coordinate origin: The coordinate axes are coincident with the local origin of the lens entity. The global bounding volume is shown.

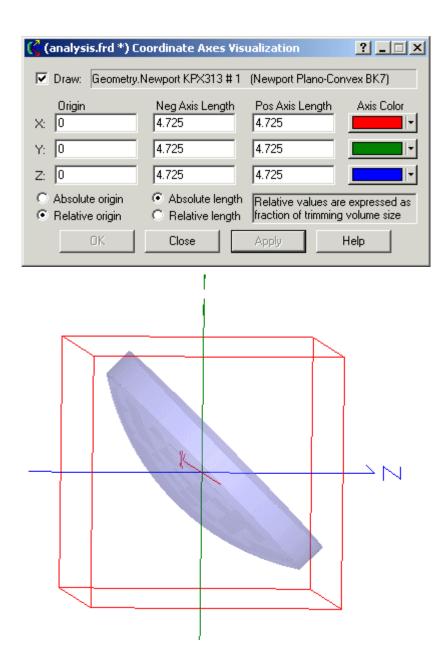
🕻 (analysis.frd *)	Coordinate Axes Vis	ualization	? _ 🗆 🗙
🔽 Draw: Geomet	ry.Newport KPX313 # 1	(Newport Plano-Co	nvex BK7)
Origin X: 0	Neg Axis Length 4.725	Pos Axis Length 4.725	Axis Color
Y: 0	4.725	4.725	•
Z: 0	4.725	4.725	•
 Absolute origin C Relative origin 	 Absolute length C Relative length 	Relative values ar fraction of trimming	
OK	Close	Apply	Help



Relative coordinate origin:

The coordinate axes are coincident with the local origin of the global bounding volume for the lens. The global bounding volume is shown.







See Also - Coordinate Axes...

Help for other options available from the right click pop-up menu is available by selecting the appropriate links.

Traceable Sequential Raytrace Draw Global Enclosing Volume Coordinate Axes... Visualization Attributes... Position/Orientation... Parent Coordinate System... Scale... Summary Report

Detailed Report

Curve Visualization Tab

Description - Curve Visualization Tab

This property tab allows you to modify the visualization attributes of the curve.

How Do I Get There? - Curve Visualization Tab

Bring up the Curve dialog by right clicking on a custom element, lens, mirror, or prism, then choose "Create New <u>Curve...</u>", or right click on an existing curve. Click the Visualization tab.

Dialog Box and Controls - Curve Visualization Tab



—

🕻 (FRED1 *) Create a New Curve as Child of: "Elem 1"	_ 🗆 X
Curve Location/Orientation Visualization	ОК
Curve	Cancel
Draw	Apply
	Help
Tesselation	
Tesselation Step Size: 0 < Enter 0 for default	
Scale Factor: 1 < Scale factor for step size	
- Bounding Volume	

Control	Inputs / Description	Defaults
Curve Color	Determines the color of the curve	Green
Draw Curve Checkbox	Draws the curve when checked	Unchecked
Tessellation Step Size	Determines the granularity of the curve when drawn. A value of zero sets the granularity to a heuristically determined default value.	0
Scale Factor	Scales the tessellation by the specified amount	1
Bounding Volume Color	Determines the color of the bounding box	Gray
Draw Bounding Volume Checkbox	Draws a box around the curve when checked	Unchecked
ОК	Applies the changes and dismisses the dialog	
Cancel	Does not apply changes and dismisses the dialog	
Apply	Applies the changes and keeps the dialog visible	
Help	Displays this help article	

Application Notes - Curve Visualization Tab

This property tab is both modeless and resizable.

See Also - Curve Visualization Tab

Curve Tab Location/Orientation Tab

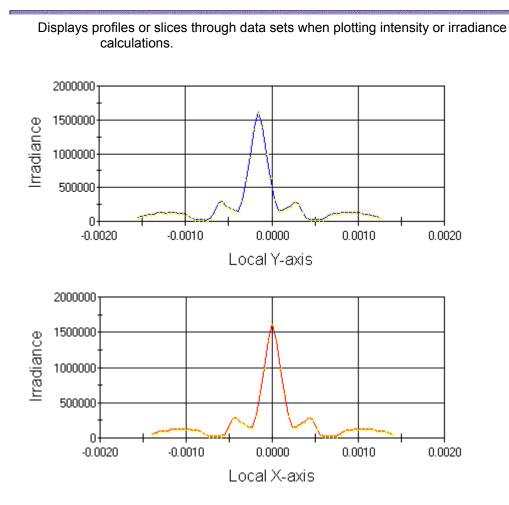


Charts Profile View

Description
How Do I Get There?
Dialog box and Controls
Application Notes
Examples
See Also

Description

Profile View



How Do I Get There? Profile View

There are three different ways to execute this command:

1. Select any of the functions below from the Analysis Menu:

ዡ Irradiance Spread Function	Ctrl+F10
Э Intensity Spread Function	Ctrl+F12
🖏 Energy Density	Ctrl+Shift+E
에 Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
<mark>∑</mark> ⊆olor Image	

2. Press any of the keyboard accelerator keys: Ctrl+F10, Ctrl+F12, Ctrl+Shift+E, Ctrl+Shift+W.

ک 😥

🖷 🎦

3. Press any of the toolbar buttons:

Dialog Box and Controls

Profile View

No dialog box is available with this function.

Application Notes Profile View

Lock Window Chart Color	Lock Window <u>Chart Color</u> Chart Symbols
Chart Symbols Copy Image to Clipboard Copy Data to Clipboard	Copy Image to Clipboard Copy Data to Clipboard Save Chart as Bmp
Save Chart as Bmp Save Data as Text File Help	Save Data as Text File Help
Advanced	Advanced

Examples Profile View

See Also.... Profile View



Chapter 23 - Decompose Wavefront

Decompose Wavefront

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Decompose Wavefront

Performs a Zernike decomposition from the computed wavefront data. The user can specify the number of Zernike terms for the fit as well as subtract out the first 6 terms.

How Do I Get There? - Decompose Wavefront

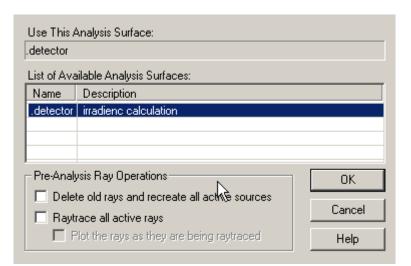
Decomposition of the wavefront into Zernike coefficients requires four steps:

1.

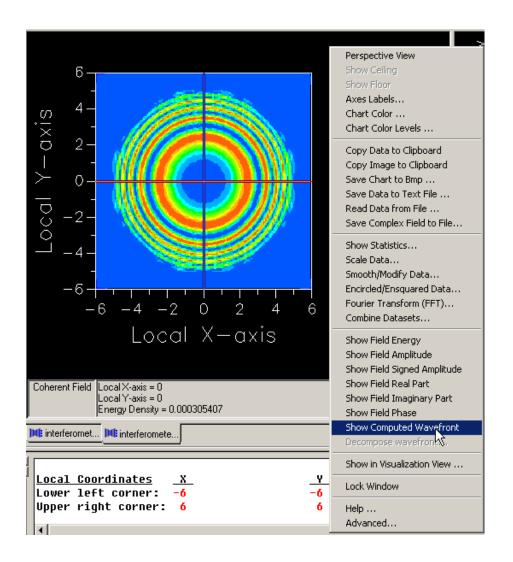
; [<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
28	📃 Ray St <u>a</u> tus	Shift+F10
_	🤝 Ray <u>S</u> ummary	Shift+F11
_	12 Ray Statistics	Shift+F12
di	Paraxial Analysis (first order)	Shift+F3
	🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S
	Pest Geometric Focus	Shift+F9
io	≒= Fiber Coupling Efficiency	Ctrl+Shift+F
	🐙 Stray Light <u>R</u> eport	
	Generate IES Output	
	🙀 Positions Spot Diagram	Ctrl+F9
	🎭 Polarization Spot Diagram	Ctrl+Shift+L
	🙏 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
	🕎 Directional Spot Diagram	Ctrl+F11
	🐢 Visualization 3D Spot Diagram	
	👾 Irradiance Spread Function	Ctrl+F10
	൙ Intensity Spread Function	Ctrl+F12
	😡 Energy Density	Ctrl+Shift+E
	Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
	💋 <u>C</u> olor Image	43



2.

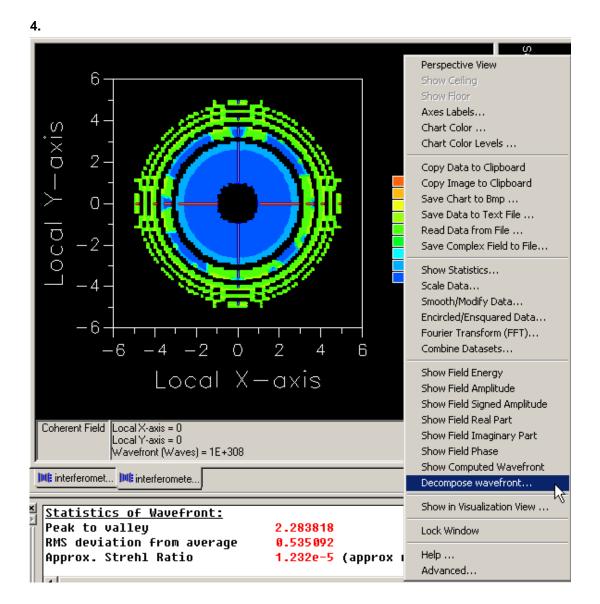


3.





—



Dialog Box and Controls - Decompose Wavefront

Decompose Wavefront		?×
Zernike Decomposition		
- Origin	Aperture	
×0: 0	×SemiAp:	1
Y0: 0	YSemiAp:	1
Max Term Number: 65		
Print coefficients in outp	ut window	
Exclude coefficients with ma	agnitudes less tha	in: 0
Wavefront Modifications		7
🔲 Subtract piston (term 0)		
🔲 Subtract tilt along X (terr	n 1)	
🔲 Subtract tilt along Y (terr	n 2)	
🔲 Subtract 0/90 deg astigr	matism (term 3)	(OK)
🗖 Subtract defocus (term 4	4)	Cancel
🔲 Subtract +-45 deg astign	natism (term 5)	Help

<u>Control</u>	<u>Defaults</u>				
Zernike Decomposition					
Origin	X,Y origin of Zernike.	0,0			
Aperture	X,Y semi-aperture of Zernike.	1,1			
Max Term Number	Maximum number of Zernike terms to include.	65			
Print coefficients	Prints coefficients to output window.	Checked			
Exclude coefficients	Exclude coefficients with magnitude less than user-defined value.	0			
	Wavefront Modifications				
Subtract piston	Subtract tilt (term 0) from Decomposed Wavefront.	Unchecked			
Subtract tilt along X	Subtract X-tilt (term 1) from Decomposed Wavefront.	Unchecked			
Subtract tilt along Y	Subtract Y-tilt (term 2) from Decomposed Wavefront.	Unchecked			
Subtract 0/90 deg astigmatism	Subtract astigmatism (term 3) from Decomposed Wavefront.	Unchecked			

Subtract defocus	Subtract defocus (term 4) from Decomposed Wavefront.	Unchecked
Subtract +/- 45 deg astigmatism	Subtract astigmatism (term 5) from Decomposed Wavefront.	Unchecked
ОК	Accept Wavefront Modifications and close dialog box.	
Cancel	Discard Wavefront Modifications and close dialog box.	
Help	Access this Help page.	

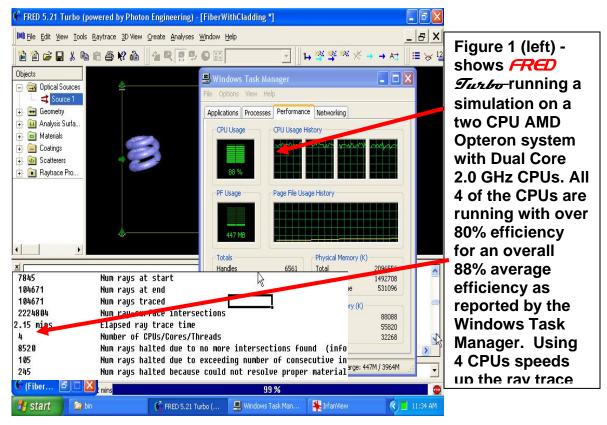
Application Notes - Decompose Wavefront

See Also - Decompose Wavefront



Chapter 24 - FRED Turbo

FRED Turbo takes advantage of the high performance capabilities of today's multi-cpu systems containing more than 2 cores. Our new **Turbo** edition dramatically increases ray trace speed by breaking up the raytracing task across multiple CPUs without user intervention. **FRED** Turbo has been tested on AMD Opteron, Intel Xeon, and Duo-Core CPU technologies. Typical benchmark results show an average ray trace speed increase of 3x for a two CPU Opteron Dual Core system (4 cores) over a single CPU. Some types of simulations which benefit from **Turbo** are tolerancing, Point Source Transmittance (PST), illumination systems requiring millions of rays to check for uniformity, non-sequential ghost analysis and thermal imaging problems.



Example Turbo results

Type of System Traced	Number or	Single Threaded	Multi-Threaded Mode-	Speed
with large ray bundle	Rays	Mode – Speedy (1	Speedy (4 CPUs) HP	Increase
	Traced	CPU) HP xw9300	xw9300 series	
		series		
Enclosed Tube multiple	54316	85.6 secs	26 secs	3.29
geometry types				
LED Lightpipe Example	45000	35.2 secs	15.7 secs	2.24
Elliptical Reflector	486245	54.9 secs	14.5 secs	3.79
Classical Cassegrain	224576	12 secs	4.53 secs	2.65



Chapter 25 – Miscellaneous Topics using FRED

Color Separation by Polarization

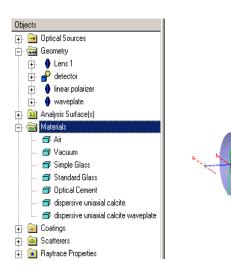
Description How Do I Get There?

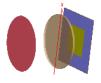
Description - Color Separation by Polarization

This example illustrates the spatial separation of color resulting from passage through birefringent optical elements. Polarized white light is incident upon a simple lens made from calcite, a uniaxial crystal. The converging bundle continues through a waveplate and a polarizing element and is captured on a screen. The Color Image feature in FRED is used to display the spatially distributed spectra.

Example - Color Separation by Polarization

Start by setting up the geometry. Included here are a plano-convex calcite lens followed by a calcite waveplate, a linear polarizer and a collection plane.





Even though there are two orientations of calcite in this model, only one calcite material need be created. The material orientation defined for the lens has its fast axis along global-z:



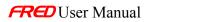
—

polari	zed_cryst	al_col	ors3_600.f	rd) Edit Material	: "dispersivo	e uniaxial calcite"	>
aterial	Absorption	n Volu	ime Scatter				0K
Name:	dispe	rsive u	niaxial calcite				Cancel
Descrip	tion:						Apply
							Help
Гуре:	Sam	olad Bir	ofringent and	l/or Optically Active	Material		
урс.	Loam	pieu bii	ennigent and	or opacally Acave	material		
N=refr	active ind	ices, (G=gyrotropi	ic coefficients, r	ight-click for	menu	
	Х		Y	Z			
Axis	0		0	1		tal axis vector	
	_			N extraordinary		G extraordinary	
0	0.425	_	1.6771	1.495	0	0	
1	0.4475	_	1.6732	1.4933	0	0	
2	0.47	_	1.6699	1.4917	0	0	
3	0.4925	_	1.667	1.4904	0	0	
4	0.515	_	1.6646	1.4893	0	0	
5	0.5375	_	1.6624	1.4883	0	0	
6	0.56	_	1.6605	1.4874	0	0	
7	0.5825	_	1.6588	1.4866	0	0	
8	0.605	_	1.6573	1.4859	0	0	
9	0.6275	_	1.656	1.4853	0	0	<u> </u>
10	0.65	_	1.6547	1.4848	0	0	
•						•	
- Comm	on Gradien	t Index	Material Para	ameters and Other F	arameters-		
						ZOffeet	
Step 0.1	5128		# Steps	X Offset	Y Offset	Z Offset	-

The calcite waveplate material is oriented with its fast axis bisecting the global +x & +y directions. The same birefringent material definition used for the lens can also be used for the waveplate by applying a coordinate transformation to the waveplate surfaces through the "Edit/View GRIN/Birefringent Position/Orientation" dialog:



waveplate		
🥜 Surface 1	✓ Iraceable	
Edge	Never Traceable (for trimming surfaces)	
] 📷 Analysis Surface(s)	Draw O <u>u</u> ter Enclosing Volume Coordinate Axes	
🍌 small area image p 구 词 Materials	Visualization Attributes	
Air Vacuum Simple Glass Standard Glass	<u>P</u> osition/Orientation Parent Coordinate S <u>v</u> stem Sc <u>a</u> le	
 	X Cut	Ctrl+X
🛄 🎁 dispersive uniaxial	Copy	Ctrl+C
-)- 🦲 Coatings	💼 Paste	Ctrl+∀
- 🔂 Scatterers	Delete (all highlighted items)	Del
-)- 💽 Raytrace Properties	Summary Report	
	Detailed Report	
	Edit/View Surface	
	Edit/View GRIN/Birefringent Material Position/Orientation.	
	<u>G</u> lue	N
	Draw Surface Trimming <u>V</u> olume	
	Edit/View Array Parameters	
	Delete Array Parameters	
A	Edit/View <u>⊂</u> urve	



	Reference Coordinate	Action	Parameters (right	mouse-click f
	Starting Coordinate System	m		
0	Geometry.waveplate ()			
			X-angle (deg)	
1	Geometry.waveplate 💌	Rotate abc 🖣	90	
	-		Z-angle (deg)	
2	Geometry.waveplate 💌	Rotate abc 🖣	45	

The polarizer has a coating that passes only light polarized along the global x-direction:

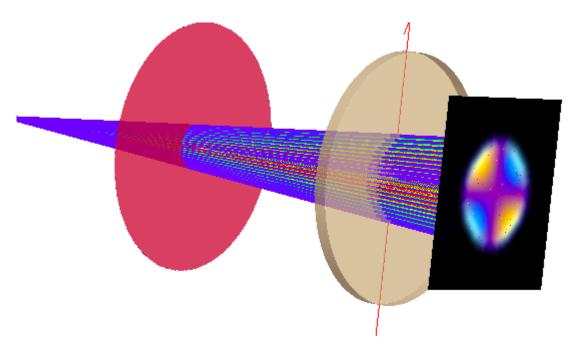
(pola	arized_o	crysta	al_colors3	_60	00.frd) Edit Coating	?	
Name:	[linear p	oolarizer			OK	
Description:						Cancel	
Гуре:	[Polariz	er/Wavepla	ate (Coating (Jones matrix)	Help	
	Value				Description		
Туре	X Linea	X Linear Polarizer 🛛 💌			Type of polarization coating (applied in transmission only)		
Coat	Transm	it		•	Coating in addition to the polarization coating		
	Ampli	itude	Phase(de	;g)			
J00	1		0		Matrix element J(row,col)		
J10	0		0		fatrix element J(row,col)		
J01	0		0		Matrix element J(row,col)		
J11	0		0		Matrix element J(row,col)		

The source is a coherent, collimated bundle polarized along the global y-direction. The "Synthesize a Color" feature was used to create and weight a range of evenly spaced wavelengths simulating the color "white".

Upon tracing the source



and evaluating the rays on the detector using the Color Image feature, the image has the following appearance. This view is obtained by invoking the "Show in Visualization View.." option in the Chart Viewer and setting the detector Visualization Attribute *Opacity* to "Invisible".

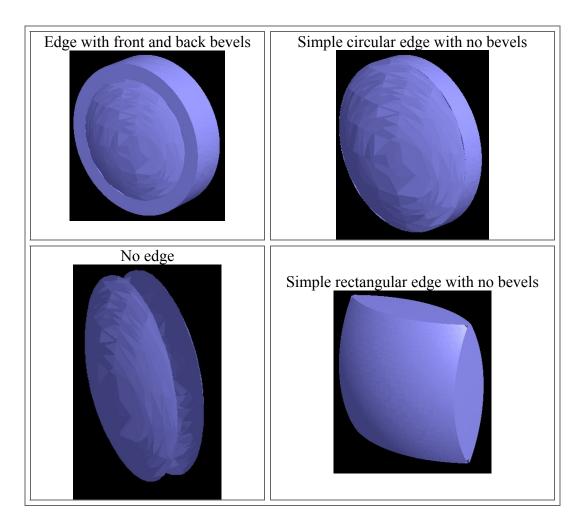




Advanced Aperture Dialog

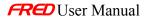
Description - Advanced Aperture Dialog

This dialog allows you to define advanced edge types for lenses and mirrors. There are four types of edge that can be defined for a lens or mirror.



How Do I Get There? - Advanced Aperture Dialog

From the Edit/Create New Lens dialog, press the "Advanced Settings..." button in the Lens Aperture Specification area.



	nos	
Lens Apr X Semi-	erture Specification ape: Y Semi-ape: 3	Materials- Name: Standard
	Advanced Settings	Air
_ Location	of the Lens (at front surface verte:	<) (right mouse

This dialog is also available on the Edit/Create New Mirror dialog, in the Mirror Aperture area. Click the "Advanced..." button.

Back:	0	C
Mirror Aperl XSemiApe 3	ture YSemiApe 3	Central Semi-a
Adva	nced	
- Location of	the Mirror (fro	nt surface v

Dialog Box and Controls - Advanced Aperture Dialog

Advanced Aperture Type of Edge: Simple circular/elliptical edge	with no bevels	
	escription	
<u>Control</u>	Inputs / Description	<u>Defaults</u>
Type of Edge:	Displays what type of edge will be placed on the object.	Simple circular/elliptical edge with no bevels
Parameters	Displays the parameters of the edge type.	X Semi-ape = 0.5 Y Semi-ape = 0.5
OK	Applies the changes to the aperture and closes the dialog.	
Cancel	Closes the dialog without applying changes to the aperture.	



Help	Displays this help article.	

Application Notes - Advanced Aperture Dialog

This dialog is resizable and modal. It must be closed before other work can be done.

See Also.... - - Advanced Aperture Dialog

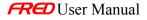
Edit/Create New Mirror Dialog Edit/Create New Lens Dialog

Encircled/Ensquared Values Dialog

How Do I Get There? - Encircled/Ensquared Values Dialog

There are three different ways to execute this command: Menu Keyboard Accelerator Toolbar Button Include Images

Dialog Box and Controls - Encircled/Ensquared Values Dialog



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候 Enciro	led/Ensquared	Valu	es			? ×
Type a	3 - Irradiance Dist and Sampling noircled (circular a nsquared (square	rea)			sition) [Analysi of Sample Point	
	Point		28.787185052 28.7872		2820.5440465 44.138	5
1 2 3 4 5 6 7 Upda	Radius		Value		Fraction)	
<u>Contr</u>	<u>rol</u>		Inputs / I	Des	<u>cription</u>	

Application Notes - Encircled/Ensquared Values Dialog

See Also - Encircled/Ensquared Values Dialog

<u>Defaults</u>

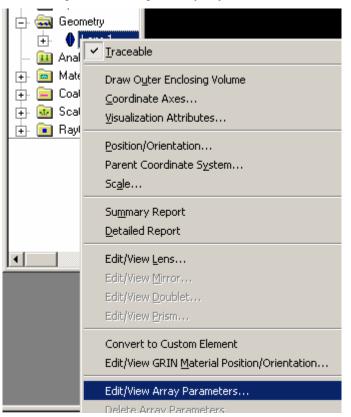
Entity Array Dialog

Description - Entity Array Dialog

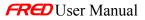
This dialog allows you to set up a planar array of entity types in the FRED system. It replicates a particular type (a lens, for example) across an array whose size and drawing specification is defined in the dialog.

For the purposes of this article, an array of default lenses will be used.

How Do I Get There? - Entity Array Dialog



Right click on a geometry object and choose "Edit/View Array Parameters..."



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Dialog Box and Controls - Entity Array Dialog

<mark>़ (</mark> FRED1 *	°) Entity Arr	ay Definitio	n		<u>_ 0 ×</u>
Entity: Geo	metry.M2 (Co	ollimating Mirro	or)		OK
	Parameters	3		Description	Cancel
	x	Y	Z		
A Spacing	1	0	0	Cell space in A dir	Apply
B Spacing	0	1	0	Cell space in B dir	
	Min	Max	Description		
I	0	0	Min/max cell	indices in A directio	
J ▲	10		Min/max cell	indices in B direction	Help
_ Drawing A	Attributes (use	caution if the		large number of cells	
🔽 Draw	the array outli	ne 📃		< Every N'th Item> directionB direction	
Draw cell outlines					
Draw cell centers				1	1 🗧
🗖 Draw	row/column o	utlines 📃	1	1 3	1 🗧
🗖 Draw	cell contents		1	3 1 3	1 🕀

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Entity	Identifies the entity which will become an array of objects	The name of the entity you right- clicked on
Parameters	Allows you to specify the size and orientation of the array	See Below
Draw the array outline	Draws a box around all the elements of the array	Checked
Draw cell outlines	Draws a box around the individual array cells	Unchecked
Draw cell centers	Draws a dot at the center of each array cell	Unchecked
Draw row/column outlines	Draws a box around a row and/or column	Unchecked
Draw cell contents	Draws the element in an array cell	Unchecked
Array Outline Color	Specifies the color of the array bounding box	Gray
Cell Outline Color	Specifies the color of the cell bounding box	Gray

Cell Center Color	Specifies the color of the center of a cell	Gray
Row/Column Outline Color	Specifies the color of the row/column bounding box	Gray
Every N'th Item: A Direction, cell outlines	Specifies how many items in the A direction will have their cell outlines drawn	1
Every N'th Item: B Direction, cell outlines	Specifies how many items in the B direction will have their cell outlines drawn	1
Every N'th Item: C Direction, cell outlines	Specifies how many items in the C direction will have their cell outlines drawn	Disabled
Every N'th Item: A Direction, cell centers	Specifies how many items in the A direction will have their cell centers drawn	1
Every N'th Item: B Direction, cell centers	Specifies how many items in the B direction will have their cell centers drawn	1
Every N'th Item: C Direction, cell centers	Specifies how many items in the C direction will have their cell centers drawn	Disabled
Every N'th Item: A Direction, row/col outlines	Specifies how many rows or columns in the A direction will have their outlines drawn	1
Every N'th Item: B Direction, row/col outlines	Specifies how many rows or columns in the B direction will have their outlines drawn	1
Every N'th Item: C Direction, row/col outlines	Specifies how many rows or columns in the C direction will have their outlines drawn	Disabled
Every N'th Item: A Direction, cell contents	Specifies how many items in the A direction will have their cell contents drawn	1
Every N'th Item: B Direction, cell contents	Specifies how many items in the B direction will have their cell contents drawn	1
Every N'th Item: C Direction, cell contents	Specifies how many items in the C direction will have their cell contents drawn	Disabled
ОК	Applies the changes and dismisses the dialog	

Cancel	Dismisses the dialog and does not apply changes	
Apply	Applies the changes and does not dismiss the dialog	
Help	Displays this help article	

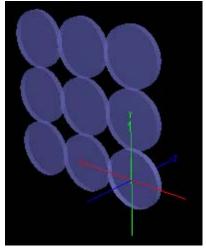
Application Notes - Entity Array Dialog

This dialog is modeless and resizable. It does not need to be dismissed before other work can be done on the FRED system.

The array is identified in the Tree View by a single entity with an array icon next to it, like this: $\overset{\text{IIII}}{\bullet} \overset{\text{Lens1}}{\bullet}$. Editing the entity will edit the parameters for all the entities in the array.

Parameters - Entity Array Dialog

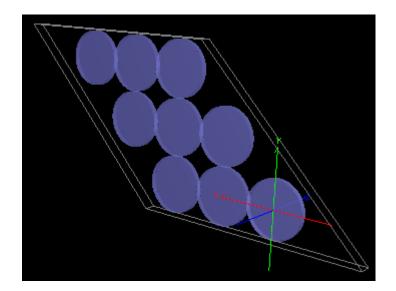
An A Spacing vector of (1, 0, 0) with a B Spacing vector of (0, 1, 0), an I value of (0, 2) and a J value of (0, 2) drawing all the cell contents produces an array like this:



An A Spacing vector of (1, 0, 0) with a B Spacing vector of (1, 1, 0), an I value of (0, 2) and a J value of (0, 2) drawing all the cell contents and the array outline produces an array like this:



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Dialog Box and Controls - Fiber Coupling Efficiency Dialog

🔆 (FRED1 '	*) Fiber Cou	pling Efficier	ю		- 🗆 🗵
Analysis St	urface:				
Analysis S	urface(s).Analy	vsis Surface ()		•
Fiber Type	(located at the	e center of the	analysis surface):	
Step-index	(central core	surrounded by	cladding)		•
	Value	Description	<u>ו</u>		
Ncore	1.55	Fiber core re	efractive index		
Nclad	1.5	Fiber claddir	ig refractive inde	x	
Semi-Ape	0.001	Fiber core s	emi-aperture		
	-				
, Tinclude	reflection (Fre	snel) losses al	the fiber end		
OK	C	ancel	Apply		Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Analysis Surface	Lists all the analysis surfaces in the FRED system.	The first Analysis Surface found in the system
Fiber Type	Lists the type of fiber available for the calculation	Step-index
Fiber Type Options	Lists the options for the selected fiber type	Ncore = 1.55 Nclad = 1.5 Semi-Ape = 0.001
Include reflection (Fresnel) losses at the fiber end	When checked, calculates Fresnel losses at the end of the fiber	Unchecked
OK	Performs the efficiency analysis and closes the dialog	
Cancel	Does not perform the efficiency analysis but closes the dialog	
Apply	Performs the efficiency analysis and does not close the dialog	
Help	Displays this help article	



Application Notes - Fiber Coupling Efficiency Dialog

This dialog is resizable and modeless.

See Also.... - Fiber Coupling Efficiency Dialog

Best Geometric Focus

Fit Data To Diffuse Binomial/Polynomial Function Dialog

How Do I Get There? - Fit Data To Diffuse Binomial/Polynomial Function

From the Tools menu, choose "BSDF Data Fitting", then "Binomial/Polynomial Data Fitting".

侯 FRED 4.11 (po	wered by Photon Engineering) - FRED2	
Eile Edit View	Tools Raytrace 3D View Create Analyses Window Help	
™ ≌ ₽ ≥ = > ⊻ ¤	User Defined Scripting Tools	 Image: Second second
	Edit/View GRIN/Birefringent Material Position/Orientation	
FRED2	Reports	
Objects	BSDF Data Fitting	Binomial/Polynomial Data Fitting
Op Ge	User-defined 3D ⊆hart View	
📃 🔤 🛄 An-	Determine Scatter Importance Sampling	Y



((FRED1) Fit Data to Diffuse Binomial/Polynomial Function								
Browse								
Function © Binomial (plane symmetric) © Polynomial (general) Type © Diffuse © Lorentzian 10000 d © Both Fit © Fit to a specific function © Regression fit Data samples Read 0 samples	Options (applied during fit) Generate out-of-plane data Ignore above maximum Ignore below minimum Parameters n m I I' 0 0 0 0 0 0 0 0							
Fit Ei	rror Summary							
# n m l l' Ave	StDev	Min	Max					
Create Model Close Pr	erform Fit		Help					

Dialog Box and Controls - Fit Data To Diffuse Binomial/Polynomial Function

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Path Box		
Browse		
Binomial Function		Selected
Polynomial Function		Unselected
Generate out-of- plane data		Unchecked

Ignore above maximum		Unchecked
Ignore above minimum		Unchecked
Diffuse		Unselected
Lorentzian		Unselected
Both		Selected
Fit to a specific binomial		Selected
Regression fit		Unselected
n		0
m		0
1		0
ľ		0
Data Samples		
Fit Error Summary		
Create Model		
Close	Dismisses the dialog	
Perform Fit		
Неір	Displays this help article	

Application Notes - Fit Data To Diffuse Binomial/Polynomial Function Dialog

This dialog is modeless and resizable. It remembers both its size and position when it is closed. It can remain open while other work is done and updates itself to reflect changes.



Fourier Transform Analysis

This command, available in the right mouse click pop-up menu, brings up the Combine Datasets dialog box. This dialog provides an environment where the current dataset can be combined with saved datasets with the same number of grid points in X and Y, the same grid spacing, and the same analysis plane size.

(FRED1 *) Fourier	Transform		<u>? ×</u>
Operation C No operation	Fourier Transform	C Inverse Fou	rier Transform
X-axis Label:		Local X-axis	
Y-axis Label:	Y Frequency	Local Y-axis	
Z-axis Label:	FFT	Irradiance	
-Data Form to View-	O Signed Ma	gnitude C f	Real
C Magnitude square	red 🔿 Phase	01	maginary
Dataset to Transform			
 Current data (col 	mplex)	OK	Cancel
C Current view dat	a (real)	Apply	Help

<u>Control</u>	<u>Function</u>	<u>Defaults</u>				
	Operation					
No operation	No operation	Not Selected				
Fourier Transform	Perform Fourier Transform	Selected				
Inverse Fourier Transform	Perform Inverse Fourier Transform	Not Selected				
X-axis Label:	Specifies label to be placed on the X-axis	X Frequency				
Y-axis Label:	Specifies label to be placed on the Y-axis	Y Frequency				
Z-axis Label:	Specifies label to be placed on the Z-axis	FFT				

Data Form to View				
Magnitude	Displays $ z $ (z=x+iy)	Selected		
Magnitude Squared	Displays $ z ^2$	Not Selected		
Signed Magnitude	Displays signed z	Not Selected		
Phase	Displays $atan(y/x)$	Not Selected		
Real	Displays x	Not Selected		
Imaginary	Displays y	Not Selected		
D	ataset to Transform	n		
Original data (real)	Transforms original dataset	Not Selected		
Current data (complex)	Transforms complex dataset	Selected		
Current view data (real)	Transforms real part of dataset	Not Selected		
ОК	Perform Fast Fourier Transform and close dialog box.			
Cancel	Close dialog box without performing Fast Fourier Transform.			
Apply	Perform Fast Fourier Transform and keep dialog box open.			
Help	Access this Help page			



Function Test Dialog

Description - Dialog name/function

How Do I Get There? - Dialog name/function

There are three different ways to execute this command:

Menu

Keyboard Accelerator

Toolbar Button

Include Images

Dialog Box and Controls - Dialog name/function

Function Test				×
The function a be iterated alo	ind derivatives wing the direction t	ill be evaluated to its intersect wi	at the position. A ray w th the surface.	vill
Input	×	Y	Z	
Position:	<u>j</u> o			1
Direction:	0	0	1	1
- Results				
Derivatives:	dF/dX 0	dF/dY	dF/dZ 0	1
Function:	0	Iterations to	converge: 0	1
Intersection:	× 0	- Y 0	Z 0	1
Summary:				1
Perform Te	est	Help	Close	
<u>Control</u>		Inputs /	Description	
]		

Application Notes - Dialog name/function

See Also.... - Dialog name/function

Generate IES Output Dialog

Description - Generate IES Output Dialog

This dialog generates IES output. The intensity is calculated at directions on a polar grid according to the specified photometry type and written to a file in ANSI/IESNA LM-63-2002 format.

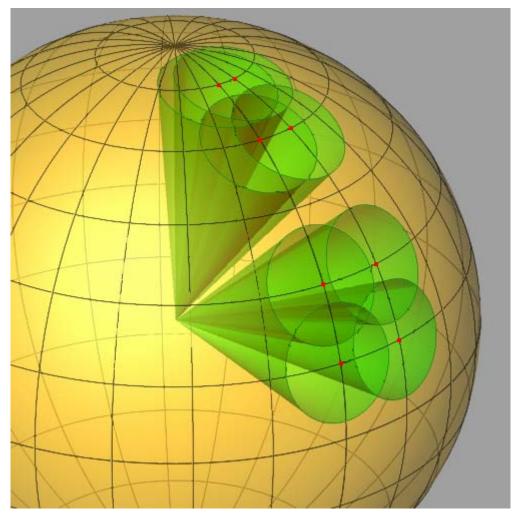
Calculation Details - Generate IES Output Dialog

The intensity calculation at a given direction is performed by binning rays with propagation directions within the specified cone half-angle of that given direction. The total flux collected along a direction is then divided by the solid angle that the acceptance cone subtends to give the intensity in that direction. One advantage of this approach is that each direction bin subtends the same solid angle, potentially giving more even statistics than an approach where the bin size varies with direction (e.g., polar grid bins).

If the cone half-angle is large enough acceptance cones for adjacent polar direction samples can overlap. This will result in some rays being collected in more than one direction bin. The intensity calculation will still be correct, but the adjacent intensity values will not be fully independent of each other. By default, the cone size is chosen to be just large enough to ensure overlap of adjacent polar directions at the equator. While such a cone size guarantees that all rays (within the specified angular range) will be binned, it also produces a substantial overlap for directions near the poles.

To help illustrate this, this figure

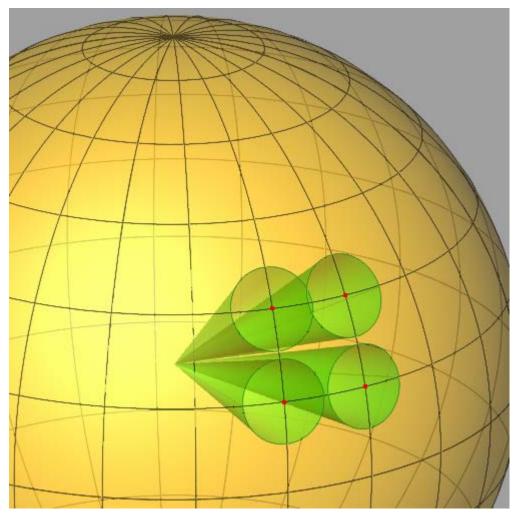




shows the direction sphere with corresponding acceptance cones for the directions marked with red dots. Note that for adjacent polar directions near the equator the overlap is much smaller than for the same size cones near the pole. The net effect is that adjacent intensities near the poles will vary less than those near the equator.

The cone half-angle can be set so that some adjacent directions do not overlap. This figure

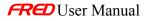


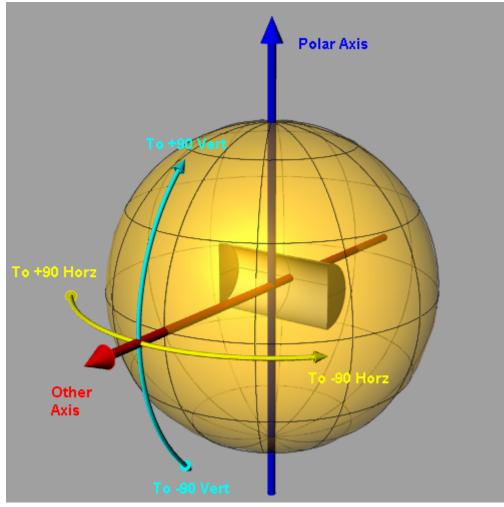


illustrates the situation. The intensities calculated for non-overlapping directions will be entirely independent. Rays with directions outside of all cones will simply not contribute to the calculation, and consequently the total number of rays binned may be less than the total within the angular range being calculated.

Photometry Types - Generate IES Output Dialog

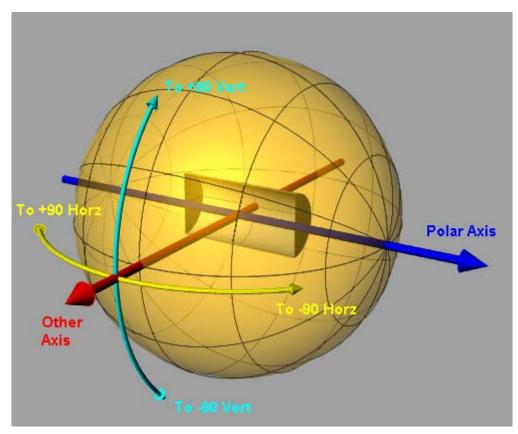
These figures illustrate how angles are defined for the different photometry types.





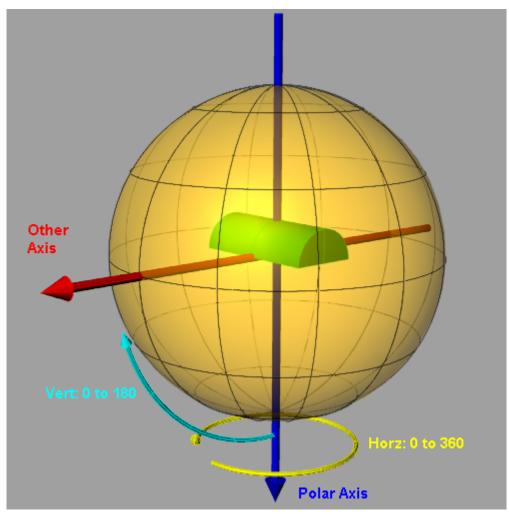
IES Type A











IES Type C

How Do I Get There? - Generate IES Output Dialog

This dialog requires a raytrace to have been performed. There are three different ways to execute this command:

- 2. On the Analyses Menu, select "Generate IES Output..."
- 3. Click the IES Output toolbar button
- 4. Use the keyboard shortcut



Dialog Box and Controls - Generate IES Output Dialog

Generate IES Output		×
IES File Name:		
Vertical Angles: 0 t	r Ranges (deg) Type C O Type B O Type A # of angles o 180 deg ▼ -90 to 90 deg ▼ -90 to 90 deg ▼ 19 • o 360 deg ▼ -90 to 90 deg ▼ -90 to 90 deg ▼ 37 •	···]
Spatial Orientation X Polar (Vertical) Axis: 0	Y Z	
Other Axis: 1	0	
Coord Sys: Glo	bal Coordinate System	
Acceptance Cone Size Set cone half-angle automatically to ensure or Intensity Values Write intensity values as Ray Selection Criteria (right m Num Operation Descript AND All rays	integers iouse-click for popup menu)	
<u>Control</u>	Inputs / Description	<u>Defaults</u>
IES File NameName of IES output file. Type the filename directly or press the '' button to select a filename by browsing with the file dialog.Bla		
Photometry Type	Specifies the IES photometry type to use, as illustrated above.	Туре С
Vertical Angles	Specifies the angular range in the vertical direction.	0 to 180 degrees

Horizontal Angles	Specifies the angular range in the horizontal direction.	0 to 360 degrees
# of angles	Specifies the number of angles at which to calculate the intensity. Note that some programs that read IES data require a sample at (0H,0V). To satisfy this requirement, specify an odd number of angles when using an angular range that doesn't end at (0H,0V).	19 vertical, 37 horizontal
Polar Axis	Specifies the axis to use as the pole. Depending on the photometry type, this can be either the vertical or horizontal axis. See figures above for more information.	(0, 0, 1)
Other Axis	Specifies the 'Other Axis' used to define the polar coordinate system. The meaning of this axis varies with photometry type, see figures above. If the axis entered is not perpendicular to the polar axis it will be used to calculate one that is. An error message will be reported if the 'Other Axis' is parallel to the polar axis.	(1, 0, 0)
Coord Sys	The coordinate system in which the polar and other axis are specified.	Global Coordinate System
Set cone half-angle automatically to ensure overlap	If checked, the cone half-angle will be automatically set to ensure overlap of cones for adjacent sample directions at the equator. This guarantees all rays in the requested angle range will be binned at least once.	Checked
Write intensity values as integers	If checked, the calculated intensities are rounded to the nearest integer when written to the IES file. This should be checked if the IES file is destined for use with software that requires integer intensities.	Unchecked
Cone Half-Angle	Specifies the size of the acceptance cone used for calculating intensity at each sample direction. See the discussion above for more information on this quantity's meaning.	10
Ray Selection Criteria	Defines the rays included in the output.	All rays
ОК	Closes the dialog and outputs the file	
Cancel	Closes the dialog without outputting the file	
Help	Displays this help article	

References - Generate IES Output Dialog

The ANSI/IESNA LM-63-2002 format is defined in "IESNA Standard File Format for the Electronic Transfer of Photometric Data and Related Information", LM-63-02, ISBN # 0-87995-178-8 (distributed by <u>http://www.techstreet.com/</u>).

Information on the coordinate systems used for the various photometry types can be found in "Goniophotometer Types and Photometric Coordinates", LM-75-01, ISBN # 0-87995-180-X (distributed by <u>http://www.techstreet.com/</u>).

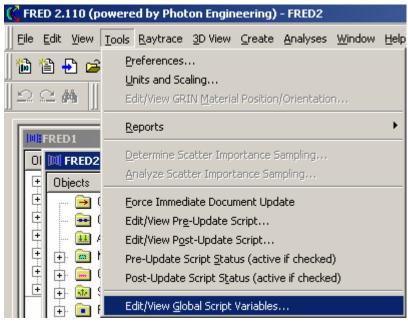
Global Script Variables Dialog

Description - Global Script Variables Dialog

This dialog allows you to enter variables that can be referenced by multiple scripts associated with a particular document. These variables are stored in a FRED document.

How Do I Get There? - Global Script Variables Dialog

With a FRED document open, open the Tools menu and choose "Edit/View <u>G</u>lobal Script Variables...".





Dialog B	ox and	Controls -	Global	Script	Variables	Dialog

子 (FRED1) Global Script Variables						<u> </u>
	Name	Туре	Initial Value	Current Value	Comment	
1		Double 💌]			
•						►
Right	mouse click fo	r popup menu.	Drag a rov	v header to reorder	rows.	
	OK	Cancel	Apply			Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Variable listing	Lists the name, type, initial & current values of the variables, as well as any comment associated with the variable.	Empty listing
ОК	Closes the dialog and applies the changes.	
Cancel	Closes the dialog and does not apply the changes.	
Apply	Applies the changes and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Global Script Variables Dialog

Right-clicking on the variable list displays a menu with various options.

((FRED1) Global Script Variables							<u> </u>		
	Name		Туре		Initial Value	Current	Value	Comment	t
1			Double	▼		8 8 8 8 8			
		Ins	ert Row						
		Del	lete Hilight	ed R	ows				
		<u>R</u> ei	initialize Hi	lighte	ed Rows				
	-								
Right r	nouse clia	ok for j	popup mer	nu.	Drag a rov	v header ti	o reorde	er rows.	
	DK		Cancel		Apply				Help

"Insert Row" inserts a row before the item you clicked on.

"Delete Hilighted Rows" deletes the row (or rows, if you selected more than one) you clicked on.

"<u>R</u>einitialize Hilighted Rows" changes the Current Value of the highlighted rows to the Initial Value for each variable.

To select multiple rows, click in one row and drag across the consecutive rows you want to delete.

You can reorganize the listing of variables by clicking on the row number (on the left of the variable list) and dragging it up or down to another place in the listing.

See Also - Global Script Variables Dialog

Tools Menu Commands

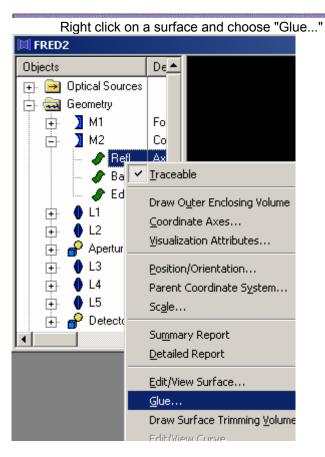


Glue Surface(s) Dialog

Description - Glue Surface(s) Dialog

This dialog allows you to glue one surface to another.

How Do I Get There? - Glue Surface(s) Dialog





Dialog Box and Controls - Glue Surface(s) Dialog

🕻 Glu	ue Surface(s)	X
Base	e Glue Surface (the surfaces belo	ow will be glued to this one)
Geo	metry.L2.Surface 1 (Axially Sym	metric Conicoid Surface)
Surfa	ace/Material Pairs to Glue to the	Base Glue Surface (right mouse-click for pop-up menu)
	Glue Surface(s)	Glue Material(s)
1	no selection	✓ no selection
J		
	OK	Cancel Help
	S	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Base Glue Surface	Identifies which surface to which others will be glued.	The surface you clicked on to display the dialog
Surface/Material Pairs to Glue to the Base Glue Surface	Identifies the surface that will be glued to the base surface and the material used as the glue.	no selection/no selection
ОК	Applies the changes and dismisses the dialog.	
Cancel	Does not apply the changes but dismisses the dialog.	
Help	Displays this help article.	

Application Notes - Glue Surface(s) Dialog

This dialog is modal and resizable.

See Also - Glue Surface(s) Dialog

Applying Glue

Trace Targeted Ray dialog

Description - Trace Targeted Ray dialog

FRED allows you to specify a raytrace that targets a particular surface in the system.

How Do I Get There? - Trace Targeted Ray dialog

There are three ways to access this dialog:

• From the Ray Trace menu, choose "Trace Targeted Ray":

<u>R</u> aytrace	<u>3</u> D View	⊆reate	<u>A</u> nalyses	<u>W</u> indow	<u>H</u> elp	
🎬 <u>T</u> race	All Source	es	C	trl+Shift+	F5	
🍄 Trace	and <u>R</u> eno	ler	C	trl+Shift+	F7	
[‱] <u>C</u> reati	e All Sourc	te Rays	C	trl+Shift+	F8	
💥 Delete	e Existing	Rays	C	trl+Shift+	F9	
\rightarrow Trace	Existing R	lays	Ctr	1+Shift+F	10	
\rightarrow Trace	Existing a	and Rend	er Ctr	Ctrl+Shift+F11		
1→ Trace	<u>S</u> ingle Ra	y		Ctrl+Shift+1		
🔶 Trace	Targeted	Ray		Ctrl+Shift-	+2	
Ray M	lanipulatio	n Utilities	VS			
<mark>#</mark> ≩ <u>U</u> ser-o	defined Ra	ay Paths.		Ctrl+Shift-	FU	
Coher	ent <u>F</u> ield :	Synthesis	;			
A <mark>≓ <u>A</u>dvar</mark>	nced Rayt	race	(Ctrl+Shift-	FA	

• On the Ray Trace toolbar, press the "Trace Targeted Ray" button:



• Use the keyboard accelerator Ctrl+Shift+2.

Dialog Box and Controls - Trace Targeted Ray dialog



🚱 (FRED1) Targeted R	ay	
Starting Point × 0 Y 0 Z 0 Coord Sys Global Coordin Hints C Into 4pi sr © Dir		Target Surface .Detector.Flat sur ▼ Make target point coordinate system same as surface Conditions Wavelength (um) 0.5875618 d (H ▼ Immersion Material Air (Air) ▼
C Towards C Po	sition C Sampled/Position	Ray Path Non-sequential
× 0 Y 0 Z 1	Towards .M1.Reflecting Sur	Options Create Source
Coord Sys Global Coordin 💌	Number of Rays 1	Pick ray color: I
- Status Ready		Controls Der Inc 0.0001 Aim Tol 0.0001
	ancel Apply	Help

<u>Control</u>	<u>Description</u>	<u>Defaults</u>
	Starting Point	
X, Y, Z	Defines the coordinates of the starting point of the ray.	0
Coordinate System	Defines which coordinate system to use for the starting point of the ray.	Global Coordinate System

	Target Point	
X, Y, Z	Defines the coordinates of the aim point of the ray	0
Coordinate System	Defines which coordinate system to use for the aim point of the ray.	Global Coordinate System
	Target Surface	
Surface List	Choose from dropdown menu of existing surfaces.	
Make target point coordinate system same as surface	Places target point and surface coordinate systems coincident.	Checked
	Conditions	
Wavelength	Defines the wavelength to use for the ray.	0.5892938
Immersion Material	Defines the material the ray will sit in when it begins tracing.	Air
Ray Path	Select any valid path from dropdown menu.	Non- sequential
	Hints	
Into 4pi sr		Not selected
Towards	Trace ray towards any valid surface.	Not selected
Direction	Trace ray in specified direction.	Selected
Position	Trace ray to specified position.	Not selected
Sampled/Direction		Not selected
Sampled/Position		Not selected
	Hint Data	
X, Y, Z	Coordinates of end point.	X, Y: 0 Z: 1
Towards	Dropdown list of valid surfaces.	First valid surface
X, Y Semiwidth (deg)	Solid angle	0
Number of Rays	Rays to trace.	1
Coord Sys	Specify ray in this coordinate system.	Global
	Options	
Create Source		Unchecked

Plot Rays	Plot rays during trace.	Unchecked
Pick Ray Color	Select color of rays.	Unchecked
	Status	
Status	Indicates status of iterated trace.	Ready
	Controls	
Der Inc	Derivative increment used in iteration.	0.0001
Aim Tol	Aim Tolerance used in iteration.	0.0001
ОК	Trace Targeted Ray and close dialog box.	
Cancel	Discard Targeted Ray and close dialog box.	
Apply	Trace Targeted Ray and keep dialog box open.	
Help	Access this Help page.	

Search Vendor Catalogs Dialog

Description - Search Vendor Catalogs Dialog

This dialog allows you to search the lens catalogs for items that match various parameters.

How Do I Get There? - Search Vendor Catalogs Dialog

From the Tree view of a FRED document, right click on the Geometry folder and choose "Search for Lens in Catalogs..."



🚰 FRED 3.20 (powered by Photon Engineering) -
Eile Edit View Tools Raytrace 3D View Create
脑 🖺 🗗 🚅 🔚 🐰 ங 💼 🎒 📢 🤋 🐽
그 으 ぬ ≔ ४ ೬ ᢘ ⊞ ♥ ∉ ୬
M FRED1
Objects
Dptical Sources
Geor Iraceable
+ Mate Draw Outer Enclosing Volume
🔁 🧰 Coati 🛛 Coordinate Axes
🕂 🚾 Scatl Visualization Attributes
Position/Orientation
Parent Coordinate System
Sc <u>a</u> le
Su <u>m</u> mary Report
Detailed Report
Create New Subassembly
Create New Custom Element
Create New Lens
Create New Mirror
Create New Doublet,
Create New Prism
Insert Lens from Catalog
Insert Prism from Catalog
Search for Lens in Catalogs
Edit/View Array Parameters



Criteria	Value	Importance				<u>C</u> ancel	
Focal Length	-					<u>H</u> elp	
1							
2. Specify Catalogs:	Edmund In	ndustrial Optics	▲ The	e search will be	nerformed		
	🗌 JML Optica	al		all checked c			
	🖂 Melles Grio	ot					
	II		<u> </u>				
3. Return the best	1	results (100 max)	<u> </u>				
3. Return the best 4. Perform search	1	· ·	<u> </u>				
4. Perform search	1 <u>S</u> earch	results (100 max)					
4. Perform search Results:	1 <u>S</u> earch (Double	results (100 max)				Padius 1	.
4. Perform search Results:	1 <u>S</u> earch (Double	results (100 max)		FRED docume Focal Length	nt) Material	Radius 1	Ri
4. Perform search Results:	1 <u>S</u> earch (Double	results (100 max)				Radius 1	Ri
4. Perform search Results:	1 <u>S</u> earch (Double	results (100 max)				Radius 1	Ri
4. Perform search Results:	1 <u>S</u> earch (Double	results (100 max)				Radius 1	Ri

Dialog Box and Controls - Search Vendor Catalogs Dialog

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Criteria List	Identifies which criteria will be used to define the ideal lens. Each criterion consists of a value to measure, the value desired, and the importance attached.	Focal Length, no value, no importance
Specify Catalogs	Identifies which catalogs will be searched	none checked
Number of results	Specifies how many lenses will be displayed from the results	1
Search	Performs the catalog search	
Results	Displays the list of entries that matched and result's values for the various criteria. Limited to 100 results.	empty
Cancel	Closes the dialog	
Help	Displays this help article	

Application Notes - Search Vendor Catalogs Dialog

This dialog is modeless and resizable.

Search criteria can be added via a right-click in the criteria list.

1. Specify Criteria:				
Criteria	Value	Importance		
Focal Length 💌	_	riterion This Criterion		

Criteria can always be added, but there is a minimum of one. You can delete all but the last criteria.

There are seven criteria you can specify: Focal Length, Diameter, Thickness, Radius 1, Radius 2, Material, and Number of Surfaces. The value for Importance must be positive. The Value cell must be filled in, but certain values will produce invalid results. For example, entering a string for Focal Length will not produce the correct results.

At least one catalog must be selected. If not, a message box appears.

The results are sorted according to their similarity to the "perfect" lens, that is, the lens described by the criteria.

Examples - Search Vendor Catalogs Dialog

Entering 1 for Focal Length with an Importance of 100 and 2 for Diameter with an Importance of 90, searching the Edmund catalog, displaying 1 result gives

See Also.... - Search Vendor Catalogs Dialog

Catalog Lens Dialog

Catalog Prism Dialog

Create/Edit Lens

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Create/Edit Lens

FRED User Manual

This dialog allows you to edit and create new singlet lenses in your FRED optical system.

How Do I Get There? Create/Edit Lens

There are four different ways to execute this command:

2. On the Create Menu, choose "New Lens..."

On u	e oreate i	vienu, chi	0030	New Lens
⊆real	e <u>A</u> nalyses	; <u>W</u> indow	Help	
⇒ ।	Jew Simplifie	d Source		Ctrl+Alt+I
, ≾i i	lew <u>D</u> etailed	Source		Ctrl+Alt+D
2	lew <u>L</u> ens			Ctrl+Alt+L
) (lew <u>M</u> irror…		N	Ctrl+Alt+M
<u> </u>	lew <u>P</u> rism…			Ctrl+Alt+P
a P	lew <u>S</u> ubasse	mbly		Ctrl+Alt+S
P	lew Custom	<u>E</u> lement		Ctrl+Alt+E
🥒 P	lew Sur <u>f</u> ace			Ctrl+Alt+F
Cr	lew Cur <u>v</u> e			Ctrl+Alt+V
<u></u>	lew A <u>n</u> alysis	Surface		Ctrl+Alt+N
@ 1	lew Ma <u>t</u> erial			Ctrl+Alt+T
🗢 M	lew <u>⊂</u> oating			Ctrl+Alt+C
19 M	lew Sc <u>a</u> tter	Model		Ctrl+Alt+A
22 N	lew <u>R</u> aytrac	e Control		Ctrl+Alt+R



3.	Right click on the	Seometry folder and choose	"Create New Lens".

Objects + Sources	Description	
+ e Geometry		
+ 💷 Analysis Surface	✓ <u>T</u> raceable	
🕂 📠 Materials	Never Traceable (for trimming s	urfaces)
⊕ ⊆ Coatings ⊕ ⊡ Scatterers	Draw O <u>u</u> ter Enclosing Volume	
🕂 直 Raytrace Prope	<u>C</u> oordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	⊂trl+>
	B Copy	Ctrl+C
	🔁 Paste	Ctrl+\
	Delete (all highlighted items)	De
	Summary Report	
	Detailed Report	
	Create New Subassembly	
	Create New Custom Element	
	Create New Lens	
	Create New Mirror 🗟	
	Create New Prism	
	Insert Lens from Catalog	
	Insert Prism from Catalog	
	Search for Lens in Catalogs	
	Edit/View Array Parameters	
•	Delete Array Parameters	

Right clicking on an existing lens in the tree and choosing "Edit/View Lens..." will also display the dialog, but will apply the changes made to the lens you selected, instead of making a new lens.

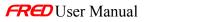
Dialog Box and Controls Create/Edit Lens

٥

4. 5.

🔆 (FRED1) Create a Nev	Lens	? _ 🗆 🗙
Parent: Geometry	▼	OK
Name: Lens 1		Cancel
Description:		Apply
		Help
0.5 0. Advanced Se Location of the Lens (at Reference C Starting Coord 0 Geometry ()	Semi-ape: Catalog: Catalog: Current Ings In	Select: Glass Immersion
Bend: 0	Back Prin: 0 Y Edge Thick: 0.1	
<u>Control</u>	Inputs / Description	<u>Defaults</u>
Parent	Identifies the Geometric Parent of the Lens. This control is grayed out when a lens is being edited and available when a lens is being created.	Geometry unles created under Subassembly.
Name	Displays the name of the Lens.	Lens 1
Description	Displays the description of the Lens (optional).	blank
	Basic Parameters	
Parameter Type	Chooses between <i>Radii</i> , <i>Curvatures</i> , and <i>Focal Length/Bending Parameter</i> for expressing front and back surface shape.	Curvatures (set in Preferences)
Front	Displays the Front Radius, Front Curvature, or Focal Length, depending on the Parameter Type selected.	0

Back Thickness	Displays the Back Radius, Back Curvature, or Bending Parameter, depending on the Parameter Type selected.Displays the value of the lens center 	0 0.1
X/Y Semi-	Displays the value of the semi-aperture in	0.5.0.5
apereture	the X direction.	0.5, 0.5
Advanced Settings	Advanced aperture specifications including edge bevels details.	
	Materials	
Glass Name	Displays the name of the material used for the lens.	Standard Glass
Immersion Name	Displays the name of the material that surrounds the lens.	Air
Glass Catalog	Displays the catalog that contains the lens material.	Current
Immersion Catalog	Displays the catalog that contains the immersion material.	Current
Select Glass	Selects lens material.	
Select Immersion	Immerse the lens in this material.	
	Location of the Lens	
Table	Displays the Location/Orientation specification for the lens.	Geometry ()
	Derived Properties	
Focal	Displays the focal length of the lens at the selected wavelength.	0
Bend	Displays the bending parameter of the lens at the selected wavelength.	0
Front Prin	Displays the location of the front principal plane location of the lens at the selected wavelength.	0
Back Prin	Displays the back principal plane location of the lens at the selected wavelength.	0
Wavelength (um)	Wavelength used to calculate the derived properties.	0.5892938



Y Edge Thick	Calculated Edge Thickness in the Y direction at the selected wavelength.	0.1
Update	Updates the derived properties display boxes.	
ОК	Create a new Lens and close dialog box.	
Cancel	Discard new Lens and close dialog box.	
Apply	Apply new Lens changes and keep dialog box open.	
Help	Access this help page.	

Application Notes Create/Edit Lens

This dialog is modeless and resizable.

See Also.... Create/Edit Lens

Create/Edit Mirror Create/Edit Prism

Position/Orientation...

Description - Position/Orientation...

The Position/Orientation dialog is accessed via the right mouse click context menu. It allows the user to view and edit the location of the selected node. Further, the position and orientation of the selected node can be expressed in the coordinate system of any other node and applied. This latter feature distinguishes this dialog from the Position/Orientation tab associated with surfaces, curves, and sources.

How Do I Get There? - Position/Orientation...

The Position/Orientation dialog is accessed via the right mouse click pop-up context menu.



Objects	Description
🕞 Optical Sources	
古 🚘 Geometry	
O Newport KPX313 # 1 O O O	✓ <u>I</u> raceable
🦾 🥒 Surf 1	Never Traceable (for trimming surfaces)
👥 Analysis Surface(s) → 💼 Materials	Draw O <u>u</u> ter Enclosing Volume
🕂 🚍 Coatings	Coordinate Axes
🕂 🔝 Scatterers	Visualization Attributes
🕂 间 Raytrace Properties	Position/Orientation
	Parent Coordinate S⊻stem.∜
	Sc <u>a</u> le

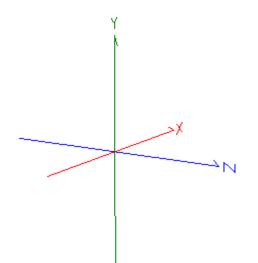
Dialog Box and Controls - Position/Orientation...

(C (FREE	01 *) Location			? _ 🗆 🗙
Name: Geomet				ОК
Descrip Fold Mir Locatio	ror			Cancel Apply Help
	Reference Coordinate	Action	Parameters (right mouse	-click for popul
0	Global coordinate syst 💌		X-angle (deg) 90	
1				×
	tions On The Above Location ess In This Coordinate System	n:		Simplify

<u>Control</u>	Inputs	<u>Defaults</u>
Name:	None.	Name of the selected node.
Description:	None.	Shows the Description associated with the selected node.
	Location	
Parent or Reference Coordinate System	Select the base coordinate system in which the transformation is to be applied.	Logical Parent Node
Action	Select the transformation operation.	Re-parent the coordinate system (make coincident).
Parameters	Enter shifts and rotations.	blank
0	perations on the Above Location Specificati	ion
Express in This Coordinate System	Select a new coordinate system in which to display the current location.	Global coordinate system
Express Now	Expresses the entity location in the selected coordinate system.	
Simplify	Reduces the list of coordinate system transformations to its most efficient form.	
ОК	Accept Location changes and close dialog box.	
Cancel	Discard Location changes and close dialog box.	
Apply	Apply Location changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Position/Orientation...

• FRED operates in a right-handed coordinate system, as shown below.



- o Positive rotations about the X axis rotate Y to Z
- o Positive rotations about the Y axis rotate Z to X
- Positive rotations about the Z axis rotate X to Y
- Changing the Position/Orientation of a node changes the location of all other nodes that are referenced to it either directly or indirectly.
- The Re-parent command has 2 effects:
 - The selected node is moved to be coincident with the Parent Coordinate System
 - An association (link) is created between the selected node and the Parent Coordinate System so that any transformations applied to the Parent Coordinate System are applied to the selected node as well.
 - In the absence of a Re-parent command, the node is referenced to the global coordinate system.
 - By default, every new entity is Re-parented to the coordinate system of its logical parent. For example, the parent coordinate system for a new Lens is the Subassembly in which it was created. Likewise, the parent coordinate system of all of the lens surfaces is that of the new Lens node. The Lens node is linked to the Subassembly. The lens surfaces are linked directly to the Lens, and indirectly to the Subassembly.
 - The link formed is not two-way: coordinate transformations on the Parent will affect the Child, but coordinate transformations of the Child will not affect the Parent.

NOTE It is strongly recommended that the Re-parent command be the first command issued in the coordinate transformation list as this command negates the operation of any that preceded it.

- The coordinate transformations are applied in the order that they are entered. Order of entry is important: a shift and then rotation may not have the same effect as a rotation and then a shift.
- Coordinate transformations are always applied <u>relative</u> to the Reference or Parent Coordinate System.

- The Parent Coordinate System for multiple transformations need not be the same.
- The 'Express Now...' and 'Simplify' buttons

Examples - Position/Orientation...

The following examples list all of the currently available coordinate transformations and a brief description of the parameter settings for each.

Re-parent the Coordinate System (make coincident)
Action

Re-parent the coordinate system (make coincident)	
	٨

This action makes the selected node coincident with the Parent Coordinate System (not shown) and links the two together.

Place at specific coordinate

Action	Parameters					
	X-pos	Y-pos	Z-pos			
Place at specific coordinate 🛛 🝷	0	0	0			

Moves the local origin of the selected node to the X, Y, and Z positions in the Parent Coordinate system.

S	h	if	t

Action	P	arameters	
	X	[
Shift in X direction)	
Action	F	arameters	•
	١	/	
Shift in Y direction		D	
Action	Р	arameters	
Action	P Z		_
Action Shift in Z direction			
	Z		
	z •		
Shift in Z direction	z •)	

Shift the local coordinate system of the selected node by X, Y, and/or Z in the Parent Coordinate System. This transformation is additive: consecutive rows of Shift X 2 and Shift X 2 will move the object 4 units. In the absence of any tilts or rotations, the order of entry is not important.

Simple rotations

Action	Parameters
	X-angle (deg)
Rotate about X-axis	0
Action	Parameters
	Y-angle (deg)
Rotate about Y-axis	• 0
Action	Parameters
	Z-angle (deg)
Rotate about Z-axis	- 0

Rotate the local coordinate system of the selected node about the origin of the X, Y, and/or Z axes of the Parent Coordinate System. The order of entry is important.

Compound Rotations

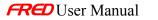
Action	Parameters				
	X-angle (deg)	Y-angle (deg)	Z-angle (deg)		Euler rotations
Rotate about X, Y, and Z axes 💌	0	0	0	XYZ order 📘	Euler angles
				XYZ order	
				ZYX order	

Rotate the local coordinate system of the selected node about the origin of the X, Y, and/or Z axes of the Parent Coordinate System. Choose the order of rotation (default is X, then Y, then Z). If the Euler angles box is open, then the rotations are all relative to coordinate axes of the Parent Coordinate System, which remain stationary. If the Euler angles box is checked, the second and third rotations are relative to the rotated coordinate axes of the previous operation(s). The latter transformation is typical of that used in optical design software.

Action	Parameters	;	
	X-angle (deg) Y-axis pos	Z-axis pos
Rotate about X-axis through a point in the Y-Z plane	Ū	0	0
		····	
Action	Parameters	\$	
	Y-angle (deg) Z-axis pos	X-axis pos
Rotate about Y-axis through a point in the Z-X plane	• 0	0	0
Action	Parameters	;	
	Z-angle (deg) X-axis pos	Y-axis pos
Rotate about Z-axis through a point in the X-Y plane	0	0	0

Rotate about a distant point

Rotate the local coordinate system of the selected node about a shifted point in the Parent Coordinate System. This action results in a tilt and a decenter for non-zero position entries. The order of entry is important.



Rotate about an axis through the origin

Action	Parameters			
	Angle (deg)	X-dir	Y-dir	Z-dir
Rotate about an axis through the origin	- 0	0	0	1

Rotate the local coordinate system of the selected node about a new axis passing through the origin of the Parent Coordinate System. The new axis is specified by its direction cosines. FRED normalizes the sum X-dir² + Y-dir² + Z-dir² to unity. The default orientation of the new axis is coincident with the Z-axis of the Parent Coordinate System.

Rotate about an arbitrary axis

Action	Parameters							
	Angle (deg)	X-pos1	Y-pos1	Z-pos1	X-pos2	Y-pos2	Z-pos2	
Rotate about an arbitrary axis 🛛 💌	0	0	0	0	0	0	1	

Rotate the local coordinate system of the selected node about a new axis that is coincident with the line connecting the points (X-pos1, Y-pos1, Z-pos1) and (X-pos2, Y-pos2, Z-pos2). The X, Y, and Z positions are referenced to the Parent Coordinate System. The default orientation of the new axis is coincident with the Z-axis of the Parent Coordinate System.

Rotate one direction to another

Location:										
	Parent Coordinate System	Action	Parameters							
			X-dir1	Y-dir1	Z-dir1					
1	Global coordinate system 💌	Rotate one direction to another 🛛 💌	0	0	1					

• • •

X-dir2 Y-dir2 Z-dir2 X-pos Y-pos Z-pos Preserve nex X-di	3 Y-dir3 Z-dir3
0 0 1 0 0 0 🔽 Preserve 0	1 0

Applies to the selected node the coordinate transformation that sweeps from one direction to another. The start and end directions are specified as direction cosines in the Parent coordinate system. The position entries specify the center of rotation. The Preserve setting is used to determine and to preserve the orientation of the new position vector, so that, for example, the YZ plane is the same in the original and rotated positions.

General Rotation Matrix

Action Parameters												
	R00	R01	R02	R10	R11	R12	R20	R21	R22	Х	Y	Z
General matrix 💽	1	0	0	0	1	0	0	0	1	0	0	0

Rotate the local coordinate system of the selected node relative to the Parent Coordinate System using a general rotation matrix and (X, Y, Z) decenter. The entries for the rotation matrix are shown below. The first column contains the (x,y,z) projections of the new X' axis onto the

coordinate axes of the Parent Coordinate System. The second and third columns have similar projections for the new Y' and Z' coordinate axes.

$$R = \begin{bmatrix} R00 & R01 & R02 \\ R10 & R11 & R12 \\ R20 & R21 & R22 \end{bmatrix} = \begin{bmatrix} X_{i}' \\ X_{j}' \\ X_{k}' \end{bmatrix} \begin{pmatrix} Y_{i}' \\ Y_{j}' \\ Y_{k}' \end{bmatrix} \begin{pmatrix} Z_{i}' \\ Z_{j}' \\ Z_{k}' \end{bmatrix}$$

FRED does not check to verify that the entries are ortho-normal. This transformation should only be used as a last resort and if the correct input data is readily available. The rotation matrix is applied first, the decenter second.

See Also.... - Position/Orientation...

Help for other options available from the right click pop-up menu is available by selecting the appropriate links.

Traceable Draw Global Enclosing Volume Coordinate Axes...

Visualization Attributes...

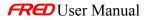
Position/Orientation...

Parent Coordinate System...

Scale...

Summary Report

Detailed Report



New Material Dialog

How Do I Get There? - New Material Dialog

There are three different ways to execute this command:

- 3. Menu
- 4. Keyboard Accelerator
- 5. Toolbar Button

Include Images

Dialog Box and Controls - New Material Dialog

🕻 (FRED1	*) Create a New M	laterial	<u>? ×</u>
Name:	Material 1		OK
Descriptio	n:		Cancel Help
Туре:	Sampled Material	(refraction indices for disc	crete wavelengths) 💌
	Wavelength (um)	Refractive Index	Imaginary Refractive
1 (0.5875618 👱	1	0
Gradient Step Si 0.1	t Index Material Comm ize Max # Steps 1000		et Z Offset
<u>Contro</u>	<u>)/</u>	Inputs / Descri	i <u>ption</u>
Name		Shows the nam	e of the material
Descrip	otion	Shows the desc	cription of the material
Туре		Shows the sele	cted type of the



<u>Defaults</u>

Material 1

empty

Step Size	Indicates the size of the step in the gradient	0.1
Max # Steps	Indicates the number of steps in the gradient	1000
X Offset		0
Y Offset		0
Z Offset		0
ОК	Applies the changes and dismisses the dialog	
Cancel	Dismisses the dialog without changing the material	
Help	Displays this help article	

The Parameters box changes to display the correct fields for the selected material type. The Sampled Material type is shown above, the other types are shown below.

The Model Material Parameters:

	Parameter	Description
Nd	1.5	Refractive index at "d" wavelength
Vd	64	ABBE number at "d" wavelength
ļ		
- Gradia	ent Index Mater	ial Common Parameters
Step	Size Max	# Steps X Offset Y Offset Z Offset
0.1	1000	0 0
	,	, , , ,

The Luneberg Gradient Index Parameters:

	Luneberg: H	1^2=N0^2[2	(R/R0)^2],	R^2=X^2+Y^2	+Z^2
	Parameters			Descripti	ion
Wav	0.5875618 💌	Wavelength	(microns)		
NO	1.5	Base refrac	tive index		
RO	1	Radial dista	nce normaliz:	ation length	
					•
– Grad	dient Index Ma	terial Commo	n Parameters		
Ste	p Size – M	ax # Steps	X Offset	Y Offset	Z Offset
0.1	10	000	0	0	0
-			,		

The Maxwell Gradient Index Parameters:

	Maxwell: N=	N0/[1+(R/R0)^2],	R^2=X^2+Y^2+	-Z^2	
	Parameters		Desc	ription	
Wav	0.5875618 💌	Wavelength (micro	ins)		
NO	1.5	Base refractive in	dex		
RO	1	Radial distance no	rmalization length		
•					Þ
Grad	dient Index Mal	terial Common Parar	neters		
		terial Common Parar ax # Steps X Off:		et Z	Offset

The Spherical Gradient Index Parameters:

	Spherical: N	I=NO+N1*F	R+N2*R^2+N3	*R^3+,	R^2=X	(^2+Y^2+ž	Z^2
	Parameters	i		Des	criptio	n	
Wav	0.5875618 💌	Wavelen	gth (microns)	I			
NO	1.5	constant	coefficient				
N1		R coeffic	;ient				
•							•
🗖 Gradi	ent Index Materi	al Commoi	n Parameters [.]				
Step 0.1	Size Max	# Steps	× Offset 0	Y Offse	·	Z Offset 0	

The selfoc Gradient Index Parameters:

	selfoc: N^2=	:N0^2[1+/-(N2*r)^2+/-(N4*r)^4+/], r^2=X^2+Y^2
	Parameters	Description
Wav	0.5875618 💌	Wavelength (microns)
NO	1.5	constant coefficient
N2		R^2 coefficient (sign determines add or subtract)
• [
 Image: Gradi 	ent Index Materia	al Common Parameters
		al Common Parameters # Steps X Offset X Offset Z Offset

The Axial/Radial Gradient Index Parameters:

	AxialRadial:	N=N0+Nz1*Z+Nz2*Z^2++Nr2*R^2+Nr4*R^4+, I	R^2=
	Parameters	Description	
Wav	0.5875618 💌	Wavelength (microns)	
NO	1.5	constant coefficient	
Nz1		Z coefficient	
Nr2		R^2 coefficient	
•			Þ
- Gradi	ent Index Materia	al Common Parameters	
Step 0.1	Size Max	# Steps X Offset Y Offset Z Offset 0 0 0 0 0	

The Script Gradient Index Material Parameters:

Сс	mpile	Test				
	1.1	ut va	unction riables riables	: (g_> g_w : g_N g_Ni	, <u>g_y</u> , <u>g</u> is the w is the r mag is t	ines the GR. _z) is the I avelength in efractive in he imaginary dy,g_dNdz) v
<u> </u>						
- Gr	adient l	ndex Mate	rial Commor	n Paramete	°S	
SI 0.		e Ma 100	x # Steps)0	X Offset	Y Offset	Z Offset

The Sampled Birefringent and/or Optically Active Material Parameters:

	X	Y	Z				
Axis	0	0	1	Uniaxial crys	stal axis ve		
	Wavelen (um)	N ordinary	N extraordinary	G ordinary	G extraord		
0	0.5875618 💌	1.5	1.5	0	0		
unused	0.5875618 💌	1.5	1.5	0	0		
•					►		
- Gradient Index Material Common Parameters							
- Gradie	Step Size Max # Steps X Offset Y Offset Z Offset						

Application Notes- New Material Dialog

See Also - New Material Dialog

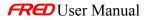
Axial/Radial Gradient Index Material Luneberg Gradient Index Material Maxwell Gradient Index Material Model Material Sampled Birefringent Material Sampled Material Script Gradient Index Material Selfoc Gradient Index Material

Material Listing/Selection Dialog

Description - Material Listing/Selection Dialog

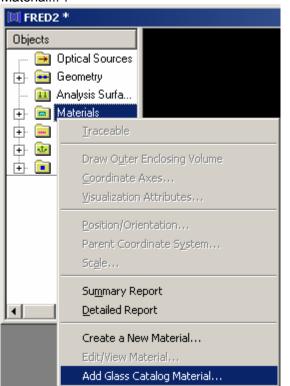
This dialog allows you to add a material from a vendor catalog to the active FRED document.

How Do I Get There? - Material Listing/Selection Dialog



—

From the Tree View, right click on the Materials folder and choose "Add Glass Catalog Material...":



Dialog Box and Controls - Material Listing/Selection Dialog

C	Material	Listing/S	election	<u> </u>
	Material Cata	alog: So	chott	-
	Material Nan	ne: 🔽		
	Click on a m	aterial to se	elect it. Click on a header to sort by that header.	
	Name	Nd	Vd	
	BASF51	1.72373	38.11	
	F2	1.62004	36.37	
	F4	1.61659	36.63	
	F5	1.60342	38.03	
	K10	1.50137	56.41	
	K7	1.51112	60.41	
	KZESNA -	1 6134	AA 29	_
	OK		Cancel Apply H	elp



<u>Control</u>	Inputs / Description	<u>Defaults</u>
Material Catalog	Displays the catalog that is currently listed in the Material List.	Schott
Material Name	Displays the name of the Material selected from the list.	
Material List	Displays the materials found in the currently selected catalog.	
ОК	Adds the material to the FRED document and closes the dialog.	
Cancel	Closes the dialog without adding a material to the FRED document.	
Apply	Adds the material to the FRED document and does not close the dialog.	
Help	Displays this help article.	

Application Notes - Material Listing/Selection Dialog

This dialog is modal and resizable.

See Also.... - Material Listing/Selection Dialog

New Material Dialog

New Mirror

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description New Mirror

This command displays a dialog that allows you to create a new mirror in the FRED optical system.

How Do I Get There? New Mirror There are four ways to access this command:

- On the Create Toolbar, click this button:
- On the Create Menu, click "New <u>Mirror..."</u>

Į	\underline{C} reate	<u>A</u> nalyses <u>W</u> indow	<u>H</u> elp
Ì	😫 Nev	v Simplified Source	Ctrl+Alt+I
	🖈 Nev	v <u>D</u> etailed Source	Ctrl+Alt+D
2	🌔 Nev	v <u>L</u> ens	Ctrl+Alt+L
	Nev	v <u>M</u> irror	Ctrl+Alt+M
	📐 Nev	v <u>P</u> rism K	Ctrl+Alt+P
	P Nev	v <u>S</u> ubassembly	Ctrl+Alt+S
	P Nev	v Custom <u>E</u> lement	Ctrl+Alt+E
	🥜 Nev	v Sur <u>f</u> ace	Ctrl+Alt+F
	C Nev	v Cur <u>v</u> e	Ctrl+Alt+V
	👑 Nev	v A <u>n</u> alysis Surface	Ctrl+Alt+N
	🗇 Nev	v Ma <u>t</u> erial	Ctrl+Alt+T
	🗢 Nev	v <u>⊂</u> oating…	Ctrl+Alt+C
	😕 Nev	v Sc <u>a</u> tter Model	Ctrl+Alt+A
	🚅 Nev	v <u>R</u> aytrace Control	Ctrl+Alt+R
	_		.

• On the Geometry folder or a Subassembly in the Tree View, right-click and choose "Create New Mirror..."

Objects	Description
📄 📄 Optical Source	ces
Geometry 🔃 Analysis Sur	✓ <u>T</u> raceable
🕂 💼 Materials	Never Traceable (for trimming surfaces)
🕂 🛄 Scatterers	Draw O <u>u</u> ter Enclosing Volume
🕂 直 Raytrace Pr	<u>C</u> oordinate Axes
	Visualization Attributes
	Position/Orientation
	Parent Coordinate System
	Sc <u>a</u> le
•	Su <u>m</u> mary Report
×	Detailed Report
=== Created	Create New Subassembly
	Create New Custom Element
	Create New Lens
•	Create New Mirror
	Create New Prism
	Insert Lens from Catalog



• Use they keyboard shortcut Ctrl+Alt+M.

Dialog Box and Controls New Mirror

代 (FRED1) C	reate a New Mirror	? <u>-</u> ×
Parent:	Geometry	OK
Name:	Mirror 1	Cancel
Description:		Apply
Basic Para Surface: Reflecting: Back:	Parameter Value: Type:	Help
0.5 Adva	YSemiApe Semi-ape: Name: Catalog: 0.5 0 Simple Glass Current	Select: Glass Immersion
R	eference Coordinate Action Parameters (right mouse-cl tarting Coordinate System ecometry ()	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Parent:	Displays the name of the tree object that will be the parent of the new mirror.	Geometry folder is the parent unless created under Subassembly.
Name:	Displays the name of the mirror.	Mirror <i>n</i>
Description:	Informative description of the mirror.	Empty String
Basic Parameters		
Reflecting Surface, Parameter Value	Defines the value for the reflecting (front) surface parameter.	0
Reflecting	Sets Radius, Curvature, or	Curvature



Surface, Type	<i>Focal Length</i> as surface specification for reflecting (front) surface.	(set in Preferences)
Back Surface, Parameter Value	Sets <i>Radius, Curvature</i> , or <i>Focal Length</i> as surface specification for back surface parameter.	0
Back Surface, Type	Defines the type of parameter for the back surface. Can be Radius, Curvature, or Focal Length.	Curvature (set in Preferences)
Conic Const:	Defines the mirror conic constant.	0
Thickness:	Defines the mirror center thickness.	0.1
	Mirror Aperture	
X/Y SemiApe	Defines the mirror semi- aperture in the X/Y direction.	0.5, 0.5
Advanced	Advanced aperture specifications including edge bevels details.	
	Central Hole	
Semi-Ape	Specifies semi-aperture of central hole in the mirror.	0
	Materials	
Glass Name	Displays name of mirror substrate material.	Simple Glass
Glass Catalog	Displays catalog name that holds mirror substrate material.	Current
Glass	Displays a Material selection dialog.	
Immersion Name	Displays the name of material the mirror is immersed in.	Air
Immersion Catalog	Displays catalog name that holds immersion material.	Current
Immersion	Displays immersion material selection dialog.	
Location of the Mirror (front surface vertex)		
Table	Specifies mirror Location and Orientation.	Starting Coordinate System: Geometry
ОК	Create a new Mirror and close dialog box.	

Cancel	Discard new Mirror and close dialog box.	
Apply	Apply new Mirror changes and keep dialog box open.	
Help	Access this Help page.	

Application Notes New Mirror

This dialog is resizable and modeless, so you can do other work in FRED without dismissing the dialog.

See Also.... New Mirror

> Create/Edit Lens Create/Edit Prism



Chapter 26 – FRED Menu Commands

File - Menu commands

The File menu offers the following commands:		
New, FRED Type	Creates a new optical layout	
New, Script Type	Creates a new script	
Import	Imports a Code V, OSLO, ZEMAX, or IGES file by creating a FRED file with the defined surfaces.	
Export	Exports an IGES or STEP file	
Save 3D View as JPEG	Exports the Visualization 3-D View as a JPEG image.	
Open	Opens an existing document, either an optical layout or a macro type	
Close	Closes an opened document.	
Save	Saves an opened document using the same file name.	
Save As	Saves an opened document to a specified file name.	
Exit	Exits FRED.	
Open From Recent Documents List	Lists the four most recent documents opened.	
Print Active View	Prints a document.	
Print Setup	Selects a printer and printer connection.	
Print Output Window	Prints the current contents of the output window.	
Output Window Print Setup	Displays the output window on the screen as it would appear printed.	
Print Preview	Displays the document on the screen as it would appear printed.	

File - New document commands Description

How Do I Get There?

Description - New document commands

Use this command to create a new optical system document or a new script document. You can open an existing document with the <u>Open command</u>.

How Do I Get There? - New document commands

There are four ways to execute this command:

On the file toolbar, click this button to create a new optical document: •

訚 Click this button to create a new script document:

- Use the Ctrl+N keyboard shortcut to generate a new optical document. Use the Ctrl+Shift+N keyboard shortcut to generate a new script document.
- On the command line, type "newsys" to generate a new optical document.
- On the File menu, select New, then "Fred Type" or "Script Type".

File - Import Dialog

Description - File Import Dialog

FRED can read a variety of files and translate them directly into the native FRED format. This is accomplished through the File Importation Dialog, which is located on the File menu. This command takes a Code V, OSLO, ZEMAX, or IGES formatted file and creates a FRED file, displaying any errors that occur during the import. process.

If there are any errors during the importing process, FRED will notify the user with a

yellow ¹ on the **Summary** page of the Import dialog.

Status	Operation	
\checkmark	File check	
\checkmark	Comments and summary	
1	Initial file scan	
	Import	

The errors are listed on the **Details** page of the dialog. Click on the **Details** tab to see the errors and warnings.

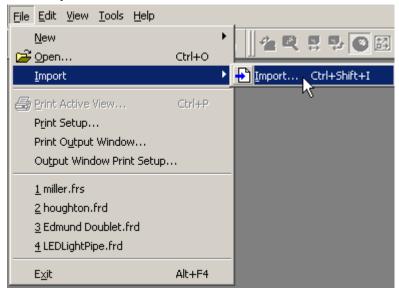
Status	Surface #	Command	Operation	2
×	Surface 1		INVALID GLASS: Material	
1	Surface 0	VUY 0. 0	Unsupported command	
1	Surface 0	VLY 0. 0	Unsupported command	
1	Surface 1	CCY 0	Unsupported command	

FRED supports many of the object or entity types defined in the IGES standard. FRED internally models these IGES objects exactly as they are defined in the standard instead of approximating the IGES objects with a FRED object. A <u>list of the IGES objects</u> supported by FRED can be used to understand the **Import** dialog **Details** report.

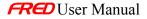
How Do I Get There? - File Import Dialog

There are three different ways to execute this command:

1. Select Import in the File menu:



- 2. Press the keyboard accelerator keys: Ctrl+Shift+I (the letter "i" and not the number "1" or the letter "L")
- 3. Press the toolbar button:



Dialog Box and Controls - File Import Dialog

This dialog is preceded by a file open dialog that asks you which file to import. When you select the file and click the Open button, this dialog appears. Although the data is read in when the file is selected, the elements are not created in a FRED file until you click the Create button on this dialog. FRED behaves this way so as to alert you to any possible errors that occurred before the system is created as a FRED file.

Import Optical/CAD File	<u>? ×</u>
\\agamemnon\f\fred\translators\iges\00006-2-surf.ig Browse	Optical Design Import Options
Comments:	Render transmitting surfaces as transparent
<u> </u>	Add Analysis Surface to image surface
<u>_</u>	Create edges and bevels on lens elements
Summary:	Create default sequential path
Number of points found = 0 Number of curves found = 0 Number of surfaces found = 0	Compute unassigned apertures from paraxial raytrace
Number of trimmed surfaces found = 38 Number of B-Reps found = 0 Number of assemblies found = 0	Minimum thickness
System units = inches	Default cement thickness 10 in microns
CAD Import Options Randomize unassigned colors on surfaces Randomize unassigned colors on curves	Dummy Surfaces
Independent Curves Surface Drawing Mode	Same material both sides
Make independent curves Shaded surface	Zero thickness to previous surface
Draw independent curves O Wire frame (fast)	Zero thickness to next surface
	Import Status
Create Dismiss Help	No errors encountered

<u>Control</u>	<u>Control</u> <u>Description</u>			
File LocationDisplays the filename of the file that being imported.		Name of the file to import		
	Allows selection of a different file to import.			
Comments:	Displays the comments found in the file being imported.			
Summary:	Displays a summary of the file being imported.			
	CAD Import Options			



Γ						
Randomize unassigned colors on surfaces	Allow FRED to choose surface colors.	Unchecked				
Randomize unassigned colors on curves	Allow FRED to choose curve colors.					
Make independent curves	Translate all curves as independent curves.	Checked				
Draw independent curves	Draw independent curves in 3D window.	Checked				
	Surface Drawing Mode					
Shaded surface/ Wireframe	Shaded surface/ Renders surfaces as Shaded or					
	Optical Design Import Options					
Render transmitting surfaces as transparent	Display transparent surfaces as transparent in 3D.	Checked				
Add Analysis Surface to image surfaceAdds an analysis plane to the last surface listed in the Code V, OSLO, or ZEMAX file. This checkbox is grayed out when importing IGES files.		Unchecked				
Create edges and bevels on lens elements	Add edges and bevels to lens elements.	Checked				
Create default sequential path	Store sequential path as path data.	Checked				
Compute unassigned apertures from paraxial raytrace	Assign apertures based upon paraxial raytrace for unassigned apertures.	Unchecked				
Minimum thickness	Force all thickness to be equal to value.	0				
Default cement thickness in microns	Choose default cement thickness.	10				
	Dummy Surfaces					
Show dummy surfaces	Import dummy surfaces.	Unchecked				
Same material both sides	Dummy surfaces have same material both sides.	Unchecked				
Zero thickness to previous surface	Add no thickness to previous dummy surface.	Unchecked				

Zero thickness to next surface	Add no thickness to next dummy surface.	Unchecked				
	Import Status					
Import Status	Displays status of import operation.					
Create	Populates a new FRED file with the elements and surfaces from the imported file.					
Dismiss	Discards dialog box and does not import any elements (if the Create button has not been pushed).					
Help	Access this Help page.					

Application Notes - File Import Dialog

This dialog is modal, which means it must be dismissed before any further work on the system can be done.

Examples - File Import Dialog

If, for example, we import a Code V file called LensFile.seq, which had a material called "BALK1" for surface 1. FRED would import the CodeV LensFile.seq file and search the FRED

catalogs for "BALK1". If it is not found, FRED would display a yellow "!", I Initial file scan for the prescan operation and list this unknown glass on the Details page.

Status	Surface #	Command	Operation
×	Surface 1		INVALID GLASS: Material "BALK1" not found in Schott catalog; substituting "Air"
	C	MINO	11

Errors in Importing

The FRED File Import Tool will intercept errors in importing surface types, materials, and coatings, as well as others. These errors fall into four main categories:

<u>Material Errors</u>: Errors occurring because of undefined or unknown materials. Errors of this type include:

UNCERTAIN CATALOG errors occur when FRED cannot determine the catalog a material came from. This error is common with ZEMAX files.

UNDEFINED GLASS errors occur when a material is not defined, whether in a vendor catalog or a user catalog

INVALID GLASS errors occur when a given material is not found in the catalog it is supposed to be in

<u>Surface Errors</u>: Errors occurring because of a surface type that FRED does not support. Errors of this type include:

UNSUPPORTED SURFACE errors occur when a file being imported has a surface that FRED does not know how to interpret.

<u>Coating Errors</u>: Errors occurring because of undefined or unknown coatings. Errors of this type include:

UNDEFINED COATING errors occur when a coating is not defined in FRED

<u>Program-specific Errors</u>: Errors occurring because of commands not supported by FRED. Errors of this type include any command that does not have a similar command in the FRED optical engineering system.

See Also.... - File Import Dialog

New Fred Document

<u>Open</u>

File - Import - Aperture Import Dialog

Description - The Aperture Import Dialog

When FRED imports a file from Code V, OSLO, or ZEMAX, it can automatically determine when a surface doesn't have aperture data specified. It then asks you for the necessary data using the Aperture Import Dialog.

How Do I Get There? - The Aperture Import Dialog

This dialog appears during a file import operation if FRED cannot determine the aperture of a given surface. It will appear automatically if the file being imported has any surface that has no aperture specification. There is no menu option that brings up this dialog.

Dialog Box and Controls - The Aperture Import Dialog



🔆 No Aperture Information	for Surface 12 of 12 ? 🗙
Please specify aperture data for	
Geometry.dbgauss.Surface 12.	Surf 12 (Plane)
Semi-Aperture X: (0> same as Y) 0 Y: 15.4544553757	Decenter X: 0 Y: 0
Shape © Circular/Elliptical	C Square/Rectangular
Apply to this surface and to any O	surface of the following have aperture information Help

Figure 1: The Aperture Import Dialog

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>			
Please specify aperture data for:	Lists the name of the surface that requires additional aperture data.				
Semi-Aperture					
X	Surface X semi-aperture value. If 0, then the X semi- aperture is set to the same value as the Y semi-aperture.	0			
Y Surface Y semi-aperture value.		Y semi-aperture of the previous surface			
Decenter					
Х	X direction offset value.	0			
Υ	Y direction offset value.	0			
Shape					
Circular/Elliptical	Selects an elliptical aperture shape.	Selected			
Square/ Rectangular	Selects a rectangular aperture shape.	Not Selected			
Apply to this surfaceThe number of surfaces to apply this data to if FRED cannot determine the aperture automatically.		0			

ОК	Apply aperture data and close dialog box.	
Неір	Access this Help page.	

Application Notes - The Aperture Import Dialog

- This is a modal dialog, which means that you must push the OK button in order to continue with the file import.
- The Y semi-aperture is determined from the last surface whose y semi-aperture was determined. For example, if a system has surfaces 1, 2, and 3, and the aperture for surface 1 is specified but surface 2 is not, FRED will ask you what the aperture information should be for surface 2 based on the data for surface 1. It will then ask you for the data for surface 3, using the data from surface 2.

See Also - The Aperture Import Dialog

File - Importation Dialog

FRED can read a variety of files and translate them directly into the native FRED format. This is accomplished through the File Importation Dialog, which is located on the File menu. This command takes a Code V, OSLO, ZEMAX, or IGES formatted file and creates a FRED file, displaying any errors that occur during the import. process.

If there are any errors during the importing process, FRED will notify the user with a yellow ¹/₂ on the **Summary** page of the Import dialog.

\\agamemnon\f\fred\translators\ige:	s\00006-2-surf.ig Browse	Optical Design Import Options
Comments:		Render transmitting surfaces as transparent
	<u> </u>	Add Analysis Surface to image surface
	<u>.</u>	Create edges and bevels on lens elements
Summary:		Create default sequential path
Number of points found = 0 Number of curves found = 0 Number of surfaces found = 0		Compute unassigned apertures from paraxial raytrace
Number of trimmed surfaces found = Number of B-Reps found = 0 Number of assemblies found = 0	38	Minimum thickness
System units = inches		Default cement thickness 10 in microns
CAD Import Options		Dummy Surfaces
Randomize unassigned color		Show dummy surfaces
Randomize unassigned color		Same material both sides
Independent Curves	Surface Drawing Mode	Zero thickness to previous surface
Make independent curves		
Draw independent curves	C Wire frame (fast)	Zero thickness to next surface
		Import Status
Create Dismiss	Help	No errors encountered

The errors are listed in the Output Window.

FRED supports many of the object or entity types defined in the IGES standard. FRED internally models these IGES objects exactly as they are defined in the standard instead of approximating the IGES objects with a FRED object. A <u>list of the IGES objects</u> supported by FRED can be used to understand the **Import** dialog **Details** report.

How Do I Get There? - The File Importation Dialog

There are three different ways to execute this command:

1. Select **Import** in the **File** menu:

C	FRI	ED					
	Eile	<u>E</u> dit	⊻iew	<u>T</u> ools	<u>H</u> elp		
Ī		<u>N</u> ew					•
Щ	Ē	<u>O</u> pen				Ctrl+O	H
	Ð	Impor	t			Ctrl+Shift+I	
	6	Print,		~\\		Ctrl+P	
	Print Setup						
	Print Output Window						
		Outpu	ut Wind	low Prin	nt Setu	p	

- 2. Press the keyboard accelerator keys: Ctrl+Shift+I (the letter "i" and not the number "1" or the letter "L")
- 3. Press the toolbar button:

Dialog Box and Controls - The File Importation Dialog

This dialog is preceded by a file open dialog that asks you which file to import. When you select the file and click the Open button, this dialog appears. Although the data is read in when the file is selected, the elements are not created in a FRED file until you click the Create button on this dialog. FRED behaves this way so as to alert you to any possible errors that occurred before the system is created as a FRED file.



GImport Optical/CAD Fi	le		<u>?×</u>
\\agamemnon\f\fred\transl	ators\iges\00006-2-surf.ig Browse	Optical Design Import Options	
Comments:		Render transmitting surfaces a	is transparent
<u> </u>		Add Analysis Surface to image surface	
	T	Create edges and bevels on la	ens elements
, Summary:			
Number of points found = 0		Create default sequential path Compute unassigned aperture	s from
Number of curves found = 0 Number of surfaces found = 0		Compute unassigned aperture paraxial raytrace	2 11 2 111
Number of trimmed surfaces found = 38		Minimum thickness	
Number of assemblies found = 0 System units = inches		Default cement thickness 10	
, ⊢ CAD Import Options		in microns	
Randomize unassig	ned colors on surfaces	Dummy Surfaces	
Randomize unassigned colors on curves		Show dummy surfaces	
- Independent Curves-	Surface Drawing Mode	Same material both sides	
Make independent	curves 📀 Shaded surface	Zero thickness to previous	surface
Draw independent of	curves C Wire frame (fast)	Zero thickness to next surf	ace
		Import Status	
Create		No errors encountered	
	Help		
ntrol	Description		<u>Defaults</u>
			The
	Displays the filename of the file that is being		name of
e Location	imported	the file	
			you want
			to import
wse Button	Allows you to select	a different file to import	
mments:	Displays the comments found in the file being		
mments.	imported		
mmary:	Displays a summary of the file being imported		
	Shows the status of a	each of the four steps of	
	Shows the status of each of the four steps of the import process. Can have one of 4 icons: blue		
mmary Tab	triangle (currently execut	ing), green check (all is	
	well), yellow exclamation (recoverable error occurred), or red X (serious problem occurred).		
	Gives details of each of the steps shown on		
tails Tab	the Summary Tab including any errors, unrecognized commands, missing materials, etc.		
ite messages to			
put window			



Render transmitting surfaces as transparent		
Randomize unassigned colors		
Add Analysis Surface to image surface	Adds an analysis plane to the last surface listed in the Code V, OSLO, or ZEMAX file. This checkbox is grayed out when importing IGES files.	
Create edges and bevels on lens elements		
Create default sequential path		
Show dummy surfaces		
Compute unassigned apertures from paraxial raytrace		
Minimum thickness		0
Default cement thickness in microns		10
Create	Populates a new FRED file with the elements and surfaces from the imported file	
Dismiss	Dismisses the dialog and does not import any elements (if the Create button has not been pushed).	
Help	Displays this help article	

Application Notes - The File Importation Dialog

This dialog is modal, which means it must be dismissed before any further work on the system can be done.

Examples - The File Importation Dialog

If, for example, we import a Code V file called LensFile.seq, which had a material called "BALK1" for surface 1. FRED would import the CodeV LensFile.seq file and search the FRED



catalogs for "BALK1". If it is not found, FRED would display a yellow "!", for the prescan operation and list this unknown glass in the Output Window.

Errors in Importing

The FRED File Import Tool will intercept errors in importing surface types, materials, and coatings, as well as others. These errors fall into four main categories:

<u>Material Errors</u>: Errors occurring because of undefined or unknown materials. Errors of this type include:

UNCERTAIN CATALOG errors occur when FRED cannot determine the catalog a material came from. This error is common with ZEMAX files.

UNDEFINED GLASS errors occur when a material is not defined, whether in a vendor catalog or a user catalog

INVALID GLASS errors occur when a given material is not found in the catalog it is supposed to be in

<u>Surface Errors</u>: Errors occurring because of a surface type that FRED does not support. Errors of this type include:

UNSUPPORTED SURFACE errors occur when a file being imported has a surface that FRED does not know how to interpret.

<u>Coating Errors</u>: Errors occurring because of undefined or unknown coatings. Errors of this type include:

UNDEFINED COATING errors occur when a coating is not defined in FRED

<u>Program-specific Errors</u>: Errors occurring because of commands not supported by FRED. Errors of this type include any command that does not have a similar command in the FRED optical engineering system.

File - Import - ASAP Import Units Dialog

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - ASAP Import Units Dialog

This dialog asks for the units of measurement for data contained in the ASAP file that is to be imported to FRED.

How Do I Get There? - ASAP Import Units Dialog

This dialog appears when you attempt to import an ASAP text file.

Dialog Box and Controls - ASAP Import Units Dialog

Select Units for Imported ASAP File	×
ASAP does not write out the system or wavelength units in the PRINTed output. Select the appropriate units here.	OK
Select System Units Select Wavelength Units	Cancel
	Help

Control	Inputs / Description	Defaults
Select System Units	Determines geometry dimensional units.	Inches
Select Wavelength Units	Determines wavelengths units.	Microns
ОК	Accept the units selections to the imported file and close dialog box.	
Cancel	Discard units selections and close dialog box.	
Help	Access this Help page.	

Application Notes - ASAP Import Units Dialog

When the OK button is clicked, the units are passed into the FRED Import Dialog.

See Also - ASAP Import Units Dialog

FRED Import Dialog

ASAP is a trademark or registered trademark of Breault Research Organization.

File - Export

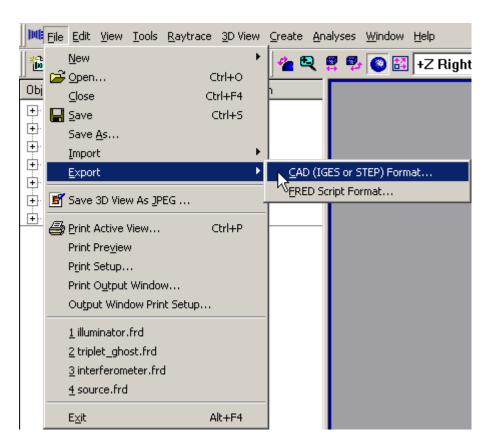
Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - File Export

Exports FRED geometry in IGES or STEP format.

How Do I Get There? - File Export

From the File menu, select Export>CAD(IGES or STEP) Format.....



Dialog Box and Controls - File Export



<u>Control</u>	Inputs / Description Defaults			
File Name	Name of file to export. FRED file nam			
File Format	Choose STEP or IGES. STEP			
Export Type	Export as Solids or Surfaces.	Solids		
Optional Author Identifiers	User input: Name and Organization blank			
Options				
Export Select an export option: Traceable Untraceable Never Traceable All Curves Current Ray Trajectories		Traceable		
Tolerance				

Coincidence Tolerance	0.0001			
	Aperture Sampling			
Azimuthal Samples	Number of samples used to compute the inner and outer trimming curves for a surface.	32		
Aspheric Surface Sampling				
Radial Samples	Number of radial samples used to compute the inner and outer trimming curves for a surface.	32		
Show fit statistics	Print fit statistics to output window.	Checked		
Fitted Surface Sampling				
Number of Patches Number of U V patches.		16, 16		
Show fit statistics	Print fit statistics to output window.	Checked		
Ruled Surface Sampling				
Number of Samples	Samples along Edges	32		
ОК	OK Accept CAD Export settings and close dialog box.			
Cancel	Discard changes and close dialog box.			
Help Access this Help page.				

Application Notes - File Export

See Also - File Export

File Import

File - Save 3D View as JPEG command

Description How Do I Get There? See Also...

Description - Save 3D View as JPEG command

Use this command to save the Visualization view as a JPEG image. When you select this command, FRED brings up a standard Windows File Save As dialog. Navigate the file system to the directory where you want to save the image, then type in a file name and click the "Save" button.

How Do I Get There? - Save 3D View as JPEG command

There are two different ways to execute this command:

- From the File menu, choose "Save 3D View as JPEG...".
- On the File Toolbar, press this button:

See Als - Save 3D View as JPEG command

Save Command Active View Copy

File - Open command

Description How Do I Get There? See Also...

Description - Open command (File menu)

Use this command to open an existing document file. You cannot open multiple documents at once. Use the Window menu to switch among the multiple open documents. See <u>Window 1, 2, ... command</u>.

When you select this command, FRED brings up a standard Windows File Open dialog, listing the FRED files in the currently selected directory. Navigate the file system to the directory that holds your file, then select it and press the Open button.

How Do I Get There? - Open command (File menu)

There are four different ways to execute this command:

1. Select **Open** in the **File** menu:

Eik	e <u>E</u> dit	⊻iew	Iools	Ray Trace	3D View
Î	New				•
💷 🚰 Open			Ct	rl+0	
: <u>C</u> lose			Ctrl+F4		
i D	Save			Chrl+S	

- 2. Press the keyboard accelerator keys: Ctrl+O
- 3. Press the toolbar button:
- 4. Type "open *filename*" on the input line, where *filename* is a valid, existing FRED file. If the file is already open a duplicate is not opened.

See Also - Open command (File menu)

File New Command Window 1, 2 ... Command

File - Close command

Description How Do I Get There?

Description - Close command

Use this command to close the active document without saving the document. If you close a document without saving, you lose all changes made since the last time you saved it.

Note: We recommend that you save your changes often.

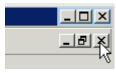
How Do I Get There? - Close command

There are three ways to close the active document:

1. Select close in the File Menu.



- 2. Using the accelerator keys, Ctrl+F4
- 3. Closing the active window by left mouse clicking on the 🔟 icon in the upper right-hand corner.



Note: If there are multiple windows open for the same optical system, you are not prompted to save changes to the system until you close the last window that relates to that system. It does not matter which window is the last window.

File - Save command

Description How Do I Get There? Dialog box and Controls See Also...

Description - Save command

Use this command to save the active document with a name in a directory. When you save a document for the first time, FRED displays the <u>Save As dialog box</u> so you can name your document. If you want to change the name and directory of an existing document before you save it, choose the <u>Save As command</u>.

- Note or Tip When dealing with multiple windows that describe the same optical system (i.e. the optical layout and various analysis plots), you are not prompted to save changes to the system until you close the last window that relates to that system. For instance, say you have cassegrain.frd open, along with a Ray Positions Plot and a Ray Irradiance Distribution Plot. If you close the Ray Positions Plot and the optical layout window, FRED will not ask you to save the changes you have made. It will only ask you to save the changes when you close the Ray Irradiance Distribution Plot. To return to the Tree View + OpenGL View, select the Window->New Window menu.
- (We recommend that you save your changes often, regardless of what windows you have open, and that you close the optical layout last. This is because after closing the optical layout, you cannot reopen it unless you close all windows relating to that system and reopen the file.

How Do I Get There? - Save command

There are three ways to access this command:

- 1. On the File Toolbar, click this button:
- 2. Use the keyboard shortcut Ctrl+S.
- 3. On the File menu, select "Save".

Dialog Box and Controls - Save command

This command brings up a standard Windows Save dialog box.

See Also - Save command

New FRED Document Open

File - Save As command

Description How Do I Get There? Dialog box and Controls See Also...

Description - Save As command

Use this command to save and name the active document. FRED displays the <u>Save As</u> <u>dialog box</u> so you can give your document a new name. To save a document with its existing name and directory, use the <u>Save command</u>.

How Do I Get There? - Save As command

From the File menu, choose Save <u>As...</u>.

Dialog Box and Controls - Save As command

This command displays a standard Windows Save As dialog box.

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See Also - Save As command

New FRED Document Open Save



File - Save As dialog box

Description How Do I Get There?

Description - File Save As dialog box

FRED allows you to save the currently open file as a copy with a different file name. When you chose this menu option, FRED displays a standard Windows Save As dialog. Enter the location and name of the copy you want to save and choose **Save**.

How Do I Get There? - File Save As dialog box

From the File menu, choose "Save As..." There is no keyboard shortcut or toolbar button for this command.

File - Exit command

Description How Do I Get There?

Description - Exit command

Use this command to end your FRED session. You can also use the Close command on the application Control menu. FRED prompts you to save documents with unsaved changes.

How Do I Get There? - Exit command

There are three ways to execute this command. Click the application's Close button in the upper right corner.



Use the keyboard shortcut Alt+F4. Type "exit" on the input line.



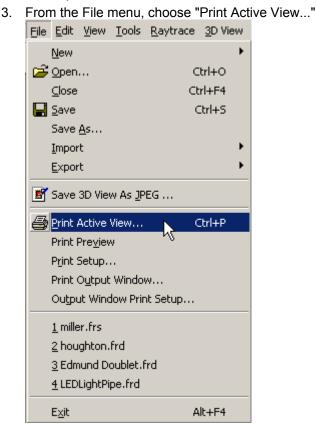
File - Print Active View...

Description How Do I Get There? Dialog box and Controls Application Notes

Description - Print dialog box

Use this command to print the active view in the current optical layout (or script, as the case may be). This command presents a standard Windows print dialog box, where you may specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options.

How Do I Get There? - Print dialog box



There are three ways to execute this command:

4. From the File Toolbar, press the Print button:



5. Press Ctrl+P on the keyboard.

Dialog Box and Controls - Print dialog box

This command brings up a standard Windows Print dialog. This dialog will vary from system to system, based on the Windows version and the printer used.

Application Notes - Print dialog box

When the OK button is pushed, the window that is printed is the active window. If, for example, you last clicked in the Visualization window, that window will be printed. If you last clicked in the Tree View, the Tree View will be printed.

File - Print Preview command

Description How Do I Get There?

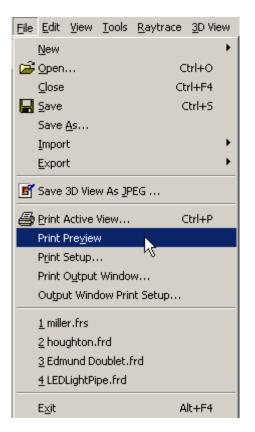
Description - Print Preview command

Use this command to display the active document, as it would appear when printed. When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The <u>print</u> <u>preview toolbar</u> offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

How Do I Get There? - Print Preview command

From the File Menu, choose Print Preview.





File - Print Setup command

Description How Do I Get There?

Description - Print Setup command

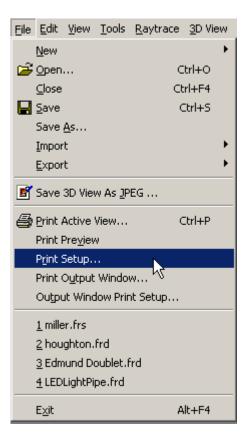
This command allows you to change the general settings for your printer. Specifically, it allows you to change which printer you use, the paper orientation, the paper size, and the paper source.

How Do I Get There? - Print Setup command

From the **File** menu, choose **P**<u>r</u>**int Setup...**.



—



Dialog Box and Controls - Print Setup command

This command displays a Windows standard print setup dialog box.

File - Print Output Window command

Description How Do I Get There?

Description - Print Output Window command

Use this command to select a printer and a printer connection. This command presents a Print Setup dialog box, where you specify the printer and its connection. After clicking OK, it sends a print job to the printer consisting of whatever is in the output grid. There are certain rules it follows that you should be aware of.

How Do I Get There? - Print Output Window command

If there is not something highlighted in the Output Window: FRED checks to see if the Print Selection option was chosen in the Print Setup dialog box.

FRED User Manual

This option is grouped with the Print All pages option and the Print Range of pages option. If it was not selected, it prints the entire grid or the range of pages selected. If it was selected, it prints the grid, beginning with the first visible row in the Output Window and ending after one page.

If there is something selected in the Output Window:

FRED prints only what is selected, even if you choose the Print All option.

There are three ways to access this command:

- On the File Toolbar, click this button:
- On the File menu, choose "Print Output Window".
- Use the Keyboard shortcut Ctrl+Shift+P.

File - Output Window Print Setup

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

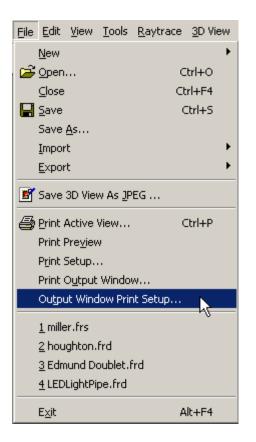
Description - Output Window Print Setup

This will bring up a dialog where you can change several printing options for the output window. There is a simple preview window in this dialog that allows you to see the effect of the changes you make. These options are not saved between FRED sessions.

How Do I Get There? - Output Window Print Setup

From the **File** menu, choose **Output Window Print Setup...**. There is no keyboard shortcut or toolbar button for this command.





Dialog Box and Controls - Output Window Print Setup

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6
Page OrderCenter on Page
First Rows, then Columns
Tennoar
Page Order Center on Pa

<u>Control</u>	Inputs	<u>Defaults</u>
Margins Left	Displays the amount of margin to allow on the left side of the page.	1.00 in
Margins Right	Displays the amount of margin to allow on the right side of the page.	1.00 in
Margins Top	Displays the amount of margin to allow at the top of the page.	1.50 in
Margins Bottom	Displays the amount of margin to allow at the bottom of the page.	1.50 in
Row Headers	Tells FRED to print the column of row numbers at the left of the Output Window.	Checked
Column Headers	Tells FRED to print the row of column letters at the top of the Output Window.	Checked
Print Frame	Prints a frame around the output window on the printed page.	Checked
Vertical Lines	Prints the vertical lines separating the columns.	
Horizontal Lines	Prints the horizontal lines separating the rows.	Checked
Only Black and White	Ignores color in the output window when printing.	Checked
First Rows, then Columns	Determines the collating order of the print job.SetSee Application Notes for details.Set	
First Columns, then Rows	Determines the collating order of the print job. See Application Notes for details.	Not Set
Center on Page vertical	Centers the printing vertically on the page.	Unchecked
Center on Page horizontal	Centers the printing horizontally on the page.	Checked
Preview	Shows how the Output Window will look printed.	
OK	Saves changes and dismisses the dialog	
Cancel	Ignores changes and dismisses the dialog	

Application Notes - Output Window Print Setup

• This is a modal dialog, which means that the dialog must be dismissed in order to return to the document(s).

• When collating pages, FRED checks the state of the Page Order option to determine which sequence to print the pages in. For example, suppose your Output Window has A-R columns and 60 rows and a page can hold 5 columns and 20 rows. If the Page Order option is set to "First Rows, then Columns", FRED will print columns A-E and rows 1-20 on the first page, then print columns A-E and rows 21-40 on the second page, then columns A-E and rows 41-60. It will then move to columns F-J, and proceed in the same manner.

If the Page Order option is set to "First Columns, then Rows", FRED will print columns A-E and rows 1-20 on the first page, then print columns F-J and rows 21-40 on the second page. It will continue in the same manner until it prints the entire print job.

See Also - Output Window Print Setup

Print Output Window

File - Print Preview command

Description How Do I Get There?

Description - Print Preview command

Use this command to display the active document, as it would appear when printed. When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format. The <u>print preview toolbar</u> offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

How Do I Get There? Print Preview command

From the File Menu, choose Print Preview.



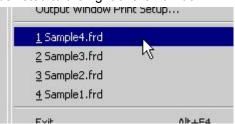
¢	🖁 FR	ED 1.2	25 (po	wered	by Photor	n Engine
	Eile	<u>E</u> dit	⊻iew	<u>T</u> ools	<u>R</u> ay Trace	<u>3</u> D View
II		<u>N</u> ew				•
	Ê	Open			Ct	rl+0
		⊆lose			Ctr	l+F4
ſ		<u>S</u> ave			C	trl+S
lr		Save	<u>A</u> s			
lŀ	· Ð	Impor	t		Ctrl+Sh	ift+I
	8	Print.			C	trl+P
Ι		Print I	Pre <u>v</u> iev	v N		
		Print :	Setup.			

File - 1, 2, 3, 4 command

Description How Do I Get There?

Description - 1, 2, 3, 4 command (File menu)

FRED allows you to rapidly open a recently used file. To do this, you select from the numbers and filenames listed at the bottom of the File menu to open the last four documents you closed. Choose the number that corresponds with the document you want to open, which will be listed to the right of the number.



How Do I Get There? - 1, 2, 3, 4 command (File menu)

From the File menu, press the 1, 2, 3, or 4 key, corresponding to the file you want to open.





Edit - Menu commands

The Edit menu offers the following commands:

Undo	Reverses the previous action
Redo	Performs the previous action again
Cut	Cuts the currently selected object onto the clipboard
Сору	Copies the currently selected object onto the clipboard
Paste	Pastes the current object on the clipboard into the currently selected position
Select All	Available only when a Script window is active. Selects all the text in the window.
<u>Find</u>	Available only when a Script window is active. Displays the find text dialog.
Find Next	Available only when a Script window is active. Finds the next instance of the string being searched for.
Replace	Available only when a Script window is active. Displays the replace text dialog.
Output Window Cut	Cuts the data that is selected in the Output Window and places it on the clipboard
Output Window	Copies the data that is selected in the Output Window and places it on

Сору	the clipboard
Output Window Paste	Pastes the data that is on the clipboard into the selected area in the Output Window
Active View Copy	Copies the current view as a bitmap to the Windows Clipboard
General File Comment	Edits the comment for the currently active file.

Edit - Undo command

Description How Do I Get There?

Description - Undo command

This command reverses the most recently taken action. For example, if you typed something, executing the Undo command will remove the typed text. This command is only available when a Script is being edited.

How Do I Get There? - Undo command

There are two ways to execute this command:

• From the Edit menu, choose "Undo".

ſ	<u>E</u> dit	<u>S</u> cript	⊻iew	<u>T</u> ools	<u>W</u> indo
1	\square	Undo		Ctrl+	z
	\simeq	<u>R</u> edo	К	Ctrl+	-Y
j	X	Cu <u>t</u>		Ctrl+	×.
1	B)	⊆ору		Ctrl+	C
	6	<u>P</u> aste		Ctrl+	٠V
•	Select All		Ctrl+A		
I	#	Eind		Ctrl+	·F
	I	R <u>e</u> place		Ctrl+	н

• Use the keyboard shortcut Ctrl+Z.

Edit - Redo command

Description

Description - Redo command

This command is not implemented yet.

Edit - Cut command

Description How Do I Get There?

Description - Cut command (Edit menu)

Use this command to remove the currently selected data from the document and put it on the clipboard. This command is unavailable if there is no data currently selected.

In general, anything that can be selected can be cut. This includes text, numbers, Tree objects, and multiple selections of these things.

How Do I Get There? - Cut command (Edit menu)

There are three ways to access this command:

- On the Edit Toolbar press this button:
- Use the Keyboard Shortcut Ctrl+X.
- From the Edit menu, choose "Cut".

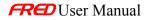
Edit - Copy command

Description How Do I Get There?

Description - Copy command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected. Copying data to the clipboard replaces the contents previously stored there.

In general, anything that can be selected can be copied. This includes text, numbers, Tree objects, and multiple selections of these things.



How Do I Get There? - Copy command

There are three ways to execute this command:

From the File toolbar, press this button: Use the keyboard shortcut CTRL+C From the Edit menu, select "Copy".

Edit - Paste command

Description How Do I Get There?

Description - Paste command (Edit menu)

Use this command to insert a copy of the clipboard contents at the insertion point. This command is unavailable if the clipboard is empty.

If something is selected and the Paste command is given, the selected item will be replaced with the item from the clipboard.

How Do I Get There? - Paste command (Edit menu)

There are three ways to execute this command:

- From the File toolbar, press this button:
- Use the keyboard shortcut Ctrl+V
- From the Edit menu, select "Paste".

Edit - Select All command

Description How Do I Get There?

Description - Select All command

This command selects all the text in a FRED Script. This command is only available when a Script document is active and when there is text to select.



How Do I Get There? - Select All command

There are two ways to access this command:

	On the Edit Menu, click "Select All"					
	<u>E</u> dit	Script	⊻iew	<u>T</u> ools	<u>W</u> indo	
ĺ	\square	Undo		Ctrl+	Z	
	\square	<u>R</u> edo		Ctrl+	-Y	
į	¥	Cut		Ctrl+	-%	
I	Þ	⊆ору		Ctrl+	-C	
	C	Paste		Ctrl+	٠V	
:		Select A	Į I	Ctrl+	A	
I	抖	Eind		Ctrl+	-F	
		R <u>e</u> place		Ctrl+	·Η	

• Use they keyboard shortcut Ctrl+A.

Edit - Output Window Cut Command

Description

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How Do I Get There?

Description - Output Window: Cut Command

This command takes the current selection in the text output window and cuts it to the Windows clipboard. The selected area remains selected. If nothing is selected, nothing gets cut.

How Do I Get There? - Output Window: Cut Command

There are three ways to execute this command:

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- From the Output Window toolbar, press this button:
- Use the Ctrl+Shift+X keyboard shortcut.
- From the edit menu, select "Output Window Cut".

Edit - Paste Output Window Command

Description How Do I Get There? This command takes the current Windows clipboard contents and pastes them into the selected text Output Window area. If nothing is selected, nothing gets pasted.

How Do I Get There? -Output Window: Paste Command

There are three ways to execute this command:

- From the Output Window toolbar, press this button:
- Use the Ctrl+Shift+V keyboard shortcut.
- From the edit menu, select "Output Window Paste".

View - Menu Commands

The View menu offers the following commands:

Toolbars	Brings up the toolbars dialog for selecting the buttons to display
Status Bar	Displays the application status bar at the bottom, showing lock key status and mouse coordinates.
Output Window -> View	Toggles displaying the Output Window
Output Window -> Cells	Displays the Output Window as a spreadsheet (with grid boxes) or a regular sheet (no grid boxes)
Output Window -> Clear Contents	Deletes any text in the output Window
Calculator	Brings up a calculator that can be attached to the perimeter of the document

Toolbars

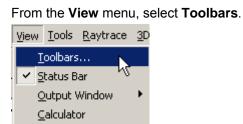
Description How Do I Get There? Dialog box and Controls



Description Toolbars

This dialog displays the various toolbars available in FRED and enables customization of the Toolbar Buttons.

How Do I Get There? Toolbars



Dialog Box and Controls Toolbars

Toolbars	2
Toolbars:	Close
✓Menu bar File	New
✓Visualization ✓Raytrace ✓Analysis	Customize
Edit	Reset
Toolbar name:	Help
Menu bar	
Show Tooltips	Cool Look
Large Buttons	

Toolbars	List of Toolbars	
Toolbar Name	Selected toolbar.	
Show Tooltips	Show tooltips on hover.	
Cool Look	Change button style.	



Large Buttons	Use Large buttons
Close	Close and accept changes.
New	Add new toolbar.
Customize	Customize existing toolbar.
Reset	Reset toolbars to default.
Help	Access this Help page.

View - Output Window Cells

Description Visualization (example) How Do I Get There?

Description Output Window Cells

The Output Window is a spreadsheet with rows and columns with two viewing options: 1) spreadsheet style with cell borders, row numbers, and column letters or 2) text file option with no cell borders, no row numbers, and no column letters. The user can toggle between the two viewing options with this command. Note, in both cases the Output Window is still a spreadsheet.

Note The colors of the text, numbers, and formulas in the Output Window can be set to difference colors in the Format page of the Preferences.

Visualization (example) Output Window Cells

	A B	C	D	E	F	G	Н	I	
126									
127	RAYTRACE SUMMARY:				(houghton	.frd)			
128									
129	97	Num rays at	start						
130	97	Num rays at	end						
131	97	Num rays tra	ced						
132	1489	Num ray-surf	ace inte	rsections					
133	0.144 sec	Elapsed ray	trace ti	.me					
134	9	Num rays hal	ted due	to no mor	e intersect	tions four	ld		
135									T



How Do I Get There? **Output Window Cells**

There are two different ways to execute this command:

To view the output window cells, select Output Window in the View Menu and toggle the Cells option.



View - Calculator

Description Visualization (example) How Do I Get There?

Description

Calculator

FRED has a basic calculator that provides for simple arithmetic. This calculator is designed as part of the toolbars, so it can be detached to float freely, or attached to anywhere on the perimeter of FRED.

Visualization (example) Calculator

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	7	8	9	1
	4	5	6	*
	1	2	3	-
		D		+
	=	E	nter	

The calculator enabled.

How Do I Get There? Calculator

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From the **View** menu, select **Calculator**.





Tools - Menu commands

The Tools menu offers the following commands:						
Preferences	Displays the dialog that lets you set the options available in FRED.					
User Defined Scripting Tools	Links to the specified scriptsthey can be run by choosing the matching menu item.					
Units and Scaling	Displays the dialog that scales an optical system and modifies the system units.					
Edit/View GRIN Material Position/Orientation	Displays the dialog that scales an optical system and modifies the system units.					
Reports -> Document Summary	Displays in the output window a summary of all the items in the system					
Reports -> Document Detail	Displays in the output window a detailed listing of all the items in the system					
Reports -> Entity Reference Coordinates	Displays in the output window coordinates of all entities in selected coordinate system.					
Reports -> Current Ray Set Summary	Displays in the output window a summary of all the rays in the ray buffer					
Reports -> Ray Detail	Displays in the output window a detailed report of a specified ray from the ray buffer					
Reports -> Raytrace Paths	Displays a spreadsheet containing all raytrace paths.					
Reports -> Stray Light Report	Displays a customizable stray light report documenting specular and scatter paths.					
Determine Scatter Importance Sampling	Automatically determines Importance Sampling for specified components.					
Analyze Scatter Importance Sampling	Evaluates efficiency of Importance Sampling assignments.					
Force Immediate Document Update	Forces an immediate update of your FRED document.					
Edit/View Pre-Update Script	Edits a Pre-Update script.					
Edit/View Post-Update Script	Edits a Post-Update script.					
Pre-Update Script Status (active if checked)	Sets status of Pre-Update script.					
Post-Update Script Status (active if checked)	Sets status of Post-Update script.					
Edit/View Global Script Variables	Displays a dialog box containing Global Script Variable assignments.					

The Tools menu offers the following commands:

Tools - Format Options Page

Description - The Format Options Page

This help article describes the options in FRED that affect the macro editor.

How Do I Get There? - The Format Options Page

From the **Tools** menu, choose **Preferences**, then click on the **Format** tab.

Dialog Box and Controls - The Format Options Page

This dialog gives a listing of the settings that can be set for displaying text in FRED.

C Preferences	<u>×</u>
Warnings Output Wind	Miscellaneous Miscellaneous 2 File Locations ow Visualization Format Units of Measurement
Category: Script Editor Text Output V <u>B</u> eset <u>S</u> cript Editor <u>I</u> ab size <u>K</u> eep T <u>C</u> Insert S	Window Colors Text ▲ Language Keywords ▲ Comments Built-In Functions Identifiers Numbers Window ✓ 4 Sample abs AaBbCcXxYuZz
	OK Cancel Help
<u>Control</u>	Inputs/Description Defaults
Category	Lists the various categories that can have their text customized.Script Editor

		Window
Reset Button	Resets the selected item listed in the Colors list to its default.	
Reset All Button	Resets all items in the Colors list to their default.	
Tab Size	Selects how large a tab is in the macro editor.	4
Keep Tabs	In the macro editor, selecting this option inserts actual tab characters when you press the tab button.	Selected
Insert Space	In the macro editor, selecting this option inserts space characters when you press the tab button, instead of tabs.	Not selected
Font	Sets the font of the text item selected in the Category list.	Fixedsys
Size	Sets the font size of the text item selected in the Category list.	9
Colors	Gives a listing of the various items in a Category that can be colored.	Text
Foreground	Sets the foreground color for the item selected in the Colors listing.	Automatic
ОК	Accept changes and close dialog box.	
Cancel	Discard changes and close dialog box.	
Help	Access this Help Page.	

See Also - The Format Options Page

Preferences Dialog

Tools - Preferences - Miscellaneous Options Page

Description How Do I Get There? Dialog box and Controls See Also...

Description - The Miscellaneous Options Page -

This help article describes the general options that can be set in FRED.

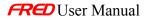
How Do I Get There? - The Miscellaneous Options Page

From the "Tools" menu, choose "Preferences". Click on the "Miscellaneous" tab in the dialog that appears.

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	a .	5	₁	<u>P</u> r	eferences	
			_		ser Defined Scripting Tools	•

Dialog Box and Controls - The Miscellaneous Options Page

This dialog gives a listing of the general settings in FRED.



🖨 Preferences	×				
Output Window Visualization Format Units of Measurement Warnings Miscellaneous Miscellaneous 2 File Locations					
Warnings Miscellaneous Miscellaneous 2 File Locations					
Play sounds					
🔽 Keep help file on top					
Allow abort recovery					
🔽 Enable IntelliMouse in grids					
Enable special treeview tooltips					
🔽 Enable Formula Engine in certain dialogs					
Enter curvatures (uncheck to enter radii)					
Use isotropic scaling in analysis windows					
Automatically lock analysis windows open					
Show tutorials/samples dialog when starting FRED					
Use 3-pane analysis plot windows (default is 4 panes)					
Reseed all random number generators before every raytrace					
Show general comment dialog when opening FRED document					
OK Cancel Help					

Control	Inputs / Description	Default Value
Play Sounds	Enables sounds to be played for various events throughout FRED.	Unchecked
Keep help file on top	When checked, keeps the help file on top of all other windows.	Checked
Allow abort recovery	Enables abort recovery from FRED Undo files.	Unchecked
Enable IntelliMouse in grids	Avoids driver conflicts with some mouse manufacturers.	Unchecked
Enable special treeview tooltips	When checked, displays supplemental tree node information in tool tips.	Checked
Enable Formula Engine in dialogs	Allows entry of formulas in dialogs that have grids.	Checked
Enter Curvatures (uncheck to enter radii)	Checking this option causes FRED to prompt for entry of the curvature of an object (1/radius) whenever appropriate. Unchecking this box causes FRED to ask for the radius.	Checked

Use isotropic scaling in analysis windows	Sets isotropic scaling in Analysis windows	Checked
Automatically lock analysis windows open	When an analysis window is opened, this option will keep it open by default when the ray set is deleted.	Unchecked
Show tutorials/samples dialog when starting FRED	When checked, displays the Tutorials and Samples Dialog when FRED starts up. Useful for beginning users.	Unchecked (Full) Checked (Demo)
Use 3-pane analysis plot windows (default is 4 panes)	Sets number of windows in Chart Viewer plots.	Unchecked
Reseed all random number generators before every raytrace	Reinitializes the random number generators when performing a raytrace.	Unchecked
Show general comment dialog when opening FRED document	When checked, displays the comment for a file when the file is opened.	Unchecked
ОК	Accept Miscellaneous changes and close dialog box.	
Cancel	Discard Miscellaneous changes and close dialog box.	
Help	Access this Help page.	

See Also - The Miscellaneous Options Page

Preferences Dialog



Tools - Preferences - The Miscellaneous 2 Options Page

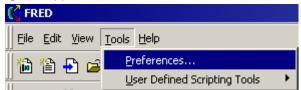
Description How Do I Get There? Dialog box and Controls See Also...

Description - The Miscellaneous 2 Options Page

This help article describes the general options that can be set in FRED.

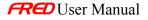
How Do I Get There? - The Miscellaneous 2 Options Page

From the "Tools" menu, choose "Preferences". Click on the "Miscellaneous 2" tab in the dialog that appears.



Dialog Box and Controls - The Miscellaneous 2 Options Page

This dialog gives a listing of the general settings in FRED.



—

🚱 Preferences					×
Output Window Warnings N	Visualization fiscellaneous	Forma Miscella		of Measure File Loca	
Number of levels of	undo (O for none):		Œ	÷
Max processor cour (0=all processors, -				0	3
Scale factor when o	drawing ray exten	sions:		1	
Size of spots in 3D	spot diagram (scr	een pixels):		2	
Ray drawing line wi	dth (screen pixels	;):		1	
Ray drawing arrow	size scale factor ((0 ==> no arr	ow):	0	
Ray drawing arrow (as fraction of propa				0.5	
Default wavelength	(micron):	0.58	75618 d (He	e)	•
When double clicki	ng a tree item:	Edit	the entity		•
		OK	Cancel		Help

<u>Control</u>	Inputs / Description	<u>Default</u> <u>Value</u>
Number of levels of undo:	Defines the number of actions that can be undone when working with FRED.	1
Max processor count	Specifies the number of processors FRED will use in raytracing. Set to zero to use all available processors.	1
Scale factor when drawing ray extensions	Determines the amount of dash to draw when a ray misses geometry and heads into infinity during a raytrace. To turn off drawing missed rays, set this value to 0.	1
Size of spots in 3D spot diagram:	Sets the default size in pixels of the ray spots in spot diagrams.	2
Ray drawing line width	Line draw width in pixels.	1
Ray drawing arrow size scale factor	Scales size of ray arrow (0 for no arrow).	0
Ray drawing arrow location	Sets location of arrow along ray draw line (as a fraction of ray propagation distance).	0.5
Default wavelength	Default wavelength for new FRED files.	0.5875618

(micron):		d (He)
When double clicking a tree item:	Defines the action to take when double clicking on a tree object. Possible options: expand the object, edit the object, edit the object's position.	Edit the entity
ОК	Accept Miscellaneous 2 changes and close dialog box.	
Cancel	Discard Miscellaneous 2 changes and close dialog box.	
Help	Access this Help page.	

See Also - The Miscellaneous 2 Options Page

Preferences Dialog Miscellaneous Options

Tools - Preferences - Output Window Preferences Tab

Description How Do I Get There? Dialog box and Controls See Also...

Description Output Window Preferences Tab

The Output Window is a spreadsheet with rows and columns. This command sets the number of columns and the number of rows in the output window.

The Output Window spreadsheet can be toggled between a spreadsheet style presentation with cell borders, row numbers, and column letters and a text file style of presentation without cell borders, row numbers, and column letters using the <u>Cells</u> command. In either case, the output window is still a spreadsheet.

Note The colors of the text, numbers, and formulas in the Output Window can be set to difference colors in the Format Tab of the Preferences.

How Do I Get There? Output Window Preferences Tab From the "Tools" Menu, Select "Preferences". The Output Window tab appears first.

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Eile Edit View	Tools Help		
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	User Defined Scripting Tools		

Dialog Box and Controls Output Window Preferences Tab

This preference dialog allows you to change the number of rows and columns in the output window.

C Preferences
Warnings Miscellaneous Miscellaneous 2 File Locations Ray Buffer Output Window Visualization Format Units of Measurement
Number of Rows 5000
Number of Columns 16
Default
Enable Formula Engine in Output Window (requires FRED restart)
OK Cancel Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Number of Rows	Specifies the number of rows to show in the Output Window.	256
Number of Columns	Specifies the number of columns to show in the Output Window.	16
Default button	Sets the number of rows & columns to 256x16.	



Enable Formula Engine in Output Window (requires FRED restart)	Allows formulae to be entered in the individual cells of the output window, when checked.	Unchecked
ОК	Accept Output Window changes and close dialog box.	
Cancel	Discard Output Window changes and close dialog box.	
Help	Access this Help page.	

See Also.... Output Window Preferences Tab

Preferences Dialog

Tools - Preferences - Units of Measurement Tab

Description How Do I Get There? Dialog box and Controls See Also...

Description Units of Measurement Tab

This preferences page allows you to set the units of measurement for new systems. Changes made on this page apply to new systems. To change the units of an existing FRED document, select "Units and Scaling ..." from the Tools menu.

How Do I Get There? Units of Measurement Tab

Select Preferences in the Tools Menu, and then select the Units of Measurement tab.





Dialog Box and Controls Units of Measurement Tab

C Preferences	X	
Warnings M Output Windo	iscellaneous Miscellaneous 2 File Locations Ray Buffer w Visualization Format Units of Measurement	
Length Units (f	or new systems): milimeter (mm)	
<u>Control</u>	Inputs	<u>Defaults</u>
Units List	Listing of all possible units of measurement	Millimeters
Use abbreviated name	Checked or Unchecked	Checked
ОК	Accept Output Window changes and close dialog box.	
Cancel	Discard Output Window changes and close dialog box.	
Help	Access this Help page.	

See Also.... Units of Measurement Tab

Preferences Dialog

Tools - Preferences - Visualization Options Tab

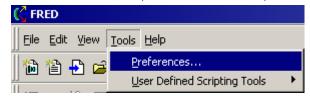
Description How Do I Get There? Dialog box and Controls See Also...

Description Visualization Options Tab

This help article describes the options that can be set for the Visualization window.

How Do I Get There? Visualization Options Tab

From the **Tools** menu, select **Preferences**, then click on the **Visualization** tab.



Dialog Box and Controls Visualization Options Tab

This dialog gives a listing of the Visualization options that can be set in FRED.



🚰 Preferences	×
Warnings Miscellaneous Miscellaneous 2 File Output Window Visualization Format	e Locations Ray Buffer Units of Measurement
 Draw local trimming volume when creating a new s Draw surface trimming volumes instead of surfaces Fit-View-To-All ignore nontraceable entities Fit-View-To-All ignore curves Show: Coordinate Axes in new systems Print Mode: Auto Bitmap MetaFile Pixel format: Safe Fast User: Set Custom Views 	
Custom View 1 💌 X Y	Giet Current View
Camera is located at: 0 0	10
Camera is aimed towards: 0	0
Camera "Up" direction: 0 1	0
OK	Cancel Help

<u>Control</u>	<u>Function</u>	<u>Default</u>
Draw local trimming volume when creating a new surface	Enables drawing the local trimming volume box around new surfaces when they are created.	Unchecked
Draw surface trimming volumes instead of surfaces	Enables drawing the surface trimming volume box around surfaces. For use with large models.	Unchecked
Fit-View-To-All ignore nontraceable entities	Ignore nontraceable entities when sizing to Fit-View- To-All.	Unchecked
Fit-View-To-All ignore curves	Ignore curves when sizing to Fit-View-To-All.	Unchecked
Show in new systems	Sets what is shown when a new FRED document is created.	Coordinate Axes
Print Mode	Auto, Bitmap or Metafile	Auto
Pixel format	Determines rendering mode FRED will use when it draws the system in the Visualization Window.	Fast
Default Orientation	Specifies which view of the system is the default when a file is opened or created. (1st entry sets out- of-page axis direction)	-Z Axis, +Y up
Screen Background	Select color of the background when viewing the optical system in FRED.	Automatic



Printer Background	Select the color of the background when printing the optical system. Warns if there is too much of a particular component in the chosen color (which could result in wasting ink).	White
	Set Custom Views	
Custom View 1, 2, 3	Displays the settings for Custom View in the text boxes shown below.	Selected
Camera is located at: (X,Y,Z)	Sets (X,Y,Z) coordinates of camera location for selected Custom View.	0, 0, 10
Camera is aimed at: (X,Y,Z)	Sets (X,Y,Z) coordinates for camera aim point for selected Custom View.	0, 0, 0
"Up" relative to camera: (X,Y,Z)	Sets (X,Y,Z) direction cosines of camera orientation for selected Custom View.	0, 1, 0
Get Current View	Get camera location, aim & up direction for current view.	
ОК	Accept Visualization changes and close dialog box.	
Cancel	Discard Visualization changes and close dialog box.	
Неір	Access this Help page.	

<u>See Also....</u> Visualization Options Tab

Preferences Dialog

Tools - Preferences - Warnings Options Tab

Description How Do I Get There? Dialog box and Controls See Also...

Description Warnings Options Tab

This help article describes the options in FRED that affect the macro editor.



How Do I Get There?

Warnings Options Tab

From the Tools menu, choose Preferences. Click on the "Warnings" tab on the dialog that appears.

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	User Defined Scripting Tools	

Dialog Box and Controls Warnings Options Tab

This dialog gives a listing of the settings that can be set for displaying text in FRED.

📢 Р	C Preferences						
	Dutput Window Visualization Format Units of Measurement						
ন ন ন ন	Warnings Miscellaneous Miscellaneous 2 File Locations Ray Buff Image: Warn if sampled coating power coefficients sum to greater than unity Image: Warn if grating diffraction efficiencies sum to greater than unity Image: Warn if grating diffraction efficiencies sum to greater than unity Image: Warn if deleting an object from the tree Image: Warn if converting a specific element to a custom element Image: Warn if an object does not have a description						
	OK Cancel Help						
<u>Control</u>	Inputs Defaults						
Warn if sampled coating power coefficie nts sum to greater	When checked, warns if the sum of power coefficients is greater than 1.						



than unity		
Warn if grating diffractio n efficienci es sum to greater than unity	When checked, warns if the sum of diffraction efficiencies is greater than 1.	Checked
Warn if deleting an object from the tree	When checked, asks confirmation on attempt to delete an object from the tree.	Checked
Warn if convertin g specific element to custom element	When checked, warns if action taken that can convert a specific element, such as a lens, mirror, or prism, to a custom element. These actions include adding or deleting curves and surfaces.	Checked
Warn if an object does not have descripti on	When checked, warns if the object currently being created has an empty description.	Unchecked
ОК	Accept Warnings changes and close dialog box.	
Cancel	Discard Warnings changes and close dialog box.	
Help	Access this Help page.	

<u>See Also....</u> Warnings Options Tab

Preferences Dialog



3D View - Menu commands

The 3-D View menu offers the following commands:				
Trackball Mode	Switches the program into Trackball Mode (the default mode upon creating a new optical layout).			
Magnify Mode	Switches the program into Magnify Mode			
Object Selection	Allows selection of objects in the <u>Visualization</u> window by clicking on them with the mouse			
Toggle Perspective	Switches between orthographic (layout or right-angle view) and perspective (real life view) mode			
View All	Zooms out to view the entire system			
Edit Background Grid	Displays a dialog for editing properties of the background grid			
Mouse Coordinates	Displays the mouse coordinates in the status bar at the bottom of the window			
Movie	Displays a dialog for creating a movie of the system			
Camera->Orbit Camera	Orbits the camera about a point in the system			
Camera- >Translate Camera	Moves the camera from its current position to a new position			
Camera->Rotate Camera	Rotates the camera about its current point in the system			
Scene->Translate Scene	Moves the scene from its current position to a new position			
Scene->Rotate Scene	Rotates the scene about the camera's location in the system			
View Towards:	Behaves the same way as the drop down menu on the toolbar: allows selection of a view towards one of the 6 axes directions, 3 saved custom views, or a specified view			

The 3-D View menu offers the following commands:

See **NEW** navigation features here: <u>Navigating FRED's 3D View</u>

	Switches the program into Trackball Mode (the default mode upon creating a new optical layout).	
Magnify Mode	Switches the program into Magnify Mode	
In Intect Netection	Allows you to select objects in the <u>Visualization</u> window by clicking on them with the mouse	
Toggle Perspective	Switches between orthographic (layout or right-angle view) and perspective (real life view) mode	

View All	Zooms out to view the entire system
Edit Background Grid	Displays a dialog that allows you to edit the properties of the background grid
Mouse Coordinates	Displays the mouse coordinates in the status bar at the bottom of the window
Movie	Displays a dialog that allows you to create a movie of the system
Camera->Orbit Camera	Orbits the camera about a point in the system
<u>Camera-</u> <u>>Translate</u> <u>Camera</u>	Moves the camera from its current position to a new position
Camera->Rotate Camera	Rotates the camera about its current point in the system
Scene->Translate Scene	Moves the scene from its current position to a new position
Scene->Rotate Scene	Rotates the scene about the camera's location in the system
View Towards:	Behaves the same way as the drop down menu on the toolbar: allows you to select a view towards one of the 6 axes directions, 3 saved custom views, or a specified view



3D View - Navigating FRED's 3D View

There are new mouse operations in the 3D View. These features are available without regard to the view's mode, and are loosely similar to how SolidWorks behaves.

- Holding down middle mouse button (wheel) and dragging now rotates scene.
- Holding down control and middle mouse button pans/translates the scene.

• Holding down shift and middle mouse button zooms the scene about screen center as mouse is dragged vertically.

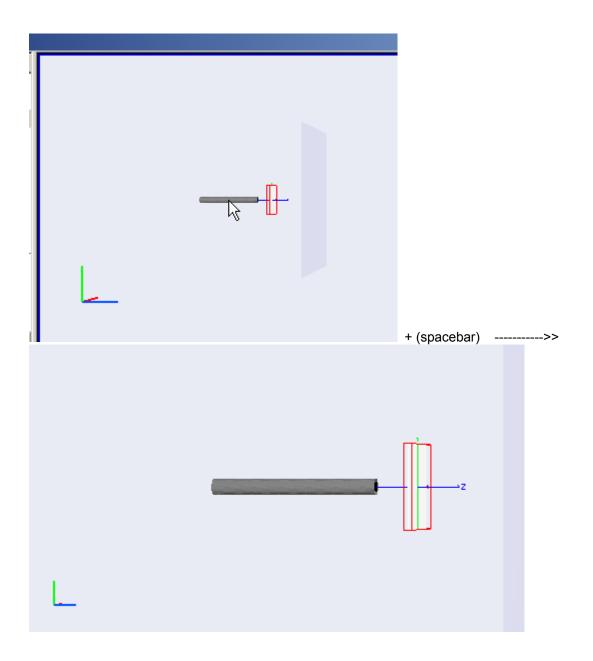
• Mouse wheel zoom now zooms about the mouse point.

• The visualization view can now be zoomed to fit the current selection(s) in the tree view by choosing "Fit view to selection" on the popup menu or by pressing Alt-Z. The rotation center will also be changed to match the center of the new view.

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Ė.	<u>a</u>	Geometry				
	÷	P diffuser				
	+ .	🔗 observa	✓ <u>T</u> raceable			
	: +	🔗 Light Sc	Never Traceable	e (for trimming surfaces)		
÷	<u></u>	Analysis Surf				
÷	**	Materials	Draw O <u>u</u> ter End	losing Volume		
÷	-	Coatings	<u>C</u> oordinate Axe	s		
÷	ste.	Scatterers	Visualization Attributes			
		Raytrace Pro	Eit View to Selec	ction	Alt-Z	
			Position/Orienta	ation		
			Parent Coordina			
				ico ogocomini		
			Sc <u>a</u> le			
			👗 Cut		Ctrl+X	
			🖹 Сору		Ctrl+C	

• The visualization view can be zoomed to fit the entity that's under the mouse by pressing the space bar (when the visualization view has focus). The rotation center will also be changed to match the center of the new view.







3D View - Trackball mode

Description How Do I Get There? Application Notes Examples See Also...

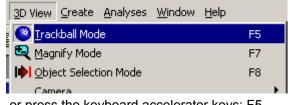
Description - Trackball mode

Allows the contents of the Visualization window to be rotated about a point. The default center of rotation is the global origin. The rotation point can be changed to the center of the trimming volume of any surface in the Visualization Window by holding the <CTRL> key down and left mouse clicking on the surface. When this done, the surface will momentarily change colors indicating that its trimming volume is now the center of rotation. To change back to the global origin, <CTRL>+left mouse click on the background in the Visualization window. When this is done, the Visualization window background will momentarily turn green.

How Do I Get There? - Trackball mode

There are three different ways to execute this command:

1. Select Trackball Mode in the 3D View Menu,



or press the keyboard accelerator keys: F5,

3. or press the toolbar button:

Application Notes - Trackball mode

None.

Examples - Trackball mode

None.

See Also -Trackball mode

None.

3D View - Magnify Mode

Description Visualization (example) How Do I Get There?

Description - Magnify Mode

This command toggles on and off the Magnification Mode. In the magnification mode the

cursor changes to a magnifying glass, **1** If the Shift key is pressed, then the mode

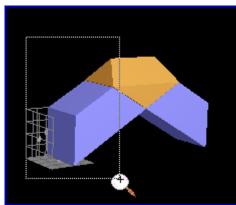
changes to demagnification and the magnification pointer changes to a minus sign, **basis**. The magnification pointer can be used in two modes: simple point and click or dragging a selection rectangle of the area to be magnified.

The point and click method will employ a magnification of 200% (2X) and a demagnification of 50% (0.5X). The point and click method will also center the coordinates of the magnification pointer in the Visualization window when it was clicked.

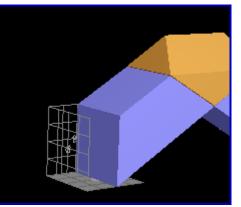
Dragging the selection rectangle over an area will take the long axis of the selected area and fit that into the visualization window.

Visualization (example) - Magnify Mode

This figure shows an example of magnification in the Visualization Window by dragging a selection rectangle over the objects.



Before magnification



After magnification



How Do I Get There? - Magnify Mode

There are three different ways to execute this command:

1. Select Magnification Mode in the 3D View Menu,

Eile Edit View Tools Raytrace 3D View Create A	nalyses <u>W</u> indow <u>H</u> elp
📗 🏠 🔁 🚅 🔚 🐰 🖻 🛍 🥙 Irackball Mode	F5
📙 🕹 🕹 🖕 🚾 🚾 🕰 Magnify Mode	F7
$1 \rightarrow \overset{\text{res}}{\Rightarrow} \overset{\text{res}}{\Rightarrow} \overset{\text{res}}{\times} \rightarrow \rightarrow \#$ $ \bullet \underline{O}$ bject Selection	n Mode F8
Comoro	•

2. or press the keyboard accelerator keys: F7,

3D View - Object Selection

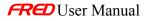
Description Visualization (example) How Do I Get There? Application Notes Examples See Also...

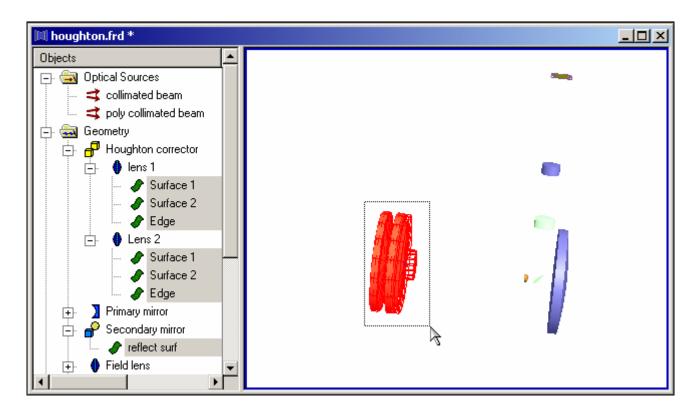
Description - Object Selection

This command toggles on and off the ability to select individual objects in the <u>Visualization</u> <u>Window</u> with the mouse. The objects can be selected with a left mouse click while pointing at the object or with by dragging a selection rectangle over the objects. Once selected, the objects will be highlighted in both the Visualization Window and the Tree View. The selected objects can then be operated on with any command that handles multiple objects, i.e. visualization attributes, traceability, gluing, etc. You can select many objects at once as well as one by one. This is equivalent to selecting the objects in <u>Tree View</u> only in the Tree View the user must use the <CTRL> with the left mouse button to make multiple selections.

Visualization (example) - Object Selection

This figure shows an example of multiple object selection in the Visualization Window by dragging a selection rectangle over the objects. Note that the selected objects are highlighted in the Tree View.

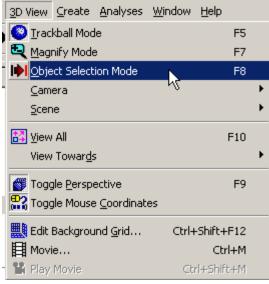




How Do I Get There? - Object Selection

There are three different ways to execute this command:

1. Select Object Selection in the 3D View Menu,



- 2. or press the keyboard accelerator keys: F8,
- 3. or press the toolbar button:

Application Notes - Object Selection

None.

Examples - Object Selection

None.

See Also - Object Selection

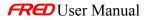
None

3D View - Scene - Translate Scene

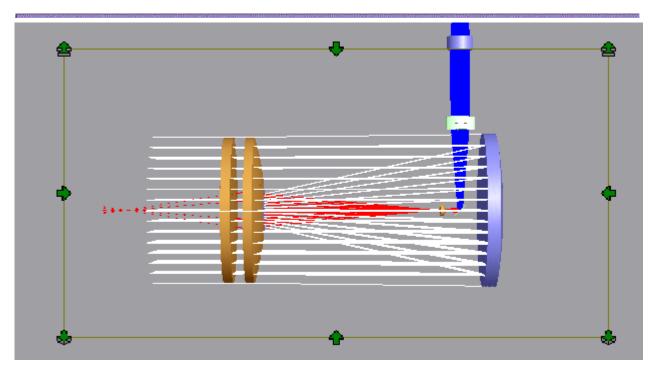
Description Visualization (example) How Do I Get There? Application Notes Examples See Also...

Description - Translate Scene

This command allows the scene in the visualization window to be translated interactively with the mouse.



Visualization (example) - Translate Scene



How Do I Get There? - Translate Scene

There are three different ways to execute this command:

1. Select Scene and then Translate Scene in the 3D View Menu,

Į	<u>3</u> D \	view ⊆	reate	<u>A</u> nalyses	<u>W</u> indow	Help		
Ì	۲	<u>T</u> rackba	all Mod	e			F5	Y Up 🔻 🛛 14 💥 🗳 🏁 🗶 🚽
	۹	<u>M</u> agnify	y Mode				F7	
1	I 🏓	<u>O</u> bject	Selecti	on Mode			F8	
1		<u>C</u> amera	э				•	
		<u>S</u> cene					÷	Translate Scene Mode Shift+F7
	1 7	⊻iew Al	I			F	10	Potate Scene Mode Science Mode
		View To	owar <u>d</u> s				•	
	6	Toggle	<u>P</u> erspe	ctive			F9	
l	822	Toggle	Mouse	<u>⊂</u> oordinat	es			
		Edit Ba	ckgrou	nd <u>G</u> rid	Ctrl+	-Shift+F	12	
	目	Movie				Ctrl+	нM	
	R	Play Mo	ovie		Ct	rl+Shift+	HM	

- 2. or press the keyboard accelerator keys: Shift+F7,
- 3. or press the toolbar button:

Application Notes - Translate Scene

None.

Examples - Translate Scene

None.

See Also - Translate Scene

None.

3D View - Scene - Rotate Scene

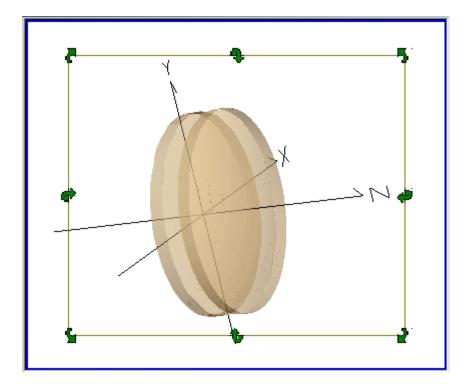
Description Visualization (example) How Do I Get There? Application Notes Examples See Also...

Description - Rotate Scene

This command allows the scene in the visualization window to be rotated interactively with the mouse.

Visualization (example) - Rotate Scene





How Do I Get There? - Rotate Scene

There are three different ways to execute this command:

1. Select Scene and then Rotate Scene in the 3D View Menu,

	<u>3</u> D View <u>C</u> reate <u>A</u> nalyses <u>W</u>	/indow <u>H</u> elp	
)	STRACKBAIL Mode	F5	Y Up 🔽 🛛 14 💥 🗳 🚧 🤻 🔸
-	🔍 Magnify Mode	F7	
-	bject Selection Mode	F8	
1	<u>C</u> amera	•	
	<u>S</u> cene	•	Translate Scene Mode Shift+F7
	😫 Yiew All	F10 -	Rotate Scene Mode Shift+F8
	View Towar <u>d</u> s	+	
	Toggle Perspective	F9	
Í	Toggle Mouse Coordinates		
	Edit Background Grid	Ctrl+Shift+F12	
	Movie	Ctrl+M	
-	📽 Play Movie	Ctrl+Shift+M	

- 2. or press the keyboard accelerator keys: Shift+F8,
- 3. or press the toolbar button:

Application Notes - Rotate Scene

None.

Examples - Rotate Scene

None.

See Also - Rotate Scene

None.

3D View - Camera - Rotate Camera

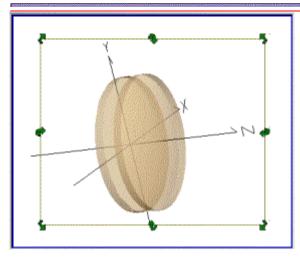
Description Visualization (example) How Do I Get There? Application Notes Examples See Also...

Description - Rotate Camera

This command allows the Camera's view of the visualization window to be rotated interactively with the mouse.

Note: The motion relative of the visualization view to the mouse motion is the opposite of the scene rotation because you are moving the camera instead of the scene.

Visualization (example) - Rotate Camera



How Do I Get There? - Rotate Camera

There are three different ways to execute this command:

1. Select Camera and then Rotate Camera in the 3D View Menu,

	<u>3</u> D View <u>C</u> reate <u>A</u> nalyses	<u>W</u> indow <u>H</u> elp	
)	Trackball Mode	F5 F7	Y Up 🔽 🛛 1+ 🚟 🗳 🚧 🔺
	Object Selection Mode <u>C</u> amera <u>S</u> cene	F8	
	View All View Towar <u>d</u> s	F10	Rotate Camera Mode Ctrl+F8
	Toggle Perspective	F9 es	
-	Edit Background <u>G</u> rid Hovie H Play Movie	Ctrl+Shift+F12 Ctrl+M Ctrl+Shift+M	

- 2. or press the keyboard accelerator keys: Ctrl+F8,
- 3. or press the toolbar button:

Application Notes - Rotate Camera

None.

Examples - Rotate Camera

None.

See Also - Rotate Camera

None.



3D View - View All

Description How Do I Get There? See Also...

Description - View All

This command will adjust the zoom of the visualization window so that all of the objects are rendered in the view. This command actually keys off the geometry parent node's outer trimming volume, so even if some objects are flagged as not traceable this command will adjust the zoom to view them even though they will not be rendered.

How Do I Get There? - View All

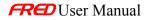
There are three different ways to execute this command:

1. Select View All in the 3D View Menu,



- 2. or press the keyboard accelerator keys: F10,
- 3. or press the toolbar button:

See Also - View All



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3D View - View Towards

Description - View Towards

This command allows you to switch the camera view of the Visualization window to look towards one of ten directions.

- 1. Six predefined directions: the plus and minus X, Y, and Z axes views.
- 2. Three custom views set in the Visualization preferences.
- 3. One custom view that can be set in the Camera Configuration dialog.

How Do I Get There? - View Towards

There are two different ways to execute this command:

1. Select View Toward	ds and the vie	w y	ou want in the 3D	View Menu
<u>3</u> D View <u>Create</u> <u>Analyses</u> <u>Wi</u>	indow <u>H</u> elp			
🔇 <u>T</u> rackball Mode	F	5	Y Up 🔻 🗛	ier xer xer
🔍 Magnify Mode	F)	,		
• 🍺 Object Selection Mode	F8	}		
⊂amera		►		
<u>S</u> cene		Þ		
👪 Yiew All	F10)		
View Towar <u>d</u> s		•	1_ (+) X-axis	Ctrl+1
Toggle Perspective	E	1	📫 (+) Y-axis	Ctrl+2
Toggle Mouse Coordinates			📫 (+) Z-axis	Ctrl+3
			📫 (-) X-axis	Ctrl+4
Edit Background <u>G</u> rid	Ctrl+Shift+F12	2	💪 (-) Y-axis	Ctrl+5
H Movie	Ctrl+N	1	🔓 (-) Z-axis 🥈	ر Ctrl+6
📽 Play Movie	Ctrl+Shift+N	1	📕 Custom View 1	Ctrl+7
			≺ Custom View 2	Ctrl+8
			≻ Custom View 3	Ctrl+9
			XVZ Specific View	Ctrl+0

2. Press the keyboard accelerator keys: Ctrl+0 thru Ctrl+9

Dialog Box and Controls - View Towards

Selecting Specific View ... or pressing <CTRL>+0 will open the Camera Configuration dialog, which allows you to position the camera anywhere in space.

<mark>((FRED1 *)</mark> Camera Co	<u>- </u>		
Dimensions: Camera is located at:	× -1.065728	Y 8.867679	Z 129.1552
Camera is aimed towards:	5.255184	8.867852	3.076072
Camera "Up" direction:	0.000621	0.999999	6.628663
Canc	el A	Apply	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Camera is located at:	Specifies the (X,Y,Z) position of the camera (in the global coordinate system).	0, 0, 9.82
Camera is aimed towards:	Specifies the point towards which the camera is aimed (in the global coordinate system).	0, 0, 0
Camera "Up" direction:	Specifies the direction in which the top of the camera is pointed. <u>Cannot be same as aim direction</u> .	0, 1, 0
ОК	Accept Camera Configuration and close dialog box.	
Cancel	Discard Camera Configuration changes and close dialog box.	
Apply	Apply Camera Configuration changes and keep dialog box open.	
Help	Access this Help page.	

Examples - View Towards

Listed below are some common camera positions that may be useful.				
Camera Position/Orientation	Description	Picture		
Location = {-7, 7, 7}; Aim Point = {0, 0, 0}; Up Direction = {0, 1, 0}	Elevated in y and spaced away in X and Z, looking towards the global origin			
Location = {-8.75, 0, 5.25}; Aim Point = {0, 0, 0}; Up Direction = {0, 1, 0}	Low, rotated view: begin at +X-axis view and rotate about the vertical (Y) axis			

Listed below are some common camera positions that may be useful.

See Also - View Towards



3D View - Background Grid Dialog

Description Visualization (example) How Do I Get There? Dialog box and Controls

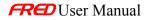
Description Background Grid Dialog

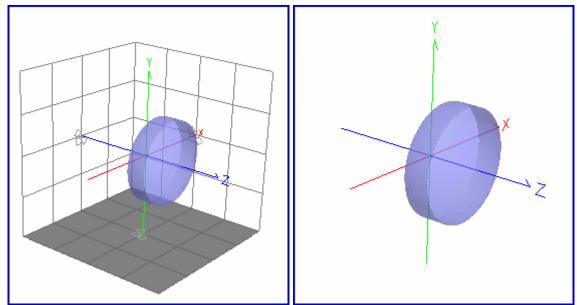
This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

🔆 Preferences				×
Warnings Miscel Output Window	laneous Miscella Visualization	neous 2 F Format	x	Ray Buffer
□ Draw surface tr ↓ Tit-View-To-All i ↓ Fit-View-To-All i ↓ Show: Coordinate Print Mode: ● Au	Axes ▼ in new : ito ○ Bitmap ○ N	ead of surface entities systems fletaFile		entation +Y Up 💌 ckground
Set Custom View	ıfe ⊙ Fast O Us s X	er <u>Io</u>	Gret Currer Z	nt View
Camera is located Camera is aimed	•	0	10 0	
Camera "Up" dire	ection: 0	1	0	
		ж	Cancel	Help

Visualization (example) Background Grid Dialog

An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.





Background Grid

No Background Grid

📢 (FRED1 *) Ba	:kgrou	nd Grid Settin	gs		? <u>- </u> ×
Gobal Cube Din	nension	s			OK 1
×min <mark>⊡</mark>	×	max 1	XDiv	risions 🛛 🛨	Cancel
Ymin <mark>-</mark> 1	Y	max 1	Y Div	isions 🛛 🕂	Apply
Z min .1	Z	max 1	ZDiv	isions 4 📫	Help
- Drawing Attribut	es of E	ach Cube Face-			
	Draw Face	Face Color	Draw Axis	Axis Color	Display As
Front (XY +z)			₽	· ·	Grid Lines 💌
Back (XY -z)	◄	── ▼	₽	· ·	Grid Lines 💌
Left (ZY -x)				· ·	Grid Lines 💌
Right (ZY +x)	▼		₽	· ·	Grid Lines 💌
Top (ZX +y)		· ·		· ·	Grid Lines 💌
Bottom (ZX -y)	•	•	◄	· ·	Filled Grid 💌

Background Grid settings for the example shown above.

How Do I Get There? Background Grid Dialog

There are three different ways to execute this command:

1. Select Edit Background Grid in the 3D View Menu,



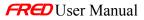
2. or press the keyboard accelerator keys: Ctrl+Shift+F12,

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3. or press the toolbar button:

Dialog Box and Controls Background Grid Dialog

🔆 (FRED1 *) Bai	ckground Grid Setting	ļs	? <u>-</u> – ×
Gobal Cube Din	nensions		OK
×min <mark>-</mark> 1	× max 1	X Divisions 🛛 🛨	Cancel
Ymin -1	Y max 1	Y Divisions 🛛 🛨	Apply
Z min .1	Z max 1	Z Divisions 🛛 🛨	Help
- Drawing Attribut	tes of Each Cube Face— Draw	Draw	
Front (XY +z)	Face Face Color	Axis Axis Color	Display As Grid Lines 💌
Back (XY -z)			Grid Lines 💌
Left (ZY -x)			Grid Lines 💌
Right (ZY +x)			Grid Lines 💌
Top (ZX +y)			Grid Lines 💌
Bottom (ZX -y)			Filled Grid 💌



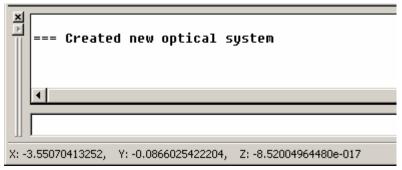
<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Global Cube Dimensions						
X/Y/Z min and max	Lists the minimum and maximum extent of the background grid on the X axis.	-1, 1				
X/Y/Z Divisions	Lists the number of divisions in the X direction of the background grid.	4				
	Drawing Attributes of Each Cube Face					
Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences).	Unchecked				
Face Color	Selects the color of the given grid face.	Dark gray				
Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox.	Checked				
Axis Color	Selects the color of the axis labels.	Light gray				
Display As	Selects the drawing style for the background grid faces. Options are Filled Grid, Grid Lines, and Grid Points.	Grid lines				
ОК	Accept Background Grid Settings changes and close dialog box.					
Cancel	Discard Background Grid Settings changes and close dialog box.					
АррІу	Apply Background Grid Settings changes and keep dialog box open.					
Help	Access this Help page.					

3D View - Toggle Mouse Coordinates

Description How Do I Get There?

Description - Mouse Coordinates

This command enables or disables the mouse coordinates from being shown on the status bar.



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How Do I Get There? - Mouse Coordinates

There are two different ways to execute this command:

1. Select "Toggle Mouse <u>C</u>oordinates" in the 3D View Menu,

Eile Edit View Tools Raytrace	<u>3</u> D View <u>C</u> reate <u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
10 19 🗗 🖆 🖨 🐰 🗈 🛱	🕙 Irackball Mode	F5
11	🔫 <u>M</u> agniry Mode	F7
$1 \mapsto \overset{\otimes i}{\rightarrow} \overset{\circ i}{\rightarrow} $	III Object Selection Mode	F8
	<u>C</u> amera	•
	<u>S</u> cene	•
FRED1	🔐 View All	F10
Objects	View Towards	•
📔 🚎 🖻 Optical Sources 📘		
🛛 📼 Geometry	Toggle Perspective	F9
💼 💿 An shutis Cunta	82 Tapala Maura Candinakan	
🔛 🔤 Analysis Surfa	Coordinates	

or press the toolbar button: (Since this button is not available by default, you will have to <u>customize</u> the toolbar to see this button.),



Description Visualization (example) How Do I Get There? Dialog box and Controls

Description - Background Grid Dialog

This command brings up the dialog that allows you to draw and change the Background Grid. Whether a new FRED document opens with a Background grid or not can be set in the preferences. The Background Grid can be added to Visualization window at any time.

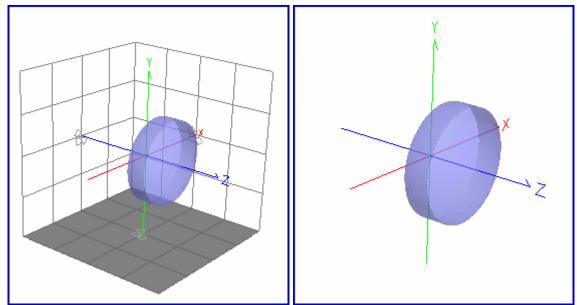
		×						
Units of Measurement Units of Measurement	Warnings Miscellaneous Visualization	File Locations						
	Draw local trimming volume when creating a new surface Draw surface trimming volumes instead of surfaces (for large models)							
Printing Mode • Auto C MetaFile C Bitmap	Show Coordinate Axes Background Grid Pixel ft Coordinate Axes	in new systems						
Default Visualization View	Nothing	er Background						

Visualization (example) - Background Grid Dialog

An example of with and without the Background Grid is shown below. The Background Grid dialog settings for the Background Grid are shown below. Note that the coordinate axes are included for reference and are not part of the background grid dialog.



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Background Grid

No Background Grid

<mark>((</mark> FRED1 *) Ba	ckgrou	nd Grid Settin	gs		? <u>- </u> ×
Gobal Cube Din	nension	s			OK
×min <mark>⊡</mark>	×	max 1	X Div	risions 🛛 🛨	Cancel
Ymin <mark>-</mark> 1	Y	max 1	Y Div	isions 🛛 🛨	Apply
Z min .1	Z	max 1	Z Div	isions 4 🛨	Help
Drawing Attribut	tes of E	ach Cube Face-			
	Draw Face	Face Color	Draw Axis	Axis Color	Display As
Front (XY +z)			V		Grid Lines 💌
Back (XY -z)	◄		•	· ·	Grid Lines 💌
Left (ZY -x)		□	V	· ·	Grid Lines 💌
Right (ZY +x)	◄		V	· ·	Grid Lines 💌
Top (ZX +y)				──	Grid Lines 💌
Bottom (ZX -y)		▼	M	-	Filled Grid 💌

Background Grid settings for the example shown above.

How Do I Get There? - Background Grid Dialog

There are three different ways to execute this command:

1. Select Edit Background Grid in the 3D View Menu,

<u>3</u> D View ⊆	reate	<u>A</u> nalyses	<u>W</u> indow	Help		
S Irackball Mode F5						
🔍 <u>M</u> agnif	y Mode	:		F7		
 <u>O</u> bject	Selecti	ion Mode		F8		
	а				•	
<u>S</u> cene						
🛟 View Al				F10		
View To	owar <u>d</u> s	:			•	
🕤 Toggle	<u>P</u> erspe	ective		F9		
🔐 Toggle	Mouse	<u>C</u> oordinat	es			
🔜 Edit Ba	ckgrou	nd <u>G</u> rid	Cti	rl+Shift+F12		
. 🗐 Movie.				Ctrl+M		
📲 Play Mo	ovie		0	Ctrl+Shift+M		

2. or press the keyboard accelerator keys: Ctrl+Shift+F12,

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3. or press the toolbar button:

Dialog Box and Controls - Background Grid Dialog

((FRED1 *) Background Grid Settings	? _ 🗆 🗙
Gobal Cube Dimensions	
×min 🗉 ×max 1 ×Divisions 4 🚍	Cancel
Y min 🖅 Y max 1 Y Divisions 4 🚍	Apply
Z min -1 Z max 1 Z Divisions 4 🚍	Help
Drawing Attributes of Each Cube Face	
Draw Draw Face Face Color Axis Axis Color	Display As
Front (XY +z)	Grid Lines 💌
Back (XY -z)	Grid Lines 💌
Left (ZY -x)	Grid Lines 💌
Right (ZY +x)	Grid Lines 💌
Top (2X +y)	Grid Lines 💌
Bottom (ZX -y)	Filled Grid 💌
Control Inputs	<u>Defaults</u>
Global Cube Dimensions	

X/Y/Z min and max	Lists the minimum and maximum extent of the background grid on the X axis.	-1, 1				
X/Y/Z Divisions	Lists the number of divisions in the X direction of the background grid.	4				
	Drawing Attributes of Each Cube Face					
Face	When checked, the cube face listed to the left will be drawn (can be set in the preferences).	Unchecked				
Face Color	Selects the color of the given grid face.	Dark gray				
Axis	When checked, draws the axis labels for the face listed to the left. Overridden by the Face checkbox. Check					
Axis Color	Selects the color of the axis labels.					
Display As	Grid lines					
ОК	Accept Background Grid Settings changes and close dialog box.					
Cancel	Discard Background Grid Settings changes and close dialog box.					
АррІу	Apply Background Grid Settings changes and keep dialog box open.					
Неір	Access this Help page.					

3D View - The FRED Movie Dialog

Description How Do I Get There? Dialog box and Controls

Description The FRED Movie Dialog

The Movie feature in FRED allows you to create a sequence of Visualization frames that, when played, fly the camera through the optical system. There can be one movie per file.

Note that this dialog is modeless, so you can both play the movie and have the dialog open at the same time. Each frame has 3 vectors, a delay, and an interpolation count. The three vectors describe the location and orientation of the camera for that frame. The delay, measured in milliseconds, shows how long the frame will last. The interpolation count tells how many steps there are in a given frame. For instance, if a given frame has a 60 ms time with an interpolation count of 4, then the camera will fly between the two orientations (the one for that frame and the one for the next), stopping at the 3 points between the two frame start points. The fourth point is the start point for the next frame.

Additional frames / entries can be appended, inserted, or deleted via a right mouse click pop-up menu.

How Do I Get There? The FRED Movie Dialog

There are three different ways to execute this command:

1. Select Movie in the 3D View Menu,



- 2. or press the keyboard accelerator keys: Ctrl+M,
 - 目
- 3. or press the toolbar button: (Since this button is not available by default, you will have to customize the toolbar to see this button.),

Dialog Box and Controls The FRED Movie Dialog



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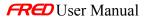
	Interp		Car	mera Positio	on		Camera i	Aim Poi
(msec)	count	X		Y	Z	X	٦	Y
30	4	0		0	10	0	0	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>		
	Movie Frame List			
Delay (msec)	Controls how long the frame will be displayed.	30		
Interp Count	Controls how many steps in the frame between the current camera position and the camera position in the next frame.	ition and the 4		
Camera Position	Camera position in the global coordinate system.	0, 0, 10		
Camera Aim Point	Camera aim point in the global coordinate system.	0, 0, 0		
Camera "Up" Direction	Camera "up" direction relative to the global coordinate system.	to the global $0, 1, 0$		
Comment	A comment of any length may be entered here.			
OK	Save the movie in the FRED document and close dialog box.			
Close	Close dialog box without saving the changes to the FRED document.			
Add Camera Pos	Insert additional camera positions.			
Apply	Save Movie Frame List changes to the FRED dialog but keep dialog box open.			

Play Movie	Play the movie.	
Help	Access this Help page.	

Raytrace - Trace All Sources

This command deletes all the existing rays, creates new rays at all the traceable sources, and then traces all the created rays. It does not render the rays in the visualization window.



How Do I Get There? - Trace All Sources

There are three ways to execute this command:

1. Select Trace All Sources in the Ray Trace Menu,



- 2. or press the keyboard accelerator keys: Ctrl+Shift+F5,
- 3. or press the toolbar button:

Raytrace - Trace Existing and Render

Description How Do I Get There? Application Notes See Also...

Description Trace Existing and Render

Traces all rays and renders them in the Visualization window. This command is unavailable until the rays have been created with the <u>Create Sources</u> command.

How Do I Get There? Trace Existing and Render

There are three different ways to execute this command:

1. Select Trace Existing Ray in the Ray Trace Menu



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Raytrace <u>3</u> D View <u>C</u> reate <u>A</u> nalyse	s <u>W</u> indow <u>H</u> elp
Trace All Sources	Ctrl+Shift+F5
🗳 Trace and <u>R</u> ender	Ctrl+Shift+F7
Sector All Source Rays	Ctrl+Shift+F8
🔀 Delete Existing Rays	Ctrl+Shift+F9
Trace Existing Rays	Ctrl+Shift+F10
→ Trace Existing and Render	Ctrl+Shift+F11
1 Trace Single Ray V	Ctrl+Shift+1
+ Trace Targeted Ray	Ctrl+Shift+2
Ray Manipulation Utilities	
#⊰ User-defined Ray Paths	Ctrl+Shift+U
Coherent <u>F</u> ield Synthesis	
A Advanced Raytrace	Ctrl+Shift+A
and the local and a second sec	

- 2. Press the keyboard accelerator keys: Ctrl+Shift+F11
- 3. Press the toolbar button:

Application Notes Trace Existing and Render

- Manipulating the system view (i.e., pan or rotate) in the Visualization window while the rays are being rendered can lead to spurious effects, particularly if a large number of rays have been selected. For best results, wait to change the view until the raytrace has completed, as indicated by the status bar at the bottom of the FRED program window.
- The number of rendered rays can be different than the number of rays defined by the source. Go to the Source dialog, select the Visualization tab, and enter the number of sources rays per rendered ray:



<mark>6 (houghton.</mark> f	rd) Edit Optical Sou	rce: "collima	ted beam"					_ 🗆 ×
Source	Positions/Directio		cation/Orientation	1	Power	Coherence lization	4	0K
	rization	Wav	elengths		visua	lization		Cancel
- Ray Starting	Positions						1	Apply
🔽 Draw	Color:	-	Draw every	1	÷ 't	ray position		Help
- Ray Colore (Juring Pou Trading (f)	sus are being a	de accuma)					
	During Ray Tracing (if							
I Modify F	Ray Colors to Track Po	wer (rays get d	IMMER as they lose	powerj				
<u>.</u>								
LandDarm	Para Malana							
Local Bound								
Draw	Color:	-						

• If a source contains multiple wavelengths, FRED automatically creates and renders the number of rays specified in the Positions/Directions tab for <u>each</u> wavelength.

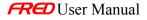
• The color of the rendered rays is specified under the Wavelengths tab of the Source dialog. The rendered color can be calculated to approximately match the wavelength. It may be different from the color of the ray starting positions (which is useful if multiple wavelengths have been assigned to a single source).

• Ray colors can also be modified during the raytrace. They can be made dimmer (i.e., blacker) as they lose power. They can also be made to change color after intersecting a surface.

FRED and FRED Turbo

The multi-core usage feature is active at the time of a raytrace unless:

- the user invokes a "Trace and Render" or "Trace Existing and Render"
- the Advanced Raytrace "Determine raypaths" check-box is checked,
- the Advanced Raytrace "Create/use ray history file" check-box is checked.



<u>See Also....</u> Trace Existing and Render

Trace and Render Trace All Sources Trace Existing Rays Trace Single Ray Delete Existing Rays Create All Source Rays

Raytrace - Create Sources

Description How Do I Get There? Application Notes See Also...

Description Create Sources

Creates the rays for all traceable optical sources. After the rays are created, their starting points will be shown in the visualization window if it is turned on, but this command does not execute the raytrace.

Note: If there are rays in the system prior to issuing this command, they are deleted before new rays are created.

How Do I Get There? Create Sources

There are three ways to execute this command:

1. Select Create All Source Rays in the Ray Trace Menu,

Ray Trace 3D View Analyses	<u>W</u> indow <u>H</u> elp
🍄 <u>T</u> race All Sources	Ctrl+Shift+F5
Trace and <u>R</u> ender	Ctrl+Shift+F7
🚟 <u>C</u> reate All Source Rays 💦	Ctrl+Shift+F8
Collete Existing Rays	Ctrl+Sbift+E9

- 2. or press the keyboard accelerator keys: Ctrl+Shift+F8,
- or press the toolbar button:

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All analysis options can be exercised on any and all of the currently traceable sources prior to execution of the raytrace. Graphical displays of the intensity and irradiance properties of a source can be created by first attaching an Analysis Plane to the source of interest and then generating either a spot diagram or spread function.

See Also... Create Sources

Trace and Render Trace All Sources Trace Existing Rays Trace Existing and Render Trace Single Ray Delete Existing Rays



Deletes all rays that are in the ray buffer. Does not delete the sources of those rays.

How Do I Get There? - Delete All Rays

There are three ways to execute this command:

1. Select Trace All Sources in the Ray Trace Menu,

<u>R</u> ay Trace	<u>3</u> D View	<u>A</u> nalyses	<u>W</u> indow	Help
🎬 <u>T</u> race /	All Sources		C	trl+Shift+F5
🍄 Trace a	and <u>R</u> ende	r	C	trl+Shift+F7
🏁 <u>C</u> reate	All Source	Rays	C	trl+Shift+F8
🔀 <u>D</u> elete	Existing R	ays 📐	C	trl+Shift+F9
	Evisting Ra			l+Shift+E10

- 2. or press the keyboard accelerator keys: Ctrl+Shift+F9,
- 3. or press the toolbar button: ...

Application Notes - Delete All Rays

All rays are deleted. As a result, all associated ray information, such as ray summary data, is lost. Further, unless they are locked, all open analysis windows (spot diagrams or spread functions) associated with the model are closed.

If no rays have been created, generating a spot diagram or spread function will automatically prompt the user for 'Pre-Analysis Ray Operations' that include recreating all active sources and executing the raytrace.



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Raytrace - Trace Existing Rays

Description How Do I Get There? Application Notes Examples See Also...

Description Trace Existing Rays

Traces, but does not render, rays in the ray buffer. This command is unavailable until the rays have been created with the <u>Create Sources</u> command.

How Do I Get There? Trace Existing Rays

There are three different ways to execute this command:

1. Select Trace Existing Ray in the Ray Trace Menu

<u>R</u> aytrace <u>3</u> D	View <u>C</u> reate	<u>A</u> nalyses	<u>W</u> indow	Help		
🍄 Irace All Sources Ctrl+Shift+F5						
🍄 Trace and	:+F7					
🎎 <u>C</u> reate A	See Greate All Source Rays Ctrl+Shift+F8					
🔀 <u>D</u> elete E>	cisting Rays		Ctrl+Shift	:+F9		
🔶 Trace <u>E</u> xi	sting Rays		Ctrl+Shift+	+F10		
→ T <u>r</u> ace Exi	sting and Rend	der ^W	Ctrl+Shift+	-F11		
1→ Trace <u>S</u> in	gle Ray		Ctrl+Shift+1			
🔶 Trace Tai	rgeted Ray		Ctrl+Shi	ft+2		
Ray <u>M</u> ani	pulation Utilitie	s				
<mark>,#</mark> ⊰ <u>U</u> ser-defi	ned Ray Paths		Ctrl+Shi	ft+U		
Coherent	: <u>F</u> ield Synthes	is				
A <mark>::</mark> <u>A</u> dvance	d Raytrace		Ctrl+Shi	ft+A		

- 2. Press the keyboard accelerator keys: Ctrl+Shift+F10
- 3. Press the toolbar button:

Application Notes Trace Existing Rays

FRED and FRED Turbo

The multi-core usage feature is active at the time of a raytrace unless:

• the user invokes a "Trace and Render" or "Trace Existing and Render"

- the Advanced Raytrace "Determine raypaths" check-box is checked,
- the Advanced Raytrace "Create/use ray history file" check-box is checked.

<u>Examples</u>

Trace Existing Rays

<u>See Also....</u> Trace Existing Rays

> Trace and Render Trace All Sources Trace Existing and Render Trace Single Ray Delete Existing Rays Create All Source Rays

Raytrace - Trace and Render

Description How Do I Get There? Application Notes See Also...

Description Trace and Render

This command creates all sources, traces their rays, and renders the rays in the Visualization window.

How Do I Get There? Trace and Render

There are three different ways to execute this command:

1. Select Trace and Render in the Ray Trace Menu

 Ray Trace
 3D View
 Analyses
 Window
 Help

 Irace All Sources
 Ctrl+Shift+F5

 Irace and Render
 Ctrl+Shift+F7

 Create All Source Rays
 Ctrl+Shift+F8

2. Press the keyboard accelerator keys: Ctrl+Shift+F7

3. Press the toolbar button:

Application Notes Trace and Render

• Manipulating the system view (i.e., pan or rotate) in the Visualization window while the rays are being rendered can lead to spurious effects, particularly if a large number of rays have been selected. For best results, wait to change the view until the raytrace has completed, as indicated by the status bar at the bottom of the FRED program window.

• The number of rendered rays can be different than the number of rays defined by the source. Go to the Source dialog, select the Visualization tab, and enter the number of sources rays per rendered ray:

🛟 (FRED1) Create a New Optical Source: "Optical Sources"	_ 🗆 🗵
Source Positions/Directions Location/Orientation Power Coherence Polarization Wavelengths Visualization	ОК
Ray Starting Positions	Cancel
✓ Draw Color: Draw every 1 + 'th ray position	Apply
	Help
Ray Colors During Ray Tracing (if rays are being drawn)	
Modify Ray Colors to Track Power (rays get dimmer as they lose power)	
Local Bounding Volume	
Draw Color:	

• If a source contains multiple wavelengths, FRED automatically creates and renders the number of rays specified in the Positions/Directions tab for <u>each</u> wavelength.

• The color of the rendered rays is specified under the Wavelengths tab of the Source dialog. The rendered color can be calculated to approximately match the wavelength. It may be different from the color of the ray starting positions (which is useful if multiple wavelengths have been assigned to a single source).

• Ray colors can also be modified during the raytrace. They can be made dimmer (i.e., blacker) as they lose power. They can also be made to change color after intersecting a surface.

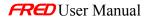
• FRED and FRED Turbo

The multi-core usage feature is active at the time of a raytrace unless:

- the user invokes a "Trace and Render" or "Trace Existing and Render"
- the Advanced Raytrace "Determine raypaths" check-box is checked,
- the Advanced Raytrace "Create/use ray history file" check-box is checked.

See Also.... Trace and Render

> Trace All Sources Trace Existing Rays Trace Existing and Render Trace Single Ray Delete Existing Rays Create All Source Rays



Raytrace - Coherent Scalar Field Synthesis

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Coherent Scalar Field Synthesis

This dialog creates a new coherent rayset based upon a Gabor synthesis of a usercalculated complex field. The field is synthesized from a collection from a collection of Gaussian beamlets whose amplitude, phase and directional distribution are determined by the the field characteristics as well as the area and spatial resolution over which the original field was calculated.

How Do I Get There? Coherent Scalar Field Synthesis

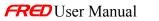
Coherent Field Synthesis is activated from the Raytrace Menu by choosing "Coherent Field Synthesis..."

ols	<u>Raytrace</u> <u>3</u> D View <u>Create</u>	<u>A</u> nalyses <u>W</u> indow <u>H</u> elp		
2	🍄 <u>T</u> race All Sources	Ctrl+Shift+F5		
	🗳 Trace and <u>R</u> ender	Ctrl+Shift+F7		
	🚟 Create All Source Rays	Ctrl+Shift+F8		
es	🔀 Delete Existing Rays	Ctrl+Shift+F9		
	Trace Existing Rays	Ctrl+Shift+F10		
ice(→ Trace Existing and Render	Ctrl+Shift+F11		
	1→ Trace Single Ray	Ctrl+Shift+1		
	🕂 Trace Targeted Ray	Ctrl+Shift+2		
	Ray Manipulation Utilities			
	#음 User-defined Ray Paths	Ctrl+Shift+U		
I Co	Coherent <u>F</u> ield Synthesis			
d	A <mark>≓ <u>A</u>dvanced Raytrace</mark>	لمري Ctrl+Shift+A		



Dialog Box and Controls Coherent Scalar Field Synthesis

G			t Scalar Field					<u>_ ×</u>		
	- Locatio	Location/Orientation (right mouse-click for popup menu) Reference Coordinate Action Parameters (right mouse-click)						Dismiss		
	0	Starting Co	oordinate System ordinate system	em	rarameter	a (right mous		Help		
								eate Rays		
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		across / down	(0)	-0.75	-0.5	-0.25	(4)	(<u>(</u> _		
		-1	0	0	0	0	0	0		
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	(2)	-0.5	0	0	0	0	0	0		
			0	0	0	0	0	0		
	(3)	-0.25	0	0	0	0	0	0		
	(4)	0	0	0	0	0	0	0		
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Contro	trol Inputs / Descriptio				ion		<u>Defau</u>	Its		
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ocatio	ation/Orientation Set coordinate sys				tem & Con of new rayset.			Global/None		
				ian Beaml		-				
	(-1	^π HW)	1	h of individ			2,2			



Max Ray Shift	Number of extra beams supplied for smoothing.	0,0					
Max Ray Angle	Maximum ray angle (in degrees) measured from plane normal direction.	0,0					
Wavelength (um)	Source wavelength	0.6328 um (He- Ne)					
Immersion material	Rays are immersed in this material.	Air					
Power Cutoff Threshold	Specify Absolute Ray Power & Fraction of Max Ray Power. Discard rays with powers below these thresholds.	0,0					
	Scalar Field Sample Grid						
Cell	Holds real and imaginary values at each field point.	0,0					
Right-click Cell	Field edit options: Set Size Read from File Write to File Modify Field Values						
Create Rays	Create coherent rays from input data.						
Append/Replace Rays	Append to current rayset or Replace current rayset.	Append					
Dismiss	Dismiss dialog box.						
Help	Access this Help page.						

<u>Application Notes</u> Coherent Scalar Field Synthesis

The general approach behind Coherent Field Synthesis is the creation of a coherent rayset that, when coherently summed, yields a desired coherent scalar field. The rayset consists of a collection of coherent Gaussian beamlets each having the same size. The spatial distribution of this collection is a rectilinear array which may span the spatial size of the scalar field or emanate from a central location. The angular distribution is rectilinear array in direction cosine space which may span a predetermined angular size. That is, at each spatial location there is a number of rays all pointing in different directions.

The coherent field to be synthesized can be entered directly in the dialog box data area or read from a text file. FRED can create a text file representation of a

coherent field after calculating the Coherent Scalar Wave Field by accessing the 'Save Complex Field to File' option from the popup menu in the Chart Viewer. The Analysis Surface used in calculating the Coherent Scalar Wave Field specifies the sampling of the scalar field to be synthesized. The Coherent Field Synthesis dialog is used to specify the Gaussian beamlet size "L" (defined as the exp(-) amplitude point), the wavelength , and the refractive index "n" of immersion material. Once this information is specified, the spatial and angular array spacings are automatically determined. The spatial array spacing is equal to the beamlet size, L. The angular spacing in direction cosine space is given by

/(n*L). The user has control over how far out to create rays in the spatial dimensions, and how far out to create rays in the direction dimensions.

In practice it is often difficult to specify the proper field sampling, beamlet size, spatial limit, and angular limits in order to create a rayset that accurately synthesizes the given field. The user must often try many different combinations of parameters before arriving at a satisfactory result. However, there are some general rules that can be used to guide this process.

- Never assume that the computed rayset gives an accurate synthesis of the field without verification. In this regard, it is recommended that a coherent field analysis be done and compared this with the original field.
- The more densely sampled the original scalar field the better. Sparse sampling can lead to inaccuracy regardless of how the user-specified parameters are set.
- In general, the more rays created, the more accurate the result will be.
- With regard to the ray size "L", bigger is better. The algorithm computes faster for bigger rays. The algorithm is also numerically more accurate for bigger rays. In fact, small rays can be inaccurate by a very large amount.
- Wider angular ranges are better than smaller ranges. When possible, however, limit the angular range of the rayset to the acceptance cone of the receiving optical system.
- You can extend spatial range to one position bigger than extent of the field using the L parameter. Occasionally, you may need a slightly bigger range to accurately model field edge effects.
- The total number of spatial ray positions is the main factor in determining how long the calculation will take. The more ray positions, the longer the time it will take. The effect of more ray directions is less important.
- Smoother fields can be synthesized with less rays than fields with sharp discontinuities.
- The angular divergence of individual beamlets is inversely proportional to the beamlet size. Smaller beamlets spread more rapidly than big beamlets as they propagate.

See Also.... Coherent Scalar Field Synthesis Modify Scalar Field Values Set Scalar Field Array Size

[1] *Gabor representation and aperture theory*, P.D. Einziger, S. Raz, and M Shapira, J. Opt. Soc. Am. A/Vol. 3, No. 4/ April 1986, p.508



Raytrace - Coherent Scalar Field Synthesis - Sizing the Scalar Wave Field

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Sizing the Scalar WaveField

Alters the number of rows and columns in the Scalar Field sample grid.

How Do I Get There? Sizing the Scalar WaveField and Amplitude/Phase Mask

Set the Scalar Field size by right-clicking in a data value cell.



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	hton.frd *) C	oherent Scal	ar Field Synt	hesis					
Locatio	on/Orientation	right mouse-clia	ck for popup m	enu)					
	Reference Coordinate Action Parameters (right mouse-cl						Dismiss		
	Starting Coordinate System						Help		
	0 Global coordinate system								
							Create Rays		
							Append rays		
<u> </u>							Replace rays		
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Dialog Box and Controls

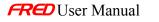
Sizing the Scalar WaveField

Scalar Field Size	×			
Semi-apertures:	× Y 1 1			
Number of samples: ((for full apertures)	3 ÷ 8 ÷			
	Cancel Help			
<u>Control</u>	Inputs / Description	<u>Defaults</u>		
Semi-apertures	Set semi-aperture widths.	1,1		
Number of samples	Set sampling over full aperture.	(8,8) (5,5)		
ОК	Accept aperture settings and close dialog box.			
Cancel	Discard aperture changes and close dialog box.			
Help	Access this Help page.			

Application Notes Sizing the Scalar WaveField

<u>See Also....</u> Sizing the Scalar WaveField

> <u>Coherent Scalar Field Synthesis</u> <u>Scalar Field Modify</u>



Raytrace - Coherent Scalar Field Synthesis -Modifying Scalar Field Values

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Scalar Field Modify Values

Specifies a subsection of the field data and modifies amplitude or phase values.

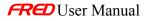
How Do I Get There? Scalar Field Modify Values

Modification of the Scalar Field values is accessed through the Coherent Field Synthesis dialog:

1. Select Coherent Field Synthesis from the Raytrace Menu,

Raytrace 3D view Create An	aiyses <u>w</u> indow <u>H</u> eip			
Yrace All Sources	Ctrl+Shift+F5			
. 🗳 Trace and <u>R</u> ender	Ctrl+Shift+F7			
🤲 Create All Source Rays	Ctrl+Shift+F8			
🔀 Delete Existing Rays	Ctrl+Shift+F9			
Trace Existing Rays	Ctrl+Shift+F10			
→ Trace Existing and Render	Ctrl+Shift+F11			
1→ Trace Single Ray	Ctrl+Shift+1			
🕂 Trace Targeted Ray	Ctrl+Shift+2			
Ray Manipulation Utilities				
#Pailor Hatter H	Ctrl+Shift+U			
Coherent <u>F</u> ield Synthesis				
A <mark>⇒</mark> <u>A</u> dvanced Raytrace	Ctrl+Shift+A			

2. Right-click in the data values area.



(hton.frd *) C	oherent Sca	lar Field Synt	hesis				
Locatio	on/Orientation (right mouse-cli	ck for popup m	enu)			<u> </u>	
	Reference Coordinate Action Parameters (right mouse-cl						Dismiss	
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FRED User Manual

Dialog Box and Controls Scalar Field Modify Values

(FRED2 *) Scalar Field Modify Values	
Applied spreadsheet area Shape: Apply the operation to: Ellipse Inside the hightlight Rectangle C Outside the hightlight	- Help I Cancel I
Operation to Perform (all phases are in unit Set to constant complex value: Multipy by constant complex value:	s of waves) real part: imaginary part: 0 0 0 0
 Multiply by Gaussian real amplitude: Scale power to: 	1/e semi-width in X: 1/e semi-width in Y: 0 0 1 1
 Set constant phase: Add constant phase: 	0
 Add Linear phase (a*X + b*Y): Add quadratic phase (a*X*X + b*Y*Y): 	a b 0 0 0 0

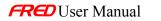
<u>Control</u>	Inputs / Description	<u>Defaults</u>					
Applied spreadsheet area							
Shape	Choose Ellipse or Rectangle	Ellipse					
Apply the operation to	Inside or outside region	Inside					
	Operation to Perform						
Set to constant complex value	Set field to constant complex value.	0,0					
Multiply by constant complex value	Multiply field by constant complex value.	0,0					
Multiply by Gaussian real amplitude	Multiply field by Gaussian real amplitude.	0,0					
Scale power to	Scale power of field.	1					
Set constant phase	Set constant phase for field.	0					
Add constant phase	Add constant phase to field.	0					

Add Linear phase	Add a linear phase to the field. $(a^*X + b^*Y)$	0,0
Add quadratic phase	Add a quadratic phase to the field. $(a^*X^2 + b^*Y^2)$	0,0
OK	Accept modifications and close dialog box.	
Cancel	Discard modifications and close dialog box.	
Apply	Apply modifications and keep dialog box open.	
Help	Access this Help page.	

Application Notes Scalar Field Modify Values

Scalar Field Modify Values

Coherent Scalar Field Synthesis Sizing the Scalar Field

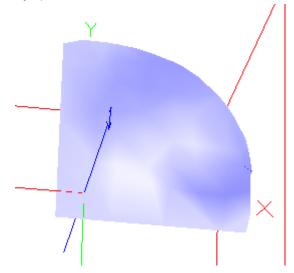


Create - New Surface - Bicubic Mesh Surface

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Surface - Bicubic Mesh Surface

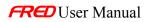
Creates a Bicubic Mesh surface from tabular data. Data points represent Z-values for evenly spaced X,Y.



How Do I Get There? - Surface - Bicubic Mesh Surface



Objects Dptical Sources Geometry Contended for the second seco		
	Vever Traceable (for trimming surfaces)	
Escutings Scatterers End Raytrace Properties	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes	
	 Position/Orientation Parent Coordinate System Sc <u>a</u> le	
	 ✗ Cut I[™] Copy I[™] Paste Delete (all highlighted items) 	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Report Detailed Report	
	Edit/View Lens Edit/View Mirror Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position/Orient</u>	ation
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface Create New <u>C</u> urve	₩



Scatte SURF/	r	eate a New Surf Visualization Aperture	Glue	of: "Elem 1"
Logical F	Parent	.Elem 1		
Name:		Surf 1		Apply
				Help
Descript	ion:			
		Traceable (thi	ie eurface can b	be raytraced) 🔲 Use for trimming only (never raytrace)
Turner	D:			
Туре:	BICUD			define smoothly connected patches)
		Mesh Z	(x,y): x increas	ise across, y
		(0)	(1)	
(0)	0	0	1	
	1	0	0	
		<u>_</u>	Ť	
(1)			<u>+</u>	<u>i</u>
	1			
	1			

Dialog Box and Controls - Surface - Bicubic Mesh Surface

<u>Control</u>	Inputs / Description	<u>Defaults</u>		
Logical Parent	Name of Parent entity.	Custom Element Name		
Name	Name of surface supplied by user.	Surf 1		
Description	Descriptive text.	blank		
Traceable	Surface can be raytraced.	Checked		
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked		
Туре	Surface type.	Bicubic Mesh Surface		
Data Table	User input data or read from file.			
ОК	Accept Bicubic Mesh Surface surface and close dialog box.			

Cancel	Discard Bicubic Mesh Surface surface and close dialog box.	
Apply	Create Bicubic Mesh Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Bicubic Mesh Surface

- The Bicubic Mesh Surface is a sagable surface. A "sagable" surface is defined as single-valued in z.
- A sample of the text file format for user-defined bicubic mesh data is shown here. This file should have a *.dat extension. The first line must have the entry *type mesh* while the second line has only the word *format*. The first row of data contains x-values while the first column contains y-values. The remaining data are the z-values.

📕 testmesh.dat - Notepad	
File Edit Format View Help	
type mesh format -2 -1 0 1 2 -2 1 3 3 3 1 -1 1 4 5 4 1 0 1 4 7 4 1 1 1 4 5 4 1 2 1 3 3 3 1	×

See Also - Surface - Bicubic Mesh Surface

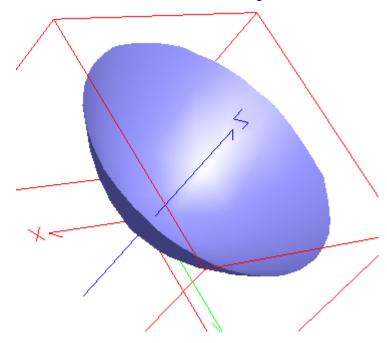


1.

Create - New Surface - Conicoid

Description - Surface - Conicoid

Creates a conicoid surface with a default aperture, material, coating, raytrace control, location, etc. The default location is at the origin.





How Do I Get There? - Surface - Conicoid

Objects Dptical Sources Geometry Elem 1		
- 💷 Analysis Surface(s)	✓ Iraceable	
 	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent Material Position/Orientation	
	Edit/View Array Parameters	
	Delete Array Parameters	
	Create New Surface	
	Create New <u>C</u> urve	



Dialoo	Box	and	Controls	- Surface -	- Conicoid

Scatt SURF	er Via ACE Parent: Ele Surf		OK Cancel Apply Help
Туре:		Traceable (this surface can be raytraced) Use for trimming only (never raytrace) Sphere, Ellipse, Parabola, Hyperbola, etc.) Description	
Rad	0	Radius (= 1/curvature)	
Conic	0	Conic constant (<-1=hyperbola, -1=parabola, <0=ellipse, 0=sphere)	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Conicoid
Rad	Radius of curvature.	0
Conic	Conic constant.	0
ОК	Accept Conicoid surface and close dialog box.	
Cancel	Discard Conicoid surface and close dialog box.	

Apply	Create Conicoid surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Conicoid

- 1 The conicoid and conic focii are only closed surfaces in FRED. They can be used to construct spheres and ellipsoids. The conicoid can also be used to create open surfaces such as hyperbolas and parabolas.
- 2. The conicoid is a "non-sagable" surface. Therefore, it cannot be used as a defroming surface. A "Sagable" surface is defined as a single-valued in z.

See Also - Surface - Conicoid

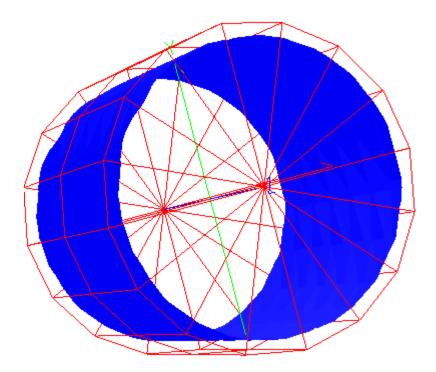
Create - New Surface - Cylinder

Description - Surface - Cylinder

Creates a cylindrical or tubular surface.



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How Do I Get There? - Surface - Cylinder



Objects Dptical Sources Geometry Contended for the second seco		
	Vever Traceable (for trimming surfaces)	
Escutings Scatterers End Raytrace Properties	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes	
	 Position/Orientation Parent Coordinate System Sc <u>a</u> le	
	 ✗ Cut I[™] Copy I[™] Paste Delete (all highlighted items) 	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Report Detailed Report	
	Edit/View Lens Edit/View Mirror Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position/Orient</u>	ation
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface Create New <u>C</u> urve	₩



Dialog Box and Controls - Surface - Cylinder	
· · ·	
	m

(FRED1 *) C	reate a Nev	v Surface as (Child of: "Elem 1"
Scatter SURFACE	Visualiza Apertu		ilue Grating Auxiliary Data Modifiers OK Cation/Orientation Materials Coating/RayControl Cancel
Logical Paren	t .Elem 1		Apply
Name:	Surf 1		Help
Description:			
	r I Tracea	ble (this surface	e can be raytraced) 🛛 🔲 Use for trimming only (never raytrace)
Type: Cylin	der (aligned	along the Z-ax	is)
	Front End	Back End	Description
X Semi-Ape	1	1	X direction semi-aperture at the ends of the cylinder
Y Semi-Ape	1	1	Y direction semi-aperture at the ends of the cylinder
Z Location	0	1	Z-axis values of the front and back ends (not for Z clipping)
Shape	0	0	Shape specification at the ends (ellipse=0 <= shape <= 1=rec

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Cylinder
X/Y semi-Ape	Semi-aperture at cylinder ends.	0
Z Location	Starting and ending location of cylinder.	0
Shape	Specifies shape at ends of cylinder (ellipse=0 <= shape <= 1=rectangle)	0
ОК	Accept cylinder surface and close dialog box.	
Cancel	Discard cylinder surface and close dialog box.	

АррІу	Create cylinder surface and keep dialog box open.	
Help	Access this Help page.	

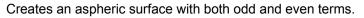
Application Notes - Surface - Cylinder

1. The Cylinder is a sagable surface.

See Also.... - Surface - Cylinder

Create - New Surface - General Asphere

Description - Surface - General Asphere





How Do I Get There? - Surface - General Asphere

Objects		
Analysis Surface(s)	✓ <u>T</u> raceable	
+ 💼 Materials	Never Traceable (for trimming surfaces)	
+ 🖬 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	Coordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation	
	Edit/View Array Parameters Delete Array Parameters	
	Create New Surface	
	Create New <u>C</u> urve	

FRED User Manual

	Dialog	Box	and	Controls -	Surface	- Gene	ral Asphere	
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(🔆 (FR	ED1	*) Cre	ate a Ne	w Surfa	ce as Child of:	"Elem 1"					
	catter		Visualiz		Glue	Grating	Auxiliary		Modifiers	ļ	ОК
SI	URFA	.CE	Apert	ure	Location/Ori	entation	Materials	Coatir	ng/RayControl	4	Cancel
Log	gical P	Parent:	.Elem 1						-		Apply
Nar	me:		Surf 1								
Des	scriptio	on:								1	Help
				11.011			(
т					surface can be				never raytrace)	ı I	
Тур	e:	Genera	al asphere	(Conico	id plus even an	d odd order radi	al polynomial tei	msj			
	-	/alue		scriptio							
Ra		0			l/curvature)						
Co	nic (0			ant (≺-1=hyper⊧		la, <0=ellipse, 0	=sphere))		
0		0	Coe	efficient o	of the r^0 polyn	omial term					

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	General Asphere
Rad	Radius of curvature.	0
Conic	Conic constant.	0
r^n	all order aspheric terms	0

ОК	Accept general asphere surface and close dialog box.	
Cancel	Discard general asphere surface and close dialog box.	
АррІу	Create general asphere surface and keep dialog box open.	
Неір	Access this Help page.	

Application Notes - Surface - General Asphere

1. The function form of the general asphere is given by

$$f(\mathbf{r}, \mathbf{z}) = \mathbf{z} - \frac{\mathbf{c}\mathbf{v} \cdot \mathbf{r}^2}{1 + \sqrt{1 - (1 + \mathbf{conic}) \cdot (\mathbf{c}\mathbf{v} \cdot \mathbf{r})^2}} - \sum_{i} \mathbf{even}_i \cdot \mathbf{r}^{2i} - \sum_{j} \mathbf{odd}_j \cdot \mathbf{r}^{2j+1} = 0$$

2. The general asphere is a sagable surface.

See Also - Surface - General Asphere

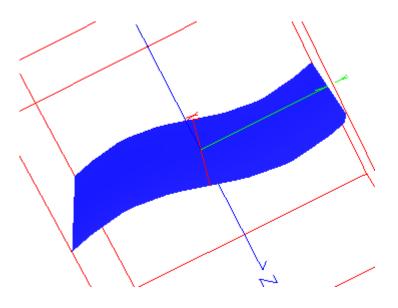
Create - New Surface - Implicit Script Surface

Description - Surface - Implicit Script Surface

Creates a Implicit Script surface from functional form defined in script. FRED supplies the x,y,z coordinates. The user supplies FRED with the functional form of the surface as f(x,y,z)=0.



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How Do I Get There? - Surface - Implicit Script Surface



Objects		
E 🔜 Geometry		
Elem 1	✓ <u>I</u> raceable	
	Never Traceable (for trimming surfaces)	
🕂 🚮 Scatterers	Draw O <u>u</u> ter Enclosing Volume Coordinate Axes	
🕂 间 Raytrace Properties	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate S <u>v</u> stem Sc <u>a</u> le	
	K Cut	 Ctrl+X
	Ba Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation.	
	Edit/View Array Parameters	
	Delete Array Parameters	
	Create New Surface	
	Create New <u>C</u> urve	



(FRED1 *) Create a New Surface as Child of: "Elem 1" Scatter Visualization Glue Grating Auxiliary Data Modifiers SURFACE Aperture Location/Orientation Materials Coating/RayControl Logical Parent: .Elem 1 • Name: Surf 1 Description: • Traceable (this surface can be raytraced) Use for trimming only (never raytrace)	OK Cancel Apply Help
Type: Implicit Script Surface (Surface defined by a script)	
Function: F(x,y,z) = 0 defines the surface. Input variables: (g_x, g_y, g_z) is the point (x,y,z). Output variables: g_f is the function value F(x,y,z). (g_dfdx,g_dfdy,g_dfdz) are the derivatives of F(x,y,z). All values are in the local coordinate system of the su:	
<pre>' Parabola: g_f = g_z - g_y * g_y - g_x * g_x g_dfdx = -2.0 * g_x</pre>	

Dialog Box and Controls - Surface - Implicit Script Surface

<u>Control</u>	Inputs / Description	<u>Defaults</u>			
Logical Parent	Name of Parent entity.	Custom Element Name			
Name	Name of surface supplied by user.	Surf 1			
Description	Descriptive text.	Blank			
Traceable	Surface can be raytraced.	Checked			
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked			
Туре	Surface type.	Implicit Script Surface			
Mesh Z(x,y)					
Data Table	User input data or read from file.				

ОК	Accept Implicit Script Surface surface and close dialog box.	
Cancel	Discard Implicit Script Surface surface and close dialog box.	
АррІу	Create Implicit Script Surface surface and keep dialog box open.	
Нер	Access this Help page.	

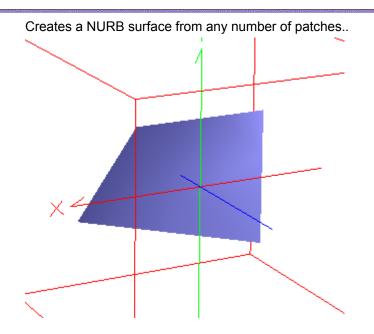
Application Notes - Surface - Implicit Script Surface

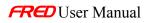
1. The Implicit Script Surface is a sagable surface.

See Also - Surface - Implicit Script Surface

Create - New Surface - NURB

Description - Surface - NURB





How Do I Get There? - Surface - NURB

Objects Dptical Sources Geometry Elem 1		
- 💷 Analysis Surface(s)	✓ <u>I</u> raceable	
🕂 💼 Materials 🕂 🥅 Coatings	Never Traceable (for trimming surfaces)	
+ 🚮 Scatterers	Draw Outer Enclosing Volume	
+ 💼 Raytrace Properties	Coordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	B Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation)
	Edit/View Array Parameters Delete Array Parameters	
	Create New Surface	
	Create New <u>C</u> urve	



Dialog Box and Controls - Surface - NURB

FRED1 *)	Create a New Si	urface as Child of:	"Elem 1"		
Scatter	Visualization	n Glue	Grating Auxiliary	Data Modifiers	: OK
SURFACE	Aperture	Location/Orie	entation Materials	Coating/RayContro	Cancel
_ogical Pare	ent: Elem 1			•	ה
Name:	Surf 1				Apply
	o din 1				- Help
Description:					
	Traceable	(this surface can be	raytraced) 🔲 Use for trimi	ming only (never raytrace	e)
Гуре: 🔃	IRB Surface (Nor	1-Uniform Rational B-	Spline surface in U,V parame	ters)	- I
			es (1=linear, 2=quadratic,		=
U Degree	1		ree in U parameter	etc.)	
V Degree	1	·····	ree in V parameter		
	Knot values (as 0	cending)	Active Range Umin		
0	0		Umax	0	
	1			•	
	1				
	Knot values (as	cending)	Active Range		
0	0		Vmin Vmax	0	
	1		VIIIdA	1	
	1				
Terms		Control Poi			
(i,j) (0,0)	X	<u>γ</u>	Z	Weight	
(0,0)		-0.5 -0.5	0	1	
		, *O.O	, v	•	
(0,1)		0.5	0	1	

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked

Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	NURB
UV Degree	Polynomial degree	blank
UV knots (Value/Range)	Knot values and Active Range.	0-360
Control Points/weights	XYZ control points and their associated weights.	X(0,0) Y(0,0) Z(0,1)
ОК	Accept NURB surface and close dialog box.	
Cancel	Discard NURB surface and close dialog box.	
АррІу	Create NURB surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - NURB

1. The NURB is a sagable surface.

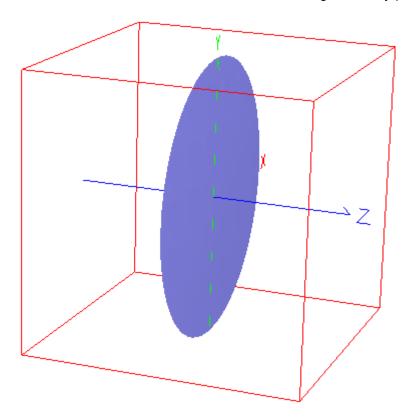
See Also.... - Surface - NURB



Create - New Surface - Plane

Description - Surface - Plane

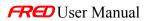
Creates a planar surface with a default aperture, material, coating, raytrace control, location, etc. The default location/orientation is at the origin in the xy-plane.





How Do I Get There? - Surface - Plane

Objects		
- 🛄 Analysis Surface(s)	✓ <u>T</u> raceable	
	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Scale	
	X Cut	Ctrl+X
	B Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report Detailed Report	
	Edit/View Lens Edit/View <u>M</u> irror Edit/View <u>P</u> rism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position/Orientation</u>	٦
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface Create New <u>C</u> urve	



Dialog	Box and	Controls	- Surface	- Plane
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(🕻 (FRED1 *) Cr	eate a New Surface as Child of: "Elem 1"	
Scatter SURFACE	Visualization Glue Grating Auxiliary Data Modifiers Aperture Location/Orientation Materials Coating/RayControl	OK Cancel
Logical Parent: Name:	Elem 1	Apply
Description:		Help
Type: Plane	✓ Traceable (this surface can be raytraced)	
No data		

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Plane
ОК	Accept Plane surface and close dialog box.	
Cancel	Discard Plane surface and close dialog box.	

АррІу	Create Plane surface and keep dialog box open.	
Help	Access this Help page.	

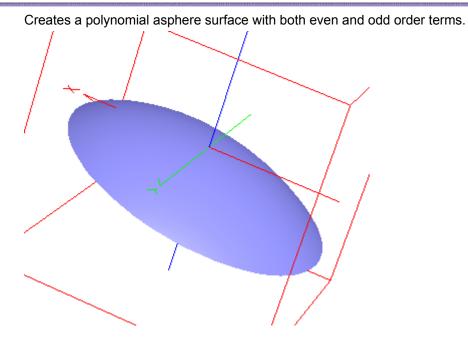
Application Notes - Surface - Plane

1. The Plane is a "Sagable" surface.

See Also - Surface - Plane

Create - New Surface - Polynomial Asphere Surface

Description - Surface - Polynomial Asphere Surface





How Do I Get There? - Surface - Polynomial Asphere Surface

Objects Dptical Sources Geometry Elem 1		
- 🔛 Analysis Surface(s)	✓ Iraceable	
+ Coatings	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw Outer Enclosing Volume	
🕂 🧰 Raytrace Properties	<u>⊂</u> oordinate Axes…	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientatio	n
	Edit/View Array Parameters	
	Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>Curve</u>	



Scatti SURF Logical Name: Descrip	ACE Ap Parent: Elem 1 Surf 1 stion:	alization Glue Grating Auxiliary Data Modifiers erture Location/Orientation Materials Coating/RayControl	OK Cancel Apply Help
Type:		beere (Conic with X and Y polynomial aspheric terms)	
Rad Conic Term	0 0	Radius (= 1/curvature) Conic constant (<-1=hyperbola, -1=parabola, <0=ellipse, 0=sphere) Term = Ai * X^m * Y^n, i = [(m+n)*2+m+3n]/2	
0	0	Coefficient of Constant polynomial term	

Dialog Box and Controls - Surface - Polynomial Asphere Surface

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Polynomial Surface
Rad	Radius of curvature.	0
Conic	Conic constant.	0
A _i coefficients	Aspheric term coefficients.	0

ОК	Accept Polynomial Asphere Surface surface and close dialog box.	
Cancel	Discard Polynomial Asphere Surface surface and close dialog box.	
АррІу	Create Polynomial Asphere Surface surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Polynomial Asphere Surface

1. The function form of the Polynomial Asphere Surface is given by

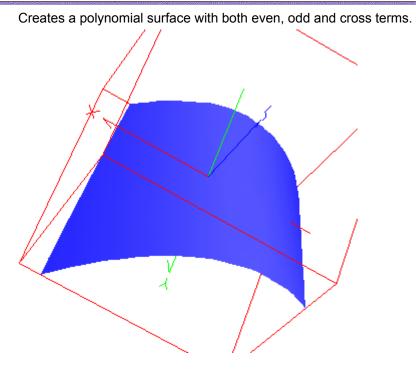
$$f(x, y, z) = z - \frac{cv \cdot r^2}{1 + \sqrt{1 - (1 + conic) \cdot (cv \cdot r)^2}} - \sum_i \sum_j A_{ij} \cdot x^{i-j} \cdot y^j$$

2. The Polynomial Apshere Surface is a sagable surface.

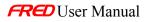
See Also.... - Surface - Polynomial Asphere Surface



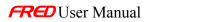
Description - Surface - Polynomial Surface



How Do I Get There? - Surface - Polynomial Surface



Objects		
- 🛃 Geometry		
Elem 1	✓ Iraceable	
	Never Traceable (for trimming surfaces)	
🕂 🔝 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes Visualization Attributes	
	 Position/Orientation	
	Parent Coordinate System	
	Scale	
	X Cut	Ctrl+X
	Copy	Ctrl+C Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position/Orientation</u> .	
	Edit/View Array Parameters Delete Array Parameters	
	Create New Surface	



Dialog Box and Controls - Surface - Polynomial Surface

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Polynomial Surface
Coefficients	Polynomial coefficients of all order.	0
OK	Accept Polynomial Surface surface and close dialog box.	

Cancel	Discard Polynomial Surface surface and close dialog box.	
АррІу	Create Polynomial Surface surface and keep dialog box open.	
Неір	Access this Help page.	

Application Notes - Surface - Polynomial Surface

1. The function form of the Polynomial Surface is given by

$$f(x,y,z) = \sum_{i=0}^n \sum_{j=0}^i \sum_{k=0}^j A_{ijk} \cdot X^{i-j} \cdot Y^{j-k} Z^k$$

2. The Polynomial Surface is a sagable surface.

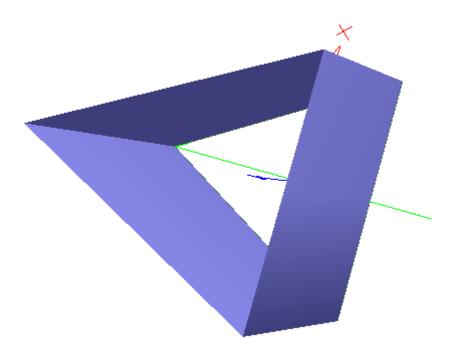
See Also - Surface - Polynomial Surface



Create - New Surface - Ruled Surface

Description - Surface - Ruled Surface

Creates a ruled surface by connecting two curves. This is a more general extrusion method.





How Do I Get There? - Surface - Ruled Surface

Objects Optical Sources Geometry Comparison Compar		
- 🛄 Analysis Surface(s)	✓ <u>T</u> raceable	
	Never Traceable (for trimming surfaces)	
+ 🔤 Scatterers	Draw Outer Enclosing Volume	
🕂 🔲 Raytrace Properties	Coordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Scale	
		Chilling .
	K Cut Ba Copy	Ctrl+X Ctrl+C
	R Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	<u>D</u> etailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation	n
	Edit/View Array Parameters	
	Delete Array Parameters	
	Create New Surface	
	Create New <u>C</u> urve	

FRED User Manual

Dialog Box and Controls - Surface - Ruled Surface

Parent entity. surface supplied by user.	Custom Element Name Surf 1
surface supplied by user.	Surf 1
ve text.	blank
can be raytraced.	Checked
ytrace. Surface used for trimming	Unchecked
ype.	Ruled Surface
	blank
curves to connect.	
	start of 1st curve to Start/End of 2nd

ОК	Accept Ruled Surface surface and close dialog box.	
Cancel	Discard Ruled Surface surface and close dialog box.	
АррІу	Create Ruled Surface surface and keep dialog box open.	
Нер	Access this Help page.	

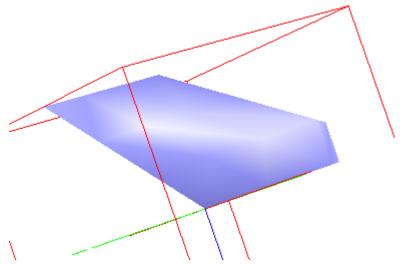
Application Notes - Surface - Ruled Surface

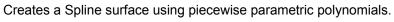
1. The Ruled Surface is a sagable surface.

See Also - Surface - Ruled Surface

Create - New Surface - Spline

Description - Surface - Spline







How Do I Get There? - Surface - Spline

Objects Optical Sources Geometry Comparison Compar		
- III Analysis Surface(s)	✓ <u>I</u> raceable	
	Never Traceable (for trimming surfaces)	
🕂 <u> I</u> Scatterers	Draw O <u>u</u> ter Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	<u>V</u> isualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation)
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>C</u> urve	

(FRED1 *) Cre	ate a New S	Surface as (Child of: "Ele	m 1"					<u> </u>
Scatter	Visualizatio	on G	lue 🗍 🗆	Grating	Auxiliary	Data	Modifi	ers	ОК
SURFACE	Aperture	E Loc	ation/Orientati	ion	Materials	Coatir	ng/RayCon	trol [Canaal
Logical Parent:									Cancel
Logical Faleni.	·							<u> </u>	Apply
Name:	Surf 1								
Description:									Help
	🗹 Traceabl	e (this surface	e can be raytra	aced) [Use for trimr	ning only (r	never raytra	ice)	
Type: Spline	Surface (co	llection of par	rametric (u,v) p	olynomia	spline patches	:)		-	
						i k	ζ	- 1	
U Degree	Polynomial		l =linear, 2=q u U parameter	uadratic,	etc.)				
V Degree	1	···· <u>-</u> ·····	V parameter					-	
v Dogroo		Begreein	* parameter						
U Breakpoints	U paramete	er breakpoi	nts in ascen	ding or a	ler			1	
0	0								
1	1								
L. Due also alata					•			-	
V Breakpoints 0	v paramete 0	er breakpoi	nts in ascen	ding or	ler				
1	1							-	
· · · ·		<u>i</u>							
Patch(0,0)	Х	Y	Z		(0 <= U <= 1)	, (0 <= V	<= 1)	1	
(0,0)	0	0	0		V^0 vector co				
(0,1)	1	0	0		VM vector co				
(1,0)	0	1	0		V^0 vector co				
(1,1)	0	0	0	UM,	VM vector co	pefficient			
]								

Dialog Box and Controls - Surface - Spline

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Spline
UV Degree	Polynomial degree	1,1

UV Breakpoints	Breakpoints	(0,1) (0,1)
Patch	Patch specifications	X(0,1)=Y(1,0)=1,all others zero
ОК	Accept Spline surface and close dialog box.	
Cancel	Discard Spline surface and close dialog box.	
АррІу	Create Spline surface and keep dialog box open.	
Неір	Access this Help page.	

Application Notes - Surface - Spline

1. The functional form of a spline is given by

$$\vec{P}(s,t) = \sum_{k=0}^{K} \sum_{l=0}^{L} \vec{C}_{kl} s^{l} t^{k}$$

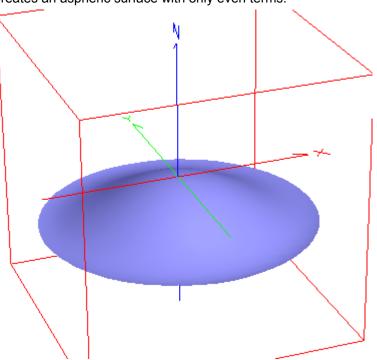
where the \textbf{C}_{ki} are for the (i,j) patch and s, t are determined by $\begin{array}{ll} Tu(i) \leq u < Tu(i+1), & i=0, \ldots M-1, & then & s=u-Tu(i) \\ Tv(j) \leq v < Tv(j+1), & j=0, \ldots N-1, & then & t=v-Tv(j) \\ U, V \mbox{ are related to } u, v \mbox{ by :} \end{array}$

$$U = \frac{u - Tu(0)}{Tu(M) - Tu(0)} \quad \text{and} \quad V = \frac{v - Tv(0)}{Tv(N) - Tv(0)}$$

2. The Spline is a sagable surface.

See Also - Surface - Spline

Description - Surface - Standard Asphere



Creates an aspheric surface with only even terms.



How Do I Get There? - Surface - Standard Asphere

Objects Dptical Sources Geometry Elem 1		
- 💷 Analysis Surface(s)	✓ <u>T</u> raceable	
	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	B Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report Detailed Report	
	Edit/View Lens Edit/View Mirror Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position</u> /Orientation	ı
	Edit/View Array Parameters Delete Array Parameters	
	Create New Surface	

🔆 (FRED:	1 *) Crea	te a New Surface as Child of: "Elem 1"	_ IX
Scatt SURF		Visualization Glue Grating Auxiliary Data Modifiers Aperture Location/Orientation Materials Coating/RayControl	OK Cancel
Logical Name:	1	Elem 1	Apply Help
Туре:		Traceable (this surface can be raytraced) Use for trimming only (never raytrace) d asphere (Conicoid plus even order radial polynomial terms)	
Bad	Value 0	Description	
Rad Conic		Radius (= 1/curvature) Conic constant (<-1=hyperbola, -1=parabola, <0=ellipse, 0=sphere)	
r^2		Coefficient of the r^2 polynomial term	

Dialog Box and Controls - Surface - Standard Asphere

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Standard Asphere
Rad	Radius of curvature.	0
Conic	Conic constant.	0
r^2. r^4, r^6	Even order aspheric terms	0

ОК	Accept Standard asphere surface and close dialog box.
Cancel	Discard Standard asphere surface and close dialog box.
Apply	Create Standard asphere surface and keep dialog box open.
Help	Access this Help page.

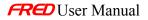
Application Notes - Surface - Standard Asphere

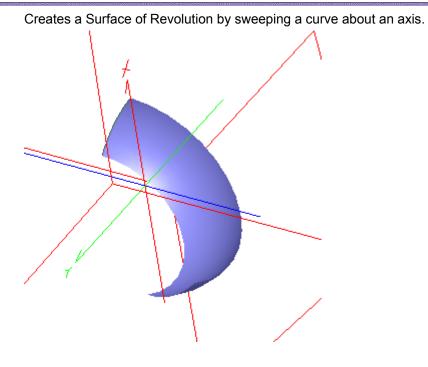
1. The function form of the Standard asphere is given by

$$f(\mathbf{r}, \mathbf{z}) = \mathbf{z} - \frac{\mathbf{c}\mathbf{v} \cdot \mathbf{r}^2}{1 + \sqrt{1 - (1 + \mathbf{conic}) \cdot (\mathbf{c}\mathbf{v} \cdot \mathbf{r})^2}} - \sum_{n=0} \mathbf{A}_n \cdot \mathbf{r}^{2n} = 0$$

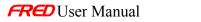
2. The Standard asphere is a sagable surface.

See Also.... - Surface - Standard Asphere





Description - Surface - Surface of Revolution



How Do I Get There? - Surface - Surface of Revolution

Objects Optical Sources Geometry Contended for the second seco		
- III Analysis Surface(s)	✓ Iraceable	
 ➡ Anaysis Surface(s) ➡ materials ➡ materials ➡ materials 	Never Traceable (for trimming surfaces)	
🕂 🔂 Scatterers	Draw Outer Enclosing Volume	
🕂 间 Raytrace Properties	Visualization Attributes	
	Position/Orientation Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	🖹 Copy 🔁 Paste	Ctrl+C Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report Detailed Report	
	Edit/View Lens Edit/View <u>M</u> irror Edit/View <u>P</u> rism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>M</u> aterial Position/Orientatio	n
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface Create New <u>C</u> urve	5

Scatter 1 SURFACE		Glue Gra ocation/Orientation	ting Auxiliary Data Modifiers Materials Coating/RayControl	OK Cancel
Logical Parent: .E	lem 1		•	Analu
Name: Si	urf 1			Apply
Description:				Help
Lupe: Curtada d	FRevolution fourwar	avaluad atound an	auia)	
Type: Surface o	f Revolution (curve r			
,	f Revolution (curve r Start Parameters		Description	
, Generatrix Curve			Description Curve that determines the shape of the surfa	
, Generatrix Curve Rotation Angles	Start Parameters	End Parameters	Description	
, Generatrix Curve Rotation Angles	Start Parameters ▼ 0	End Parameters 360	Description Curve that determines the shape of the surfa Starting and ending rotation angles (deg). Er	
, Generatrix Curve Rotation Angles X Coord	Start Parameters 0 0	End Parameters 360 0	Description Curve that determines the shape of the surfa Starting and ending rotation angles (deg). Er Rotation axis X coords for starting and endin	

Dialog Box and Controls - Surface - Surface of Revolution

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Surface of Revolution
Generatrix Curve	Specifies curve to sweep	blank
Rotation angle	Angle to sweep curve through.	0-360
Connection	XYZ start/End points of vector to sweep around.	X(0,0) Y(0,0) Z(0,1)

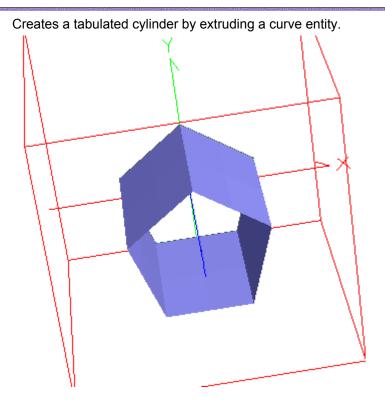
ОК	Accept Surface of Revolution surface and close dialog box.
Cancel	Discard Surface of Revolution surface and close dialog box.
Apply	Create Surface of Revolution surface and keep dialog box open.
Неір	Access this Help page.

Application Notes - Surface - Surface of Revolution

1. The Surface of Revolution is a sagable surface.

See Also - Surface - Surface of Revolution





Description - Surface - Tabulated Cylinder

How Do I Get There? - Surface - Tabulated Cylinder



Objects Dptical Sources Geometry Control Elem 1		
	Vever Traceable (for trimming surfaces)	
Escutings Scatterers End Raytrace Properties	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes	
	 Position/Orientation Parent Coordinate System Sc <u>a</u> le	
	 ✗ Cut I[™] Copy I[™] Paste Delete (all highlighted items) 	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Report Detailed Report	
	Edit/View Lens Edit/View Mirror Edit/View Prism	
	Convert to Custom Element Edit/View GRIN/Birefringent <u>Material Position/Orient</u>	ation
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface Create New <u>C</u> urve	₩



Scatter	Visualization Glue Grating Auxiliary Data Modifiers Aperture Location/Orientation Materials Coating/RayControl	OK Cancel
Logical Parent:	.Elem 1	
Name:	Surf 1	Apply
Description:		Help
o coonpaon.		
	Traceable (this surface can be raytraced)	
	ted Cylinder (straight line extruded curve)	
rype. <u>I rabula</u>		
	Parameters Description	
Directrix Curve	Curve that determines the shape of the surface	
X Direction	0 X extrusion length. The directrix is extruded along this vector.	
Y Direction	0 Y extrusion length. The directrix is extruded along this vector.	
Z Direction	1 Z extrusion length. The directrix is extruded along this vector.	

Dialog Box and Controls - Surface - Tabulated Cylinder

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Tabulated Cylinder
Directrix curve	Curve used for extrusion.	first existing curve
X/Y/Z Direction	Direction/length to extrude	X=0,Y=0,Z=3

ОК	Accept Tabulated Cylinder surface and close dialog box.	
Cancel	Discard Tabulated Cylinder surface and close dialog box.	
АррІу	Create Tabulated Cylinder surface and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Surface - Tabulated Cylinder

1. The Tabulated Cylinder is a "non-sagable" surface. Therefore, it cannot be used as a deforming surface.

See Also - Surface - Tabulated Cylinder



Creates a toroidal aspheric surface with only even order terms.

Description - Surface - Toroidal Asphere



How Do I Get There? - Surface - Toroidal Asphere

Objects Dptical Sources Geometry Elem 1		
- 🔛 Analysis Surface(s)	✓ <u>T</u> raceable	
	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	<u>V</u> isualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Ba Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation	n
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>C</u> urve	

Scatt SURF	er Visua FACE App Parent: Elem 1 Surf 1	lization erture Lo	S Child of: "Elem 1" Glue Grating Auxiliary Data Modifiers Docation/Orientation Materials Coating/RayControl	Cancel Apply Help
Туре:	Toroidal Asphe	re (Toroid, Pota	ce can be raytraced) Use for trimming only (never raytrace) ato chip, etc. with non-symmetric aspheric terms)	
De d	X Parameter	-	Description	
Rad	0	0	X/Y Radii (= 1/curvature)	
Conic Term		U Piecofficient	X/Y conic constants (<-1=hyperbola, -1=parabola, <0=ellipse, 0= Term = Ai*((1-Bi)*X*2 + (1+Bi)*Y*2)*i	
2			Coefficients (A2, B2)	
•				

Dialog Box and Controls - Surface - Toroidal Asphere

ne of Parent entity. ne of surface supplied by user. criptive text.	Custom Element Name Surf 1 blank
criptive text.	
•	blank
1 , 1	
ace can be raytraced.	Checked
er raytrace. Surface used for trimming	Unchecked
ace type.	Toroidal Asphere
Y radii of curvature.	0
Y Conic constants.	0
	0
	Y radii of curvature. Y Conic constants. Y aspheric term coefficients.

ОК	Accept Toroidal asphere surface and close dialog box.	
Cancel	Discard Toroidal asphere surface and close dialog box.	
АррІу	Create Toroidal asphere surface and keep dialog box open.	-
Неір	Access this Help page.	

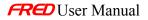
Application Notes - Surface - Toroidal Asphere

1. The function form of the Toroidal asphere is given by

$$f(x, y, z) = z - \frac{C_x \cdot x^2 + C_y \cdot y^2}{1 + \sqrt{1 - (1 + K_x) \cdot (C_x \cdot x)^2 - (1 + K_y) \cdot (C_y \cdot y)^2}} - \sum_i A_i ((1 - B_i) \cdot x^2 + (1 + B_i) \cdot y^2)^i$$

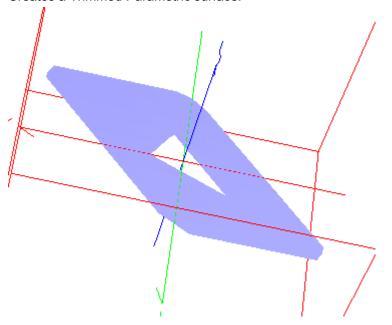
2. The Toroidal asphere is a sagable surface.

See Also - Surface - Toroidal Asphere



Create - New Surface - Trimmed Parametric

Description - Surface - Trimmed Parametric



Creates a Trimmed Parametric surface.



How Do I Get There? - Surface - Trimmed Parametric

Objects Optical Sources Geometry Comparison Compar		
- III Analysis Surface(s)	✓ <u>I</u> raceable	
	Never Traceable (for trimming surfaces)	
🕂 <u> I</u> Scatterers	Draw O <u>u</u> ter Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	<u>V</u> isualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation)
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>C</u> urve	

🚰 (FRED1 *) Creat	e a New Surface as Child of: "Elem 1"	
Scatter SURFACE Logical Parent: .E Name: S Description:	Visualization Glue Grating Auxiliary Data Modifiers Aperture Location/Orientation Materials Coating/RayControl Elem 1 urf 3 Traceable (this surface can be raytraced) Use for trimming only (never raytrace) Parametric (parametric surface with trimming curves)	OK Cancel Apply Help
Type: [Thinined	Surf/Curve Designation Description	
Surface	None The parametric surface	
Outer Boundary	None Closed outer boundary curve (may be "None")	
Inner Boundaries	List of closed inner boundary curves	
1	None	

Dialog Box and Controls - Surface - Trimmed Parametric

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Trimmed Parametric
Surface	Parametric surface to be trimmed.	None
Outer Boundary	Curve used to trim outer boundary.	None
Inner Boundary	Curve or curves used to trim inner boundary.	None

ОК	Accept Trimmed Parametric surface and close dialog box.	
Cancel	Discard Trimmed Parametric surface and close dialog box.	
Apply	Create Trimmed Parametric surface and keep dialog box open.	
Неір	Access this Help page.	

Application Notes - Surface - Trimmed Parametric

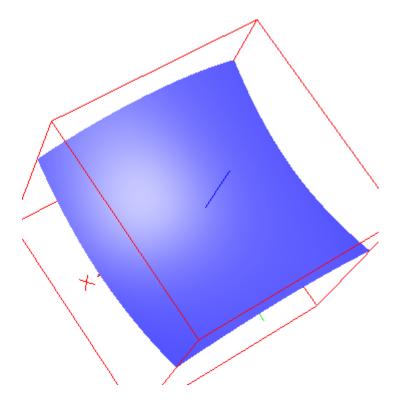
1. The Trimmed Parametric is a sagable surface.

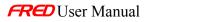
See Also.... - Surface - Trimmed Parametric



Description - Surface - XYToroidal Asphere

Creates an X or Y toroidal aspheric surface with both even and odd order terms.





How Do I Get There? - Surface - XYToroidal Asphere

Objects Dptical Sources Geometry Elem 1		
- 🛄 Analysis Surface(s)		
+ Coatings	Never Traceable (for trimming surfaces)	
+ 🚾 Scatterers	Draw O <u>u</u> ter Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	Visualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	В Сору	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation	ı
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>C</u> urve	

(FRED1 [*] Scatter SURFA		т. т	OK Cancel	
Logical P Name:	gical Parent: .Elem 1			
Type: Xtoroid O Y toroid O X or Y toroid selection				
X Rad Y Rad	0	X Radius (= 1/curvature) Y Radius (= 1/curvature)		
Y Conic Term	0 Y conic constant (<-1=hyperbola, -1=parabola, <0=ellipse			
0	0	Coefficient A0		

Dialog Box and Controls - Surface - XYToroidal Asphere

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	XYToroidal Asphere
Toroid Type	Choose an X- or Y-toroid.	Y toroid
X,Y Rad	X & Y radii of curvature.	0
X,Y Conic	X or Y Conic constants.	0
A _i coefficients	Aspheric term coefficients.	0

ОК	Accept Toroidal asphere surface and close dialog box.
Cancel	Discard Toroidal asphere surface and close dialog box.
Apply	Create Toroidal asphere surface and keep dialog box open.
Неір	Access this Help page.

Application Notes - Surfce - XYToroidal Asphere

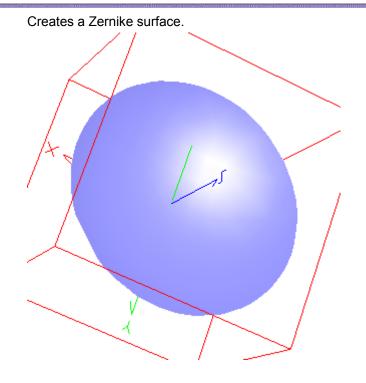
1. The function form of the XYToroidal asphere is given by

$$f(x, y, z) = z - \frac{(C_x \cdot (x^2 - G^2) + 2G)}{1 + \sqrt{1 - C_x (C_x (x^2 - G^2) + 2G)}}$$

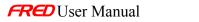
where
$$G = \frac{C_y \cdot y^2}{1 + \sqrt{1 - (1 + K_y) \cdot (C \cdot y)^2}} + \sum_i A_i \cdot y^i$$

2. The XYToroidal asphere is a sagable surface.

See Also.... - Surface - XYToroidal Asphere



Description - Surface - Zernike Surface



How Do I Get There? - Surface - Zernike Surface

Objects		
- 💷 Analysis Surface(s)	✓ <u>T</u> raceable	
🕂 💼 Materials	Never Traceable (for trimming surfaces)	
🕂 📻 Coatings 🕂 💀 Scatterers	Draw Outer Enclosing Volume	
🕂 直 Raytrace Properties	<u>C</u> oordinate Axes	
	<u>V</u> isualization Attributes	
	Position/Orientation	
	Parent Coordinate System	
	Scale	
	X Cut	Ctrl+X
	Copy	Ctrl+C
	🔁 Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Summary Report	
	Detailed Report	
	Edit/View Lens	
	Edit/View Mirror	
	Edit/View Prism	
	Convert to Custom Element	
	Edit/View GRIN/Birefringent Material Position/Orientation	ı
	Edit/View Array Parameters Delete Array Parameters	
	Create New <u>S</u> urface	
	Create New <u>⊂</u> urve	

(FRED1 *) Cre	ate a New Surfac	e as Child of: "Elem 1"		
Scatter	Visualization	Glue Grating Auxiliary Data Modifiers OK		
SURFACE	Aperture	Location/Drientation Materials Coating/RayControl		
		Cancel		
Logical Parent:	.Elem 1	▼ + +		
Name:	Surf 1			
_	,	Help		
Description:				
	J Tota a seconda de la contra	un (and a sector of the fact in size of the sector of the		
		surface can be raytraced) 🔲 Use for trimming only (never raytrace)		
Type: <mark> Zernik</mark> e	e Surface (Surface	e defined by Zernike polynomials		
	Value	Description		
Conic Base S	urface			
Rad	0	Radius (= 1/curvature)		
Conic	0	Conic constant (<-1=hyperbola, -1=parabola, <0=ellipse		
Aspheric Coe	fficients			
Asph 1	0	R^2		
Asph 2	0	R^4		
Asph 3	0	R^6		
Asph 4	0	R^8		
Asph 5	0	RM0		
Asph 6	0	RM2		
Asph 7	0	R^14		
Asph 8	0	R ^M 6		
• • • • •				
-	n of Zernike Coef			
Wavlen	0.5875618	ernike coefficients as being in units of wavelengths Wavelength (um) that zernike coefficients are in terms c		
vvavien	0.3073010			
Zernike Norn	nalization Apertur	re		
Semi-Ape X	1	Zernike normalization semi-aperture in X direction		
Semi-Ape Y	1	Zernike normalization semi-aperture in Y direction		
Zernike Coef	ficients			
Zern 0	0	1		
Zern 1	0	R cos(A)		
Zern 2	0	R sin(A)		
Zern 3	0	R^2 cos(2A)		
Zern 4	0	2R*2-1		
- , -	1.0			

Dialog Box and Controls - Surface - Zernike Surface

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Logical Parent	Name of Parent entity.	Custom Element Name
Name	Name of surface supplied by user.	Surf 1
Description	Descriptive text.	blank
Traceable	Surface can be raytraced.	Checked
Use for trimming only	Never raytrace. Surface used for trimming only.	Unchecked
Туре	Surface type.	Zernike Surface
	Conic Base Surface	
Rad	Radius of curvature for base surface.	0
Conic	Base surface conic constant.	0
	Aspheric Coefficients	
Asph n	Even order aspheric coefficients.	0
	Interpretation of Zernike Coefficients	
Coeffs in Wavelen	Interpret the Zernike coefficients in waves. If unchecked, use system units.	Unchecked
Wavelen	Wavelength for coefficient interpretation.	0.5875618
	Zernike Normalization Aperture	
SemiApe X/Y	Normalization Aperture (Standard Zernike coefficients are normalized to a unit semi-aperture).	1,1
	Zernike Coefficients	
Zern n	Coefficient values in waves or system units.	0
ОК	Accept Zernike Surface surface and close dialog box.	
Cancel	Discard Zernike Surface surface and close dialog box.	
АррІу	Create Zernike Surface surface and keep dialog box open.	
Неір	Access this Help page.	

1. The Zernike Surface is a sagable surface.

See Also - Surface - Zernike Surface

Create - New Curve - Introduction to Curves

FRED has a number of curve-based surface types: the **Tabulated Cylinder**, the Ruled Surface, and the **Surface of Revolution**. These surfaces allow for a great deal of flexibility to generate complicated surface geometries, but have some simple rules and limitations that do not apply to more conventional surface functions.

First among these is that a curved-based surface cannot be used to trim another surface. This is because the surfaces are generated as parametric functions, and, as such, do not have an easily identifiable positive and negative side. In other words, the +Z direction of the local surface normal, which is used to establish rules for trimming, is ambiguous. However, these surfaces are bounded and can be trimmed by function-based surface types.

Second, at least some portion of the generating curve must be located inside the bounding volume of the surface. Only that portion of the curve inside the bounding volume will be created. Putting both the curve and the surface in the same coordinate system most easily satisfies this requirement.

Curves may be used to create surfaces, not volumes. For example, a rod lens that uses a surface of revolution to create the cylinder must also include separate surfaces for each end to close the volume. Failure to do so may result in ray failures because FRED may propagate a ray that sees a change in the refractive index as it exits the volume occupied by the cylinder without intersecting a surface. Without a surface intersection, FRED cannot refract the ray.

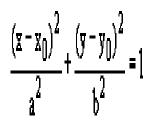
Types of Curves - Introduction to Curves

FRED has number of simple curve types. In general, each curve is defined parametrically over an interval from [0,1]. The starting point is always at u = 0. Likewise, the ending point is at u = 1. Curves alone are not traceable.

A brief description of each curve type follows.

<u>Line segment</u> - This is the simplest curve type. It is defined as the line connecting the point $(x, y, z)_{start}$ with the point $(x, y, z)_{end}$.

<u>Circular arc</u> – As the name implies, this is a simple circular arc. By default, it is defined in the local XY plane. It is centered at (x_0, y_0) and has a radius *r*. The start and end points for the arc are given by the start angle and the sweep angle, respectively. These are polar angles are measured in degrees, counter-clockwise from the X-axis (= 0). Both the start and sweep angles can be between 0 and 360 degrees.



<u>Conic arc</u> – The conic arc is a more general form of the circular arc. It is used primarily for IGES[™] import. It is defined by the equation



The function f(x,y) is a second-degree curve if both A and C are not 0. The curve is a parabola if the product AC = 0. The curve is an ellipse if the product AC > 0. It is a circle if A=C. The curve is a hyperbola if the product AC < 0. The B coefficient represents a rotation of the coordinate axes. If B = 0, the curves are not rotated about the local x- and y-axes. The D and E coefficients represent coordinate shifts.

User inputs include the desired coefficients and the range of values over which the curve is defined: x_{start} , y_{start} and x_{end} , y_{end} . These points do not have to lie on the curve. Rather they define the polar angle subtended by the curve, analogous to the convention used for the circular arc. The starting angle is simply

$$-2A \cdot x_0$$

Likewise, the ending angle is

$$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$$

Parabola

A parabola in y has the form $Ey = Ax^2 + Bxy + Dx + F$. For any such parabola, the coefficients A and E cannot be zero and the C coefficient must be zero. The B and D coefficients rotate and shift the curve, respectively. The coefficient F is a constant offset that moves the curve up and down along the y-axis.

Ellipse

An ellipse centered at the point (x_0, y_0) has the form

$$a = \frac{r}{1+k}$$

where a and b are the semi-major and semi-minor axis lengths, respectively. The coefficient values A..F can be found by equating the two forms. To create an ellipse in which both *a* and *b* are known and is not rotated in the XY-plane, the conversion to the curve coefficients is found in Table 1.

Curve Coefficient	Value
А	$\frac{D^2}{4} \frac{e^i}{4c} - 1$
В	0
С	$\frac{1}{b^2}$
D	-2A·x0
E	-2С·у0
F	$\frac{D^2}{4A} + \frac{E^2}{4C} - 1$

Table 1 Coefficient Conversion for an Ellipse

If the conic constant k and the radius of curvature r are known, then a and b can be computed using the following relationships $(-1 < k \le 0)$.

$$a = \frac{r}{1+k}$$
$$b = a \cdot \sqrt{1+k}$$

Hyperbola

A hyperbola centered at the point (x_0, y_0) has the form

$$\frac{(x-x_0)^2}{a^2} - \frac{(y-y_0)^2}{b^2} = 1$$

which describes a curve that intersects the x-axis (A > 0, C < 0). If the signs are reversed (A < 0, C > 0) the curve intersects the y-axis. The terms *a* and *b* do not have the same geometric significance for a hyperbola as they do for an ellipse and are not used except to calculate the asymptotes of the curve

$$\mathbf{y} - \mathbf{y}_0 = \pm \frac{\mathbf{a}}{\mathbf{b}} (\mathbf{x} - \mathbf{x}_0)$$

When A > 0 both x_{start} and x_{end} should be greater than zero. Further, y_{start} and y_{end} should be chosen so that the start and ending angles are between the asymptote lines. When A < 0, choose y_{start} and y_{end} greater than zero and x_{start} and x_{end} to be between the asymptote lines. Following these rules will help avoid unexpected results arising from creating multiple branches of the curve.

The curve coefficients for the hyperbola are analogous to those of the ellipse except A and C have opposite signs. Table 2 shows a similar coefficient conversion based on knowledge of *a* and *b*.

Curve Coefficient	Value
А	$\frac{1}{a^2}$
В	C
С	$\frac{1}{b^2}$
D	-2A·x ₀
E	-2C y ₀
F	$\frac{D^2}{4A} - \frac{E^2}{4C} - 1$

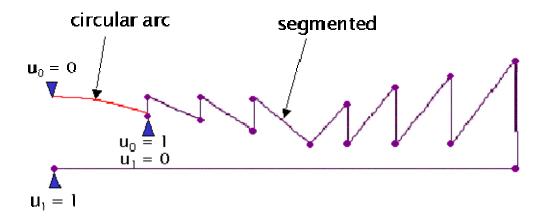
 Table 2 Coefficient Conversion for a Hyperbola (A>0)

<u>Segmented</u> - A segmented curve is simply a collection of points in (x, y, z) connected by straight lines. It is not necessary for the curve to be closed and FRED will not automatically close the surface. To close the surface, simply enter the same coordinates for the last point as were entered for the first. A right mouse click in the active cell area in the dialogue box allows for row addition or deletion.

<u>Composite Curve</u> – A composite curve is two or more curves joined in the following fashion,

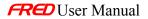
start end, start end, .., start end

The start point ($u_k = 0$) of each subsequent curve is coincident with the end point ($u_{k-1} = 1$) of the previous curve. When 2 or more curves are joined, the parameterization is renormalized so that the curve starts at $u_{composite} = 0$ and ends at $u_{composite} = 1$. The curves do not need to be the same type. Multiple composite curves can be joined as well. The following figure shows a circular arc joined with a series of line segments.



If the segments are not properly positioned, FRED issues an error message. A common error is to have the parameterization reversed so that FRED is trying to connect the start point of one curve to the start point of a different curve, which is an invalid operation. It is often useful (but not required) to define the curves in that same coordinate system. The composite curve should also be located in the proper coordinate system as well. After creating the composite curve, it is recommended that each component curve be placed in the coordinate system of the composite. This way, the composite curve can be repositioned anywhere in the system and the component curves will automatically follow.

Any curve used to create the composite can be edited. Changes are reflected automatically. The rules governing the endpoint connections must still be obeyed. If a composite curve is copied, FRED automatically creates a duplicate set of the generating curves.



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Other curve types

FRED also has a number of special curve types that are used primarily to import IGES[™] files and lenses from CODE V[™], OSLO[™], and ZEMAX[™]. These surface types are: *NURB* (Non-Uniform Rational B-spline), *Spline* (polynomial segments), and *Aperture Curve Collection*. FRED automatically creates the fit coefficients for the NURB and Spline curves during a CAD system import. The user is not required to enter points manually. The Aperture Collection Curve is used to create complex or segmented apertures on a single surface (instead of creating multiple copies of the same surface). These curves must be closed and are used only to establish trimming boundaries in the aperture settings for the surface. Aperture curves will be created automatically during a lens file import. The user can also create and apply them manually.

Create - New Analysis Surface

Description How Do I Get There? Dialog Box and Controls

Description New Analysis Surface

This command displays a dialog that allows you to create a new Analysis Surface in the FRED optical system.

How Do I Get There? New Analysis Surface

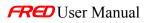
There are four ways to access this command:

On the Create Toolbar, click this button:



2. On the Create Menu, click "New Analysis Surface..."

<u>Create</u> <u>Analyses</u> <u>W</u> indow <u>H</u>	<u>t</u> elp				
록INew <u>D</u> etailed Source	Ctrl+Alt+D				
New Lens	Ctrl+Alt+L				
New Mirror	Ctrl+Alt+M				
New Prism	Ctrl+Alt+P				
🗗 New Subassembly	Ctrl+Alt+S				
P New Custom <u>E</u> lement	Ctrl+Alt+E				
🖋 New Sur <u>f</u> ace	Ctrl+Alt+F				
C New Cur <u>v</u> e	Ctrl+Alt+V				
₩ New A <u>n</u> alysis Surface	Ctrl+Alt+N				
🗇 New Ma <u>t</u> erial	Ctrl+Alt+T				
🗢 New <u>C</u> oating	Ctrl+Alt+C				
😕 New Sc <u>a</u> tter Model	Ctrl+Alt+A				
22 New <u>R</u> aytrace Control	Ctrl+Alt+R				



3. On the Analysis Surfaces folder in the Tree View, right-click and choose "New Analysis Surface..."

Objects	Description	
Geometry	monochromatic collim, poly chromatic	
+ 💷 Analysis Surface(s)	Iraceable	
🕂 💼 Materials 🕂 📄 Coatings	Never Traceable (for trimming sur	faces)
🕂 🐱 Scatterers	Draw Outer Enclosing Volume	
🕂 间 Raytrace Properties	<u>C</u> oordinate Axes	
	⊻isualization Attributes	
	Position/Orientation	
	Sc <u>a</u> le	
	X Cut	Ctrl+X
	暗 Copy	Ctrl+C
	R Paste	Ctrl+V
	Delete (all highlighted items)	Del
	Su <u>m</u> mary Report	
	Detailed Report	
	New Analysis Surface	
	Edit Analysis Surface	NS .
	Attach Analysis Surface	
	Remove Analysis Surface Plot	

4. Use they keyboard shortcut Ctrl+Alt+N.

Dialog Box and Controls New Analysis Surface

(FRED 1	l *) Analys	is Surface							? _ 🗆
ame:	4								(OK
nalysis									Cancel
escriptio	on:							_	Apply
A									Help
Analysis Min X [-0.5		lax 5	Divi: 21	sions	Scale	Factor: 1			✔ Draw Grid Lines ▼
Y -0.5	0.	.5	21	-	Min/M	tax vals: 🖟	At edge of		
🔽 Aut	osize to Data	Force	: 1:1 A	spect R	latio	- Interpr	et Min/Ma	ax as Ai	ngles (degrees
	ing Area (for								
Min	<u> </u>	lax		sions					🔽 Draw
X [-1	1		2	-					Grid Lines 💌
Y Ӣ	1		2	÷					-
Locatio	n								
	Referenc	e Coordin	ate	Action		Paramet	ers (righ	t mou	se-click for
1	Starting Co Global coo	oordinate Sy ordinate sys	/stem tem						
┓]						▶
Ray Sel	lection								
Num	Operation	Description	٦						
1	AND	All rays							
•	 								F
			_						

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Enter the name of the plane here	Analysis <i>n</i>
Description	Enter a description here that is shown in <u>Tree View</u>	Blank
	Analysis Area	
Autosize to Data	Use ray data to autosize window.	Checked
X, Y Min	Minimum X,Y coordinates of window.	-0.5, -0.5

	Maximum X,Y	
X, Y Max	coordinates of window.	0.5, 0.5
X, Y Divisions	Number of window divisions.	21, 21
Scale Factor	Scale window size.	1
Force 1:1 Aspect Ratio	Force isotropic window.	Checked
Interpret Min/Max as Angles (deg)	For use with directional analysis.	Unchecked
Draw	Draw window in 3D View.	Checked
Draw as	Window display method: <i>Filled Grid</i> <i>Grid Lines</i> <i>Grid Points</i>	Grid Lines
Drawing Color	Grid color	Copper
	Rendering Area	
X, Y Min	Minimum X,Y coordinates of render area.	-1, -1
X, Y Max	Maximum X,Y coordinates of render area.	1, 1
X, Y Divisions	Number of divisions in render area.	2, 2
Draw	Draw render area in 3D View.	Checked
Draw as	Render display method: <i>Filled Grid</i> <i>Grid Lines</i> <i>Grid Points</i>	Grid Lines
Drawing Color	Rendering color	Gray
	Location	
Table	Shows a list of the <u>Location</u> <u>Modifiers</u> that define the location and orientation of the plane in the	Global Coordinate System



	· · · · · · · · · · · · · · · · · · ·					
	system					
	Ray Selection					
Table	Rays included for analysis.	AND, All rays				
ОК	Create a new Analysis Plane and close dialog box.					
Cancel	Discard the Analysis Plane and close dialog box.					
Арріу	Create/Apply changes to Analysis Plane and keep dialog box open.					
Неір	Access this Help page.					

Create - New Material

Description How Do I Get There? Dialog Box and Controls

Description New Material

This command displays a dialog that allows you to create a new material in the FRED optical system.

How Do I Get There? New Material

There are four ways to access this command:

1. On the Create Toolbar, click this button:



2. On the Create Menu, click "New Material..."

<u>Create</u> <u>A</u> nalyses <u>W</u> indow <u>H</u> elp	р
式 New Simplified Source	Ctrl+Alt+I
➡ 💐 New <u>D</u> etailed Source	Ctrl+Alt+D
New Lens	Ctrl+Alt+L
New Mirror	Ctrl+Alt+M
New Prism	Ctrl+Alt+P
P New Subassembly	Ctrl+Alt+S
P New Custom Element	Ctrl+Alt+E
New Surface	Ctrl+Alt+F
C New Cur <u>v</u> e	Ctrl+Alt+V
₩ New Analysis Surface	Ctrl+Alt+N
🗇 New Ma <u>t</u> erial	Ctrl+Alt+T
🗢 New <u>C</u> oating 🌇	Ctrl+Alt+C
😕 New Sc <u>a</u> tter Model	Ctrl+Alt+A
55 New <u>R</u> aytrace Control	Ctrl+Alt+R



3. On the Materials folder in the Tree View, right-click and choose "Create a New Material..."

Objects		Description	
⊕			
Analysis Surf Materials Coatings Scatterers	Iraceable		.
🕂 💀 Scatterers	Never Tracea	ble (for trimming surfac	tes)
	Draw Outer Enclosing Volume Coordinate Axes Visualization Attributes		
	<u>P</u> osition/Orier Parent Coord Sc <u>a</u> le,	ntation inate System	
	X Cut		Ctrl+X
	🖹 Copy 🕞 Paste		Ctrl+C Ctrl+V
		hlighted items)	Del
-	Su <u>m</u> mary Rep <u>D</u> etailed Repo		
	Create a New Edit/View Mat Add Glass Ca		

4. Use they keyboard shortcut Ctrl+Alt+T.

Dialog Box and Controls

New Material

			avelengths)	OK OK Cancel Apply Help
0	Wavelength (um) 0.5875618	Refractive Index	Imaginary Refractive Inde 0	
	10.3013010			
Commo	on Gradient Index Material F	arameters and Other Param	eters-	
Step 9 0.1	Size Max # Steps	X Offset Y C	Offset Z Offset	

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name:	Displays the name of the new material	Material <i>n</i>
Description:	Displays the description of the new material	Empty String
Туре:	Displays the type of new material. Options are: Sampled Material (refraction indices for discrete wave Model Material (Refraction Index and Abbe number)	Sampled Material
Parameters	Displays the data necessary to define the material type	Varies
ОК	Create a new material and close dialog box.	
Cancel	Discard new material and close dialog box.	
Help	Access this Help page.	

Create - New Coating

Description How Do I Get There? Dialog Box and Controls

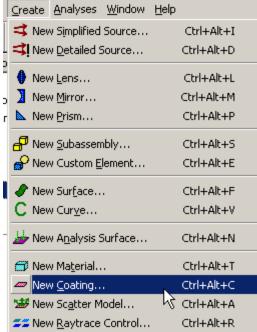
Description New Coating

This command displays a dialog that allows you to create a new coating in the FRED optical system.

How Do I Get There? New Coating

There are four ways to access this command:

- 1. On the Create Toolbar, click this button:
- 2. On the Create Menu, click "New <u>C</u>oating..."



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3. On the Coatings folder in the Tree View, right-click and choose "Create a New Coating..."

Objects		Description	
← ← Geometry ← ← ← Analysis S ← ← ← ← Materials	nated beam collimated beam	monochromatic collim- poly chromatic	
 		le (for trimming surfaces	;)
	Draw Outer En Coordinate Axe Visualization At	35	
	Position/Orient Parent Coordin Sc <u>a</u> le		
	X Cut Copy Paste Delete (all high	lighted items)	Ctrl+X Ctrl+C Ctrl+V Del
	Su <u>m</u> mary Repo Detailed Report		
•	Create a New (Edit/View Coati		
×	Plot		

4. Use they keyboard shortcut Ctrl+Alt+C.

Dialog Box and Controls New Coating

候 Coati	ng							? ×
Name: Coating 1							OK.	
Description:						Cance	el 🛛	
Type: Sampled Coati		iating (reflection/transmiss	sion for discrete wavele	ngths) 💌	Help		
	Wave	length (um	,		Coefficient		ansmissio	n Cc
1	0.5892	2938	• 0	Power	Phase (deg)	0	wer	0
	_		<u>-</u> -		1	. <u>.</u>		<u>.</u>
•								▶

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Name:	The name of the new coating	Coating n				
Description:	The description of the new coating	Empty String				
Туре:	Type of coating to be created. Can be one of the following: Sampled Coating (reflection/transmission for discrete wavelengths)Type:Uncoated (bare surface with no coating) Thin Film Layered Coating General Sampled Coating (table of reflection/transmission coefficients) Polarizer/Waveplate Coating (Jones matrix)					
Parameters	Parameters Lists the parameters needed for the different types of coating available.					
OK	Create a new coating and close dialog box.					
Cancel	Discard coating and close dialog box.					
Help	Access this Help page.					

Create - New Scatter Model

Description How Do I Get There? Dialog Box and Controls See Also...

Description New Scatter Model

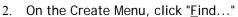
This command displays a dialog that allows you to create a new scatter model in the FRED optical system.

*

How Do I Get There? New Scatter Model

There are four ways to access this command:

1. On the Create Toolbar, click this button:



<u>Create</u> <u>A</u> nalyses <u>W</u> indow <u>H</u> elj	P
< New Simplified Source	Ctrl+Alt+I
. ≰! New <u>D</u> etailed Source	Ctrl+Alt+D
🚯 New Lens	Ctrl+Alt+L
New Mirror	Ctrl+Alt+M
New Prism	Ctrl+Alt+P
P New Subassembly	Ctrl+Alt+S
P New Custom Element	Ctrl+Alt+E
New Surface	Ctrl+Alt+F
C New Cur <u>v</u> e,	⊂trl+Alt+V
₩ New A <u>n</u> alysis Surface	Ctrl+Alt+N
🗇 New Material	Ctrl+Alt+T
🗢 New <u>C</u> oating	Ctrl+Alt+C
😕 New Sc <u>a</u> tter Model	Ctrl+Alt+A
ジェ New <u>R</u> aytrace Control ^K で	Ctrl+Alt+R



3. On the Scatterers folder in the Tree View, right-click and choose "Create a New Scatterer..."

ОЪје	ects				Description	
		Optical Sources Geometry Analysis Surface(s) Materials Coatings				
+). +).	<u>.</u>	Scatterers Raytrace Properties		Trace		
				Draw <u>C</u> oorc	 Traceable (for trimming Outer Enclosing Volume linate Axes ization Attributes 	(surraces)
					on/Orientation t Coordinate S <u>v</u> stem	
			Pa R	Cut Copy Paste Delete	e (all highlighted items)	Ctrl+X Ctrl+C Ctrl+V Del
					ary Report ed Report	
					e a New Scatterer iew Scatterer	- √-
					D (Angle) D (Beta - Beta0) D	

4. Use they keyboard shortcut Ctrl+Alt+A.

Dialog Box and Controls New Scatter Model

🕻 Scatt	er		<u>? ×</u>
Name:	Scat	ter 1	OK
Description:			Cancel
Type: Lambertian (equal scatter in all directions)		✓ Help	
	Value	Description	
Refl	0.04	Reflectivity (0>1) 0=black absorbing, 1=white reflect	ing

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Name	Name of scatter type.	Scatter n
Description	Description of scatter type.	blank
Туре	Type of scatter model to be created. Options are: Lambertian (equal scatter in all directions) Harvey-Shack (polished surface scatter) ABg scatter (polished surface scatter) Phong scatter (Cos ⁿ from specular) Flat Black Paint Surface Particle (Mie) Scatter Diffuse Polynomial	Lambertian
Parameter Field	Displays parameters of selected scatter model.	Varies
	Additional data	
Apply on Reflection	When checked, applies the scatter properties when a ray is reflected.	Checked
Apply on Transmission	When checked, applies the scatter properties when a ray is transmitted.	Unchecked
Halt Incident Ray	When checked, will generate an incident ray in the ray buffer but will not trace it.	Checked
ОК	Create or modify a scatter model and close dialog box.	

CONSIGNATION OF CONSIGNATION OF CONSIGNATION OF CONSIGNATION OF CONSIGNATION OF CONSIGNATION OF CONSIGNATION OF

Cancel	Discard scatter model or modifications and close dialog box.	
Help	Access this Help page.	

See Also.... New Scatter Model

General Information on Scatter Models

Create - New Raytrace Control

Description How Do I Get There? Dialog Box and Controls

Description New Raytrace Control

This command displays a dialog that allows you to create a new Raytrace Control in the FRED optical model.

How Do I Get There? New Raytrace Control

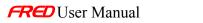
There are four ways to access this command:

1. On the Create Toolbar, click this button:



2. On the Create Menu, click "New <u>Raytrace Control...</u>"

<u>Create</u> <u>Analyses</u> <u>W</u> indow	<u>H</u> elp
< New Simplified Source	Ctrl+Alt+I
록! New <u>D</u> etailed Source	Ctrl+Alt+D
New Lens	Ctrl+Alt+L
New Mirror	Ctrl+Alt+M
New Prism	Ctrl+Alt+P
🗗 New Subassembly	Ctrl+Alt+S
P New Custom Element	Ctrl+Alt+E
New Surface	Ctrl+Alt+F
C New Cur <u>v</u> e	Ctrl+Alt+V
₩ New A <u>n</u> alysis Surface	Ctrl+Alt+N
🗇 New Ma <u>t</u> erial	Ctrl+Alt+T
🗢 New <u>C</u> oating	Ctrl+Alt+C
🐸 New Sc <u>a</u> tter Model	Ctrl+Alt+A
55 New <u>R</u> aytrace Control	Ctrl+Alt+R



3. On the Raytrace Properties folder in the Tree View, right-click and choose "Create a New Raytrace Control Set..."

Objects			Description	
	ptical Sources eometry nalysis Surface(s) aterials oatings catterers			
庄 💼 R	aytrace Properties	∐race	eable	
	ĺ	Neve	r Traceable (for trimmin	g surfaces)
	-	⊆oor) Oyter Enclosing Volume dinate Axes lization Attributes	;
			ion/Orientation nt Coordinate S <u>v</u> stem 	
		X Cut		Ctrl+X
		🖹 Copy		Ctrl+C Ctrl+V
			e (all highlighted items)	Del
			nary Report iled Report	
			te a New Raytrace Cont a Raytrace Control Set	24

4. Use they keyboard shortcut CtrI+Alt+R.



Dialog Box and Controls New Raytrace Control

🕻 (FRED1) Create a New Raytrace Control Set	<u>? ×</u>
Name	
Raytrace Control 1	OK
Description	Close
	Apply
	Help
Specular Ray Power Cutoff Thresholds	Intersection Count Cutoff
Absolute power Relative power Reflected Ray: 1e-014 1e-009	Total: 1000
Transmitted Ray: 1e-014 1e-009	Consecutive: 100 🛨
Scatter Ray Power Cutoff Thresholds	Ancestry Level Cutoff
Absolute power Relative power Reflected Ray: 0 0	Specular: 2 -
Transmitted Ray: 0	Scatter: 1 🛨
Allowed Specular Operations Allow reflected ray Allow transmitted ray Allow Total Internal Refl	Parent Ray Specifier Cargest incoherent power Transmitted Reflected Monte-Carlo (1 ray only)

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>				
Name	The name of the Raytrace Control	Raytrace Control n				
Description	The description of the Raytrace Control	blank				
	Specular Ray Power Cutoff Threshold					
Reflected Ray- Abs/Rel Power	Controls specular reflected ray cutoff.	1e-014, 1e-009				
Transmitted Ray- Abs/Rel Power	Controls specular transmitted ray cutoff.	1e-014, 1e-009				
	Scattered Ray Power Cutoff Threshold					
Reflected Ray- Abs/Rel Power	Controls scattered reflected ray cutoff.	0, 0				

Transmitted Ray- Abs/Rel Power	Controls scattered transmitted ray cutoff.	0, 0
	Intersection Count Cutoff	
Total	Total number of allowed ray intersections.	1000
Consecutive	Number of consecutive ray intersections with single object.	100
	Ancestry Level Cutoff	
Specular	Number of specular splits.	2
Scatter	Number of times a parent ray can scatter.	1
	Allowed Specular Operations	
Reflected ray	Allow reflection.	Checked
Transmitted ray	Allow transmission.	Checked
Total Internal Reflection	Allow TIR.	Checked
	Allowed Scatter Operations	
Reflected ray	Allow scatter in reflection.	Checked
Transmitted ray	Allow scatter in transmission.	Checked
	Parent Ray Specifier	
Largest incoherent power	Largest power direction determines parent.	Selected
Transmitted	Transmitted ray is parent.	Not selected
Reflected	Reflected ray is parent.	Not selected
Monte- Carlo (1 ray only)	Statistically chooses the transmitted, reflected or scattered ray	Not selected
ОК	Create a raytrace control or apply changes and close dialog box.	
Close	Discard a raytrace control or applied changes and close dialog box.	
Apply	Apply raytrace control changes and keep dialog box open.	
Help	Access this Help page.	

Analyses - Ray Status

Description How Do I Get There? Application Notes Examples See Also...

Description

Ray Status

The Ray Status command outputs the status of all the rays in the system in the <u>Output</u> <u>Window</u>. The Ray Status output is very useful for diagnosing a FRED document with errors.

	A	B	C	D	E	F	G	H
88	RAY STAT	US SUMMARY:				(houghton	n.frd)	
89								
90	97	total rays	s created					
91	97	active (t				1	1	
92	8		(not trace	able)				
93	8	polarized	1					
94	97	coherent						
95	8	scatter	9	1			1	
96	88	stopped by	y the surf	ace's rayt	race cont	rol specifi	ication	
97	0	fell belo	w absolute	transmitt	ed power	threshold	2	
98	8	fell belo	w absolute	reflected	power th	reshold	1	
99	8			transmitt				
100	8			reflected				
101	0	could not	resolve m	aterial am	biguity			
102	8	could not	resolve t	ransmitted	glue mat	erial ambig	quity	
103	6	could not	resolve r	eflected g	lue mater	ial ambigui	ity	
104	8	exceeded 1	total inte	rsection c	ount		1	
105	8	exceeded (consecutiv	e intersec	tion coun	t	(
106	8	exceeded s	specular a	ncestry th	reshold			
107	6	exceeded s	scatter an	cestry thr	eshold			
108	6	had coher	ent second	ary ray er	rors			
109	8	are evanes	scent					
110	6	are halte	d because	total inte	rnal refl	ection not	allowed	
111	6		a bad posi				1	
112	8	acquired a	a bad dire	ction				
113	S 6	exceeded a	allowed nu	nber of st	eps in an	inhonogen	uous materia	1
114								
115	S.							

How Do I Get There? Ray Status

There are three different ways to execute this command:

1. Select Ray Status in the Analysis Menu

ace <u>3</u> D View <u>C</u> reate <u>Analyses</u> <u>W</u> indow <u>H</u> elp	
s 🚭 💦 🖓 🎼 🕌 🏪 Ray St <u>a</u> tus	Shift+F10
🖂 📈 😽 Ray Summary	Shift+F11
12: Ray Statistics	Shift+F12
Derevial (nelucic (first order)	SHIFF-F3

D Derevial (polycic (first order)

2. Press the keyboard accelerator keys: Shift+F10

Ξ

3. Press the toolbar button:

Application Notes Ray Status

None.

See Also Ray Status

> **Ray Statistics Ray Summary**

Analyses - Ray Summary

Description How Do I Get There? **Application Notes** Examples See Also...

Description Ray Summary

The Ray Summary command produces a count of the rays and their total incoherent power for all the rays associated with traceable objects (sources and surfaces marked Traceable) in the FRED document. Rays associated with untraceable objects are omitted from the Ray Summary. The ray's associated surface is named using the hierarchy naming convention.

The data stored with a ray includes its present location, power, direction, and associated surface or source. A ray is associated with the last surface that it intersected. If a ray has not been traced or it did not intersect a surface, then it is associated with the source that defined the ray. Unless the ray position is otherwise altered after a ray trace, the ray's location will be at the intersection it made last surface it intersected or on the ray's source if it did not intersect a surface or was not traced.

The Ray Summary is printed in the output window.



	A	B	C	D	E	F	G	H
123								
124	SUMMARY	OF RAY LOCA	TIONS:			(houghton)	.frd)	
125								
126	10	Total						
127	Ray	Incoheren						
128	Count	Power	1	Nane				
129		and the state of t						
130	36	0.185567	1	.Houghton d	orrecto	r.lens 1.Su	face 1	
131	352	1.814428		.image.imag	le			
132			K.	1	C1010101000010101010101		5	
133	388	1.999995	10	TOTALS				
134				1				

An example of the Ray Summary.

How Do I Get There? Ray Summary

There are four different ways to execute this command:

1. Select Ray Summary in the Analysis Menu

<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
:≣ Ray St <u>a</u> tus	Shift+F10
😽 Ray Summary	Shift+F11
12 Ray Statistics √	Shift+F12
Paraxial Analysis (first order)	Shift+F3

- 2. Press the keyboard accelerator keys: Shift+F11
- 3. Press the toolbar button:

Application Notes Ray Summary

None.

See Also.... Ray Summary

> Ray Statistics Ray Status

Analyses - Ray Statistics

Description How Do I Get There?

—

Description Ray Statistics

The Ray Statistics command outputs the statistical average, standard deviation, minimum, and maximum of the position and direction coordinates in relation to the global coordinate system for rays associated with <u>traceable</u> objects in the FRED document. The output is printed in the <u>output window</u>.

	A	Barris	C	Deser	E	F	Chiefe Group	alara 🛛 daras	1	States J (Secol	1000	CONCLUSION	1000
72	18										(
73 74	RAY STATI	STICS:				(houghton.	.frd)						
74		-			1								
75	1	X AUG	Y AUG	Z AUG	X STD	Y STD	Z STD	X HIN	X HBX	Y HIN	Y MAX	ZMIN	Z MAX
76													
77	.Houghton	corrector.	lens 1.Su	face 1		Tot Pur=	8.892783		Aug Per=	0.010309		Ray Cnt=	9
78 79 88	Pos	8.41e-17	7.478-17	-0.002228	8.558117	8.558117	8.881117	-0.684036	0.684036	-8.684836	8.684836	-8.883346	8
79	Dir	-1.63e-17	-1.86e-17	-0.993377	0.081207	0.081207	8.883311	-0.099531	8.899531	-8.899531	8.099531	-1	-8.998865
88													
81	.image.im	age				Tot Pwr-	8.987216		Avg Pwr-	0.010309		Ray Cnt-	88
82	Pos	-1.84e-16	28.7	16.12386	8.888724	8	9.000724	-8.001291	8.881291	20.7	28.7	16.12257	16.12515
83	Dir	-2.15e-17	8.998129	-2.285e-5	0.043222	8.000875	0.043222	-0.074390	8.874398	8.996882	8.999551	-8.074413	8.874367
84	8					{							
85	Tot Pur-	1			Tot Rays-	97 N							
86						15							
4	a consideration of the					100 C 100							

The Ray Statistics for Houghton example are shown.

Note that the minimum and maximum position values for the X, Y, and Z axes define a box around all the rays associated with a given FRED traceable object.

This command is essentially an expanded version of <u>Ray Summary</u>, since it also prints out the ray count and total power.

How Do I Get There? Ray Statistics

There are three different ways to execute this command:

1. Select Ray Statistics in the Analysis Menu

_

<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
🔚 Ray St <u>a</u> tus	Shift+F10
😽 Ray Summary	Shift+F11
12 Ray Statistics	Shift+F12
P Para <u>x</u> ial Analysis (first order)	Shift+F3
🛚 🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S
Sest Geometric Focus	Shift+F9
= Eiber Coupling Efficiency	Ctrl+Shift+F
🐙 Stray Light <u>R</u> eport	
Generate IES Output	
Positions Spot Diagram	Ctrl+F9
🎭 Polarization Spot Diagram	Ctrl+Shift+L
🙏 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
🕎 Directional Spot Diagram	Ctrl+F11
🐢 Visualization 3D Spot Diagram	
Irradiance Spread Function	Ctrl+F10
. () Intensity Spread Function	Ctrl+F12
😡 Energy Density	Ctrl+Shift+E
전 Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
🔀 <u>C</u> olor Image	

- 2. Press the keyboard accelerator keys: Shift+F12
- 3. Press the toolbar button: 12

See Also... Ray Statistcs

Ray Summary Ray Status

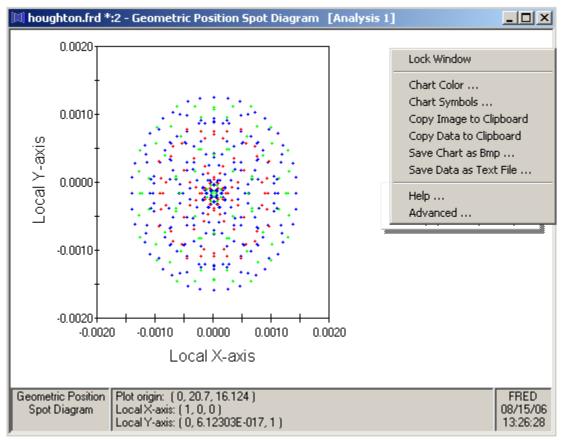
Analyses - Position Spot Diagram

Description How Do I Get There? Dialog box and Controls Application Notes Examples

Description Position Spot Diagram

—

This command generates a ray position spot diagram based on the rays filtered by the user selected analysis plane. The axes of the position spot diagram represent the local X and Y axes of the analysis plane regardless of where the rays are positioned. For example, the analysis plane can attached to one object and filter/select rays from multiple objects. In that case, the ray positions on the spot diagram will be referenced to the analysis plane origin and not the surfaces or sources where the rays current are positioned.



Position Spot Diagram from the image plane of the Houghton sample

Note The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.

The following commands are available via a right mouse click pop-up menu.

Lock Window	Lock Window
Chart Color	Chart Color …
Chart Symbols	Chart Symbols …
Copy Image to Clipboard	Copy Image to Clipboard …
Copy Data to Clipboard	Copy Data to Clipboard …
Save Chart as Bmp	Save Chart as Bmp …
Save Data as Text File	Save Data as Text File …
Help	Help
Advanced	Advanced

In addition to the graphical ray position plot, textual information about the number of filtered rays is listed in the output window.

	A	B	C	D	E	F	G
159							
160	RAY POSITI					(houghton.	frd)
161							
162	Rays plott	ed:		88		1	
163							
16.1	1		I manufacture and the second s			i i i i i i i i i i i i i i i i i i i	

Position spot diagram plot information is printed in the output window

How Do I Get There? Position Spot Diagram

There are three different ways to execute this command:

1. Select Position Spot Diagram in the Analysis Menu



<u>A</u> nalyses <u>W</u> indow <u>H</u> elp									
I Ray St <u>a</u> tus Shift+F10									
😽 Ray Summary	Shift+F11								
12 Ray Statistics	Shift+F12								
P Paraxial Analysis (first order)	Shift+F3								
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S								
Best Geometric Focus	Shift+F9								
≒= Eiber Coupling Efficiency	Ctrl+Shift+F								
🐙 Stray Light <u>R</u> eport									
Generate IES Output									
No	Ctrl+F9								
Positions Spot Diagram Age Polarization Spot Diagram	Ctrl+F9 Ctrl+Shift+L								
	Ctrl+F9 Ctrl+Shift+L Ctrl+Shift+G								
Polarization Spot Diagram	ん Ctrl+Shift+L								
Polarization Spot Diagram	い Ctrl+Shift+L Ctrl+Shift+G								
Polarization Spot Diagram <u>C</u> Gaussian Ray Size Spot Diagram Directional Spot Diagram	い Ctrl+Shift+L Ctrl+Shift+G								
Polarization Spot Diagram <u>C</u> Gaussian Ray Size Spot Diagram Directional Spot Diagram <u>V</u> isualization 3D Spot Diagram	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11								
Polarization Spot Diagram <u>G</u> aussian Ray Size Spot Diagram <u>P</u> Directional Spot Diagram <u>P</u> Visualization 3D Spot Diagram <u>P</u> Irradiance Spread Function	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10								
 Polarization Spot Diagram Gaussian Ray Size Spot Diagram Directional Spot Diagram Visualization 3D Spot Diagram Irradiance Spread Function Intensity Spread Function 	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10 Ctrl+F12								
 Polarization Spot Diagram Gaussian Ray Size Spot Diagram Directional Spot Diagram Visualization 3D Spot Diagram Visualization 3D Spot Diagram Inradiance Spread Function Intensity Spread Function Energy Density 	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10 Ctrl+F12 Ctrl+Shift+E								

- 2. Press the keyboard accelerator keys: Ctrl+F9
- 3. Press the toolbar button:

Dialog Box and Controls Position Spot Diagram

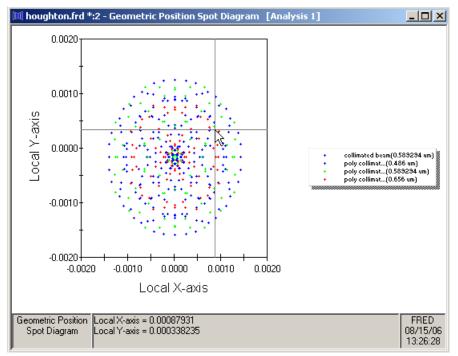
📢 (houghte	on.frd *) Ray Positions Plot (Spot Diag	ram) ? X
Analysis 1 List of Avail	nalysis Surface: able Analysis Surfaces: Description image surface	
🗖 Delete	is Ray Operations old rays and recreate all active sources ace all active rays of the rays as they are being raytraced	OK Cancel Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted Analysis Surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid Analysis Surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
ОК	Plot Spot Diagram and close dialog box.	
Cancel	Discard Spot Diagram and close dialog box.	
Help	Access this Help page.	

Application Notes Position Spot Diagram

Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).





An example of crosshairs

<u>See Also...</u> Position Spot Diagram

Direction Spot Diagram

Analyses - Paraxial Analysis - Third Order

	A	B	C	D	E	F	G	н	I	J	K	L
284	THIRD OR	DER ABERRATI	ON COEFFIC	IENTS:								
285												
286		Surface Co	ontribution	<u>15</u>		-		Element Co	ntributior	<u>15</u>		
287	Surf	SPH3	CMA3	AST3	PTZ3	DIS3		SPH3	CMA3	AST3	PTZ3	DIS3
288												
289	6	6	6	6	S	6		6	6	5	5	5
290												
291	1	-0.000304	-0.000143	-6.777e-5	-9.950e-5	-7.898e-5						
292	2	0.002161	0.000571	0.000151	0.000151	8.005e-5		0.001857	0.000428	8.349e-5	5.185e-5	1.072e-6
293												
294	3	-0.216668	-0.011685	-0.000630	-0.000849	-7.982e-5						
295	4	0.130665	0.007922	0.000480	0.000763	7.540e-5		-0.086003	-0.003762	-0.000149	-8.658e-5	-4.419e-6
296												
297	5	0.117266	0.009703	0.000802	-0.002041	-0.000102		0.117266	0.009703	0.000802	-0.002041	-0.000102
298	1											
299	6	-0.034823	-0.004040	-0.000468	0.004480	0.000465		-0.034823	-0.004040	-0.000468	0.004480	0.000465
1000	1					1						

Auto Select Aperture Stop

This command selects the limiting surface aperture from the selected ray path and makes it the stop surface for the paraxial ray trace calculations done in the Paraxial Analysis dialog



box. The surface selected is likely to change depending the on the other settings in the Paraxial Analysis dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

(ho	ughton.f	rd) Paraxial A	nalysis			
Select	ted Path:	standard path	1			
	Flags	Radius	Thickness	Material	Semi-Apert	Name
0		0	1e+20	Air	-2.6350e+19	<object></object>
1		-139.804562	0.699379	BK7	5	Houghton corrector lens 1 Surface 1 (/
2		-91.90905700	1.500016	Air	5	j <u>M</u> ake Aperture Stop
3		-16.368758	0.4999849	BK7	5	I <u>A</u> uto-Select Aperture Stop
4	S	-18.225471	15.290178	Air	5	Direct Numerical Aporture
5	R	-40	-20.39845099	Air	5.25	Object Numerical Aperture

The Auto Select Aperture Stop command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box

Image Numerical Aperture

This command sets the stop surface semi-aperture to meet the image space numerical aperture entered into the Image Space Numerical Aperture dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

Selec	ted Path:	standard path	1			
	Flags	Radius	Thickness	Material	Semi-Apert	Name
0		0	1e+20	Air	-2.6350e+19	<object></object>
1		-139.804562	0.699379	BK7	5	H Make Aperture Stop
2		-91.90905700	1.500016	Air	5	Auto-Select Aperture Stop
3		-16.368758	0.4999849	BK7	5	t
4	S	-18.225471	15.290178	Air	5	Diject Numerical Aperture
5	R	-40	-20.39845099	Air	5.25	Object Working F/#
6		0	0	Air	5.25	 Image Numerical Aperture
						Image Working E(#

The Image Numerical Aperture command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

🔆 Numerical Aperture	<u>? ×</u>
Numerical Aperture in image	e space
0.417514	
, [ОК]	Cancel

The Image Space Numerical Aperture dialog box

Image Semi-Field Angle

This command sets the object and image semi-apertures (object and image heights) to meet the Image semi-field angle entered by the user in the Image Semi-Field Angle dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

	Flags	Radius	Thickness	Material	Semi-Apert	Name
		0	1e+20	Air	-2.6350e+19	<object></object>
		-139.804562	0.699379	BK7	5	llevenheten sommerten levend Ormderen d
1	-	-91.90905700	1.500016	Air	5	<u>M</u> ake Aperture Stop
		-16.368758	0.4999849	BK7	5	Auto-Select Aperture Stop
	s	-18.225471	15.290178	Air	5	: Object Numerical Aperture
	R	-40	-20.39845099	Air	5.25	 Object Warking F/#
		0	0	Air	5.25	Image Numerical Aperture
						image Numerical Aperture

The Image Semi-Field Angle command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

C F/Number	<u>?×</u>
F/Number in image space	
1.19756	
(COK	Cancel

The Image Semi-Field Angle dialog box Image Working F/#...

This command sets the stop surface semi-aperture using paraxial calculations to meet the Image space working F/# entered into the Image Working F/# dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

_

elect	ted Path:	standard path	ו			<u> </u>
	Flags	Radius	Thickness	Material	Semi-Apert	Name
)		0	1e+20	Air	-2.6350e+19	<ohiect></ohiect>
1		-139.804562	0.699379	BK7	5	Hi Make Aperture Stop
2		-91.90905700	1.500016	Air	5	Hi Auto-Select Aperture Stop
3		-16.368758	0.4999849	BK7	5	.Hi
1	s	-18.225471	15.290178	Air	5	Object Numerical Aperture
5	R	-40	-20.39845099	Air	5.25	Object Working F/#
3		0	0	Air	5.25	Image Numerical Aperture
						Image Working F/#

The Image Working F/# command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

🕻 F/Number		<u>?×</u>
F/Number in imag	je space	
2.00938		
OK)	Cancel	Help

The Image Working F/# dialog box

Make Aperture Stop

This command makes the surface under the cursor the stop surface for the paraxial ray trace calculations done in the Paraxial Analysis dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

👌 (ho	ughton.l	rd) Paraxial	Analysis			
Select	ted Path:	standard pat	h			
	Flags	Radius	Thickness	Material	Semi-Apert	Name
0		0	1e+20	Air	1.64733e+18	<object></object>
1		-139.804562	0.699379	BK7	5	Houghton corrector.lens 1.Surface 1 (Axially
2		-91.90905700	1.500016	Air	5	Houghton corrector.lens 1.Surface 2 (Axially
3		-16.368758	0.4999849	BK7	5	Houghton corrector.Lens 2.Surface 1 (Axiall
4	s	-18.225471	15.290178	Air	5	Hou Make Operture Stop
5	R	-40	-15.289178	Air	5.25	Print Make Aperture Stop / Sy Auto-Select Aperture Stop
6	R	-18.22555952	12.123777	Air	1.5	.Sec(1)
7		-0.59671	0.3	SK4	0.29	Field Object Numerical Aperture
8		-0 702015000	1	Air	0.38	Field observations role Conid

The Make Aperture Stop command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

Object Numerical Aperture

This command sets the stop surface semi-aperture to meet the object space numerical aperture entered into the Object Space Numerical Aperture dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

🔆 (houghton.frd) Paraxial Analysis

Selec	ected Path: standard path							
	Flags	Radius	Thickness	Material	Semi-Apert	Name		
0		0	100	Air	-8.614325398	<object></object>		
1		-139.804562	0.699379	BK7	5	Houghton corrector leng 1 Surface 1 - (Ay)		
2		-91.90905700	1.500016	Air	5	Hou Make Aperture Stop		
3		-16.368758	0.4999849	BK7	5	Hou Auto-Select Aperture Stop		
4	s	-18.225471	15.290178	Air	5	Hou Object Numerical Academics		
5	R	-40	-15.289178	Air	5.25	Print Object Numerical Aperture		
6	R	-18.22555952	12.123777	Air	1.5	Sec Image Numerical Aperture		

The Object Numerical Aperture command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

🚱 Numerical Aperture	? ×						
Numerical Aperture in object space							
-0.0484674							
	Cancel						
[]							

The Object Space Numerical Aperture dialog box

Object Semi-Field Angle

This command sets the object and image semi-apertures (object and image heights) to meet the object semi-field angle entered by the user in the Object Semi-Field Angle dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.



—

🏠 (houghton.frd) Paraxial Analysis

	Flags	Radius	Thickness	Material	Semi-Apert	Nam	e
0		0	100	Air	-8.614325398	<ohie< th=""><th></th></ohie<>	
1		-139.804562	0.699379	BK7	5	.Ho	Make Aperture Stop
2		-91.90905700	1.500016	Air	5	.Ho	Auto-Select Aperture Stop
3		-16.368758	0.4999849	BK7	5	.Ho	A.
4	s	-18.225471	15.290178	Air	5	.Ho	Object Numerical Aperture
5	R	-40	-15.289178	Air	5.25	Pri	Object Working F/#
6	R	-18.22555952	12.123777	Air	1.5	.Se	Image Numerical Aperture
7		-0.59671	0.3	SK4	0.29	.Fie	Image Working F/#
8		-0.702015000	1	Air	0.38	.Fie	Object Semi-field Angle 🔪 🖸
9	TR	0	-5.500000001	Air	0.71	.Fo	Image Semi-field Angle
10	T	-13,13628899	-0.3	LAEN7	1	.rel	Image Semi-rield Angle v

The Object Semi-Field Angle command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

C Object Angle
Object angle (deg) in object space
4.81394
OK Cancel

The Object Semi-Field Angle dialog box Object Working F/#...

This command sets the stop surface semi-aperture using paraxial calculations to meet the object space working F/# entered into the Object Working F/# dialog box.

This command does not affect on the FRED model. It only affects the paraxial raytrace calculations.

	d Path:	standard pat	h				
	Flags	Radius	Thickness	Material	Semi-Apert	Nam	e
)		0	100	Air	-8.614325398	<obje< td=""><td>ect></td></obje<>	ect>
1		-139.804562	0.699379	BK7	5	.Hot"	abten corrector long 1 Surface 1 - Ci
2		-91.90905700	1.500016	Air	5	.Hot	Make Aperture Stop
3		-16.368758	0.4999849	BK7	5	.Ηοι	Auto-Select Aperture Stop
4	s	-18.225471	15.290178	Air	5	.Hou	Object Numerical Aperture
5	R	-40	-15.289178	Air	5.25	Prir	
3	R	-18.22555952	12.123777	Air	1.5	.Sec	Object Working F/# WImage Numerical Aperture
7		-0.59671	0.3	SK4	0.29	.Fiel	[•]

The Object Working F/# command is in the right mouse click pop-up menu in the Paraxial Analysis dialog box.

🕻 F/Number	<u>?×</u>
F/Number in object space	
-10.3162	
[OK]	Cancel

The Object Working F/# dialog box

Paraxial Trace

The Paraxial Trace command lists the paraxial Y height, the paraxial ray angle relative to the optical axis, and the paraxial angle of incidence with the surface for the chief ray and marginal ray. The marginal ray information has the "a" subscript and the chief ray information has the "b" subscript.

It is important to note that these are paraxial quantities. By calling them paraxial, we are assuming that the rays have been raytraced in a tiny "pencil" of rays around the optical axis. The rays in this tiny pencil have infinitesimal Y heights and angles. In this limit small angles we can assume that U=sin(u), U=tan(u), and 1=cos(u) where u is in radians. "Since these infinitesimal values have finite relative magnitudes, we may use any finite numbers to represent paraxial quantities, but we must remember to assume that each number is to be multiplied by a very small factor such as 10^{-50} , so that a paraxial angle written as 2.156878 does not mean 2.156878 radians but 2.156878 x 10^{-50} radians."[1]

	•	B	C	D	E	F	G	H
249	FIRST OR	DER PARAXIAL	RAYTRACE					
250	10							
251	Surf	<u>Ya</u>	<u>Ua'</u>	<u>Ia</u>	<u>Yb</u>	UD'	<u>Ib</u>	
252								
253	8	8	4.95e-20	4.95e-28	1.64e+18	-0.016473	-0.016473	
254								
255	1	4.957588	0.012080	-0.035460	0.037671	-0.010769	-0.016742	
256	2	4.966829	-0.009596	-0.041951	0.030139	-0.016503	-0.011097	
257								
258	3	4.951635	0.096732	-0.312101	0.005384	-0.010768	-0.016832	
259	4	5	0.004956	-0.177608	0	-0.016333	-0.010768	
260								
261	5	5.075790	0.248832	-0.121937	-0.249743	0.003846	-0.010090	
262								
263	6	1.271343	-0.109320	0.179076	-0.308552	-0.037705	0.020776	
264								
₹fr	7	0 0FL00F	0 400404	8 840741	8 747407	0 740075	4 967674	

[1] Kingslake, Rudolf, Lens Design Fundamentals, San Diego, Academic Press, 1978

FIRST ORDER SYSTEM DATA:	
<u>SYSTEM DATA</u>	
Effective Focal Length:	-19.92334
Magnification:	-1.99e-19
Overall Lens Length:	17.98955
Object-To-Image Length:	1e+20
Lagrange Invariant:	1.306371
Petzval Curvature:	-0.050850
<u>DBJECT/IMAGE CONJUGATE DATA</u>	
Object Angle (deq):	14.76242
Image Angle (deg):	-3.520842
Object Height:	-2.63e+19
Image Height:	5.25
Object Dist:	-1e+20
Image Dist:	-20.39845
DBJECT/IMAGE SPACE BEAM DATA	
Object Numerical Aperture:	-4.95e-20
Image Numerical Aperture:	0.248832
Object Working F/#:	-1.00e+19
Image Working F/#:	2.009383
Object F/#:	-2.009383
Image F/#:	-0.469177
ENTRANCE/EXIT PUPIL DATA	
Entrance Pupil Semi-Ape:	4.957577
Exit Pupil Semi-Ape:	21.23222
Entrance Pupil Dist:	2.286793
Exit Pupil Dist:	64.92889
CARDINAL POINT DATA	
Front Principal Pt Dist	17.55817
Rear Principal Pt Dist:	-0.475105
Front Nodal Pt Dist:	-22.28851
Rear Nodal Pt Dist:	-0.475105
Front Focal Pt Dist:	
Rear Focal Pt Dist:	-20.39845
Dbject space distances are measured ·	from surface '
Image space distances are measured	

Construction

×	FIRST ORD	ER CONSTRUC	TION DATA:			
	<u>Surf</u>	<u>Rd</u>	<u>Th</u>	<u>N</u>	<u>Conic</u>	<u>A4</u>
	0	infinity	1e+20	1	0	0
	1	-139.8045	0.699379	1.516800	8	0
	2	-91.90905	1.500016	1	0	0
	3	-16.36875	0.499984	1.516800	0	0
	4	-18.22547	15.29017	1	0	0
	5	-40	-20.39845	-1	0	0
	6	infinity	0			
	•					

Analyses - Surface Incident/Absorbed Power

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Surface Incident/Absorbed Power

Writes tabulated surface data to the Output Window. The listing includes incident power, absorbed power and number of rays broken out into specular and scatter categories.

How Do I Get There? - Surface Incident/Absorbed Power

There are three different ways to execute this command: 1. Menu



<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
<mark>∶≣</mark> Ray St <u>a</u> tus	Shift+F10
🤝 Ray ≦ummary	Shift+F11
12: Ray Statistics	Shift+F12
P Paraxial Analysis (first order)	Shift+F3
😤 Surface Incident/Absorbed Power	Ctrl+Shift+S
Sest Geometric Focus	Shift+F9
≒= Eiber Coupling Efficiency	Ctrl+Shift+F
🐗 Stray Light <u>R</u> eport	
Generate IES Output	
🔯 Positions Spot Diagram	Ctrl+F9
🌆 Polarization Spot Diagram	Ctrl+Shift+L
📩 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
🕎 Directional Spot Diagram	Ctrl+F11
🐢 Visualization 3D Spot Diagram	
Geometric <u>O</u> PD Map	
Irradiance Spread Function	Ctrl+F10
൙ Intensity Spread Function	Ctrl+F12
🕼 Energy Density	Ctrl+Shift+E
Coherent Scalar Wave Field	Ctrl+Shift+W
<mark>∕∕</mark> <u>⊂</u> olor Image	
2. Keyboard Accelerator -	Ctrl+Shift+S

3. Toolbar Button

Dialog Box and Controls - Surface Incident/Absorbed Power

No dialog box appears with this feature. Application Notes - Surface Incident/Absorbed Power

Sample ouptut from Surface Incident/Absorbed Powers: INCIDENT/ABSORBED SURFACE INCOHERENT POWERS: (ghost.frd) (from most recent raytrace) Total Absorbed Incident Incident Incident # of Rays Total Total Specular Specular Specular Scatter Scatter Scatter <u>Incident</u> <u>Level 0</u> <u>Level 1</u> <u>Level 2</u> <u>Level Ø</u> <u>Level 1</u> <u>Level 2</u> Power <u>Power</u> <u>Surface</u> 2.825e-6 1.013960 0.013957 1.013960 418 .triplet.Lens 1-2.Surface 1 1.31e-17 ß 0 1 650 0 1.008640 0.997272 0.011324 4.339e-5 1.008640 0 0 .triplet.Lens 1-2.Surface 2 0.000261 0.000261 0 0.000261 0.000261 0 0 .triplet.Lens 1-2.Bevel 2 8 0 128 0.000167 0.000167 0 0.000130 3.713e-5 0.000167 0 0 .triplet.Surface 3.Surf 3 701 5.57e-17 1.004440 0.994588 0.009798 5.400e-5 1.004440 0 0 .triplet.Lens 4-5.Surface 4 779 1.001987 0.991848 0.010040 9.769e-5 1.001987 .triplet.Lens 4-5.Surface 5 0 0 0 220 0.001800 0.001800 0 0.001653 0.000147 0.001800 ß ß .triplet.Lens 4-5.Edge 0.001260 0.001260 .triplet.Lens 4-5.Bevel 1 24 0 0.001260 0 0.001260 0 0 0.994281 0.989147 7.761e-5 .triplet.Lens 6-7.Surface 6 696 1.87e-17 0.005056 0.994281 0 0 0.000114 696 1.39e-18 0.984239 0.984125 0 0.984239 0 0 .triplet.Lens 6-7.Surface 7 3.315e-6 .triplet.Lens 6-7.Bevel 1 24 3.315e-6 0 3.315e-6 3.315e-6 0 0 0 0.979148 0.979148 0.979068 592 0 7.966e-5 0.979148 0 A .triplet.Surface 8.Surf 8



See Also - Surface Incident/Absorbed Power

Analyses - Fiber Coupling Efficiency Dialog

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description - Fiber Coupling Efficiency Dialog

This dialog allows you to calculate the fiber coupling efficiency for a system given data about the fiber.

How Do I Get There? - Fiber Coupling Efficiency Dialog

There are three different ways to execute this command:

 After tracing rays, on the Analysis menu, choose "<u>Fiber Coupling Efficiency...</u>" eering) - FRED1

<u>C</u> reate <u>Analyses</u> <u>W</u> indow <u>H</u> elp	
🤊 👔 🏣 Ray St <u>a</u> tus	Shift+F10
	Shift+F11
📜 🎏 🕼 🔤 Ray Statistics	Shift+F12
P Paraxial Analysis (first order)	Shift+F3
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S
Best Geometric Focus	Shift+F9
Fiber Coupling Efficiency	Ctrl+Shift+F
Positions Spot Diagram	Ctrl+E9
Use the keyboard accelerator Ctrl+Shift+F	

3. Press the Fiber Coupling toolbar button

Dialog Box and Controls - Fiber Coupling Efficiency Dialog

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2.

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		vsis Surface () 🔽 e center of the analysis surface):
		surrounded by cladding)
	Value	Description
Ncore	1.55	Fiber core refractive index
Nclad	1.5	Fiber cladding refractive index
Semi-Ape	0.001	Fiber core semi-aperture
Include		snel) losses at the fiber end ancel Apply Help

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Analysis Surface	List all analysis surfaces in the FRED system.	The first Analysis Surface found in the system
Fiber Type	List the type of fiber available for the calculation. Options are: <i>Step-index</i> <i>Gaussian fundamental mode</i>	Step-index
Fiber Type Options	List the options for the selected fiber type.	Ncore = 1.55 Nclad = 1.5 Semi-Ape = 0.001
Include reflection (Fresnel) losses at the fiber end	Calculate Fresnel losses at the end of the fiber.	Unchecked
ОК	Perform efficiency analysis and close dialog box.	
Cancel	Discard efficiency analysis and close dialog box.	
Apply	Perform efficiency analysis and keep dialog box open.	
Help	Access this Help page.	

Application Notes - Fiber Coupling Efficiency Dialog

This dialog is resizable and modeless.

See Also -Fiber Coupling Efficiency Dialog

Best Geometric Focus

Analyses - Stray Light Path Report

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Stray Light Path Report Dialog

Provides a customized report of stray light paths included number of rays, power and scattering surfaces.

How Do I Get There? Stray Light Path Report Dialog

This command requires an Advanced Ray Trace with the "Determine ray paths" option enabled. There are two different ways to execute this command.

1. From the Analyses menu, choose "Stray Light <u>Report..."</u>:



<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
🔚 Ray St <u>a</u> tus	Shift+F10
😸 Ray Summary	Shift+F11
12: Ray Statistics	Shift+F12
P Paraxial Analysis (first order)	Shift+F3
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S
Best Geometric Focus	Shift+F9
= Eiber Coupling Efficiency	Ctrl+Shift+F
📌 Stray Light <u>R</u> eport	
Generate IES Output 🕅	
No. Desitions Spot Disgram	Ctrl+F9
🕵 Positions Spot Diagram	C01+F9
Relarization Spot Diagram	Ctrl+Shift+L
🐅 Polarization Spot Diagram	Ctrl+Shift+L
Note: Polarization Spot Diagram	Ctrl+Shift+L Ctrl+Shift+G
and the second	Ctrl+Shift+L Ctrl+Shift+G
Image: Polarization Spot Diagram Image: Gaussian Ray Size Spot Diagram Image: Directional Spot Diagram	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11
Image: Polarization Spot Diagram Image: Gaussian Ray Size Spot Diagram Image: Directional Spot Diagram Image: Visualization 3D Spot Diagram Image: Irradiance Spread Function	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10
Image: Polarization Spot Diagram Image: Gaussian Ray Size Spot Diagram Image: Directional Spot Diagram Image: Polarization 3D Spot Diagram <	Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10 Ctrl+F12

2. On the Analyses Toolbar, press the Stray Light Report Button:



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Dialog Box and Controls

Stray Light Path Report Dialog

(<mark>À</mark> (FRED1 *) S	tray Lig	jht Path Rep	ort				-D×
Report Param Path Type: Receiver:	e			r "ghost" paths e (Axially Symmetric Conic		catter/ghost level: 1 📑 ace) 🔽	Cancel Help
Reference po	wer: To	otal scatter pow	er on the receiv	ver	•	Scatter Pwr: 0	
	evel 1 pa	aths: 0 Path‡	Count Ray Cou	Incoherent Power		Filter for the Report (not implem that header)	ented yet)
Path#	#Rays	Power %	Power	1st scatter surface			
Totals	0		0				
1							

<u>Control</u>	Inputs / Description	<u>Defaults</u>				
	Report Parameters					
Path Type:	Scatter Path					
Scatter/ghost level	Number of generations	1				
Receiver	Any valid surface	First surface in list				
Reference Power	Set reference power to which path powers are compared.	Total scatter power on receiver				
Scatter Power	User-defined power.	Grey				
	Receiver Path Summary					
Only/Thru level 1 paths	Path selection filter.	Only				
Path Count	Number of paths.	0				
Ray Count	Number of rays in all considered paths.	0				

Incoherent Power	Total power in all considered paths.	0
Peak power level <i>n</i> path: Path #	Path number with largest power.	-1
Peak power level <i>n</i> path: Ray Count	Number of rays in path with largest power.	0
Peak power level <i>n</i> path: Incoherent Power	Power in path with largest power.	0
Report	Tabulated Path data.	empty
Cancel	Cancel Straylight Report and close dialog box.	
Help	Access this Help page.	

Application Notes Stray Light Path Report Dialog

This dialog is resizable and modeless. It requires that at least one ray path be defined in order for the dialog to be displayed.

<u>See Also....</u> Stray Light Path Report Dialog

Advanced Raytrace Dialog

Analyses - Position Spot Diagram

This command generates a ray position spot diagram based on the rays filtered by the user selected analysis plane. The axes of the position spot diagram represent the local X and Y axes of the analysis plane regardless of where the rays are positioned. For example, the analysis plane can attached to one object and filter/select rays from multiple objects. In that case, the ray positions on the spot diagram will be referenced to the analysis plane origin and not the surfaces or sources where the rays current are positioned.



	A	B	C)	E	F	6
159							
160	RAY POSITI					(houghton	.frd)
161							
162	Rays plott	ed:		88			
163							
16)1							haveberhavaeeee

Position Spot Diagram from the image plane of the Houghton sample

Note The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.

The following commands are available via a right mouse click pop-up menu.

Analyses Window Help Ray Status Ray Summary Paraxial Analysis (first order) Surface Incident/Absorbed Power Best Geometric Focus Fiber Coupling Efficiency Generate IES Output	Shift+F10 Shift+F11 Shift+F12 Shift+F3 Ctrl+Shift+S Shift+F9 Ctrl+Shift+F	Lock <u>Window</u> Advanced
Positions Spot Diagram Image: Polarization Spot Diagram	Ctrl+F9 Ctrl+Shift+L Ctrl+Shift+G Ctrl+F11 Ctrl+F10 Ctrl+F12 Ctrl+Shift+E Ctrl+Shift+W	

In addition to the graphical ray position plot, textual information about the number of filtered rays is listed in the output window.

📢 (houghta	n.frd *) Ray Positions Plot (Spot Diagra	am) ? ×
Analysis 1 List of Avail Name	nalysis Surface: able Analysis Surfaces: Description image surface	
Delete	is Ray Operations old rays and recreate all active sources ice all active rays of the rays as they are being raytraced	OK Cancel Help

Position spot diagram plot information is printed in the output window

How Do I Get There? - Position Spot Diagram

There are three different ways to execute this command:

1. Select Position Spot Diagram in the Analysis Menu

<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
Paraxial Analysis (first order)	Shift+F3
Pest Focus	Shift+F9
🔚 Ray St <u>a</u> tus	Shift+F10
≫ Ray-Surface <u>S</u> ummary	Shift+F11
12 Ray Statistics	Shift+F12
Positions Spot Diagram	Ctrl+F9
Irradiance Spread Function K	Ctrl+E10

- 2. Press the keyboard accelerator keys: Ctrl+F9
- 3. Press the toolbar button:

Dialog Box and Controls - Position Spot Diagram

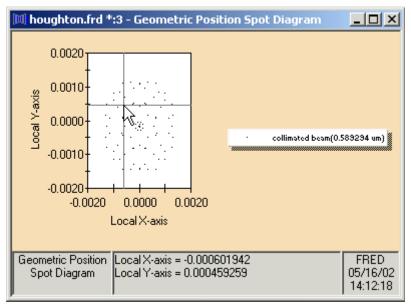
候 (houghta	on.frd *) Ray Positions Plot (Spot Diag	ram) ? X
Use This Ar Analysis 1	nalysis Surface:	
List of Avail	able Analysis Surfaces:	
Name	Description	
.Analysis 1	image surface	
Pre-Analys	is Ray Operations	ОК
🗌 🗌 Delete	old rays and recreate all active sources	
🗌 🔲 Raytra	ice all active rays	Cancel
E Plo	ot the rays as they are being raytraced	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	
ОК		
Cancel		
Нер		

Application Notes - Position Spot Diagram

Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).





An example of crosshairs

Examples - Position Spot Diagram

Analyses - Polarization Spot Diagram

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

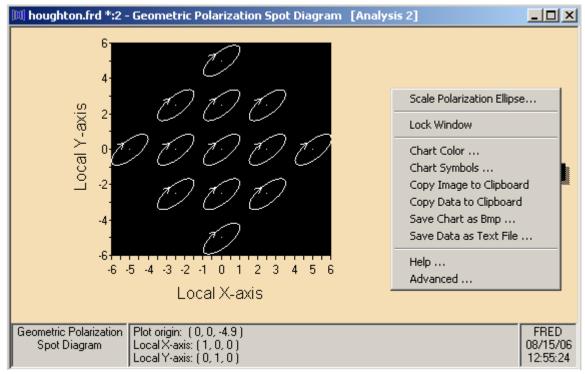
Description Polarization Spot Diagram

The Polarization Spot Diagram command generates a 2D polarization state plot of the rays filtered by the analysis plane selected by the user. The polarization ellipses can be scaled via the right mouse click menu.

Note The spot diagram windows are deleted if anything in the FRED document is altered unless the spot diagram windows have been locked.



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Polarization Spot Diagram

The following commands are available via a right mouse click pop-up menu.

Scale Polarization Ellipse
Lock Window
Chart Color
Chart Symbols
Copy Image to Clipboard
Copy Data to Clipboard
Save Chart as Bmp
Save Data as Text File
Help
Advanced

Scale Polarization Ellipse Lock Window Chart Color ... Chart Symbols ... Copy Image to Clipboard ... Copy Data to Clipboard ... Save Chart to Bmp ... Save Data as Text File ... Help ... Advanced...

Right mouse click menu options

In addition to the graphical polarization plot, textual information about the number of filtered rays is listed in the output window.

	A	B	C	D	E	F	G
129							
130		RIZATION SPO				(houghton.	
131		-					
132	20	total rays	s plotted				
133	20	polarized	rays plotte	d			
134							
:1-		1	1				

_

Polarization plot information is printed in the output window <u>How Do I Get There?</u> Polarization Spot Diagram

There are three different ways to execute this command:

1. Select Intensity Spread Function in the Analysis Menu

<u>A</u> nalyses <u>W</u> indow <u>H</u> elp		
🔚 Ray St <u>a</u> tus	Shift+F10	
😽 Ray Summary	Shift+F11	
12 Ray Statistics	Shift+F12	
Paraxial Analysis (first order)	Shift+F3	
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S	
Best Geometric Focus	Shift+F9	
📜 Eiber Coupling Efficiency	Ctrl+Shift+F	
🐙 Stray Light <u>R</u> eport		
Generate IES Output		
Positions Spot Diagram	Ctrl+F9	
Rolarization Spot Diagram	Ctrl+Shift+L	
🉏 💪 🖞 🖞 🖞 🕺 🕺 🕺 🕺 🕺 🕹	Ctrl+Shift+G	
<u>~</u>		
Pirectional Spot Diagram	Ctrl+F11	
	Ctrl+F11	
Directional Spot Diagram	Ctrl+F11 Ctrl+F10	
Directional Spot Diagram Pisualization 3D Spot Diagram		
Directional Spot Diagram Visualization 3D Spot Diagram Irradiance Spread Function	Ctrl+F10	
Directional Spot Diagram Visualization 3D Spot Diagram Irradiance Spread Function Intensity Spread Function	Ctrl+F10 Ctrl+F12	
 Directional Spot Diagram Visualization 3D Spot Diagram Irradiance Spread Function Intensity Spread Function Energy Density 	Ctrl+F10 Ctrl+F12 Ctrl+Shift+E	

- 2. Press the keyboard accelerator keys: Ctrl+Shift+L
- 3. Press the toolbar button:

Dialog Box and Controls Polarization Spot Diagram



🕻 (houghte	on.frd *) Ray Polarization Plot (Polariza	ation Diagram) 🛛 📪 🗙
	nalysis Surface:	
Analysis 1	able Analysis Surfaces:	
Name	Description	
.Analysis 1	image surface	
	is Ray Operations	OK
	e old rays and recreate all active sources ace all active rays	Cancel
E PI	ot the rays as they are being raytraced	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>	
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted Analysis Surface	
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid Analysis Surface	
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked	
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked	
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked	
ОК	Plot Ray Polarization and close dialog box.		
Cancel	Discard Ray Polarization Plot and close dialog box.		
Help	Access this Help page.		

Application Notes Polarization Spot Diagram

The data in the chart can be <u>saved to a text data file</u>, but only the ray locations are presently saved. The polarization information is not saved with the ray locations. A modified chart style can be saved and made the <u>default</u> file.

See Also.... Polarization Spot Diagram

Scale Polarization Ellipse

Analyses - Directional Spot Diagram

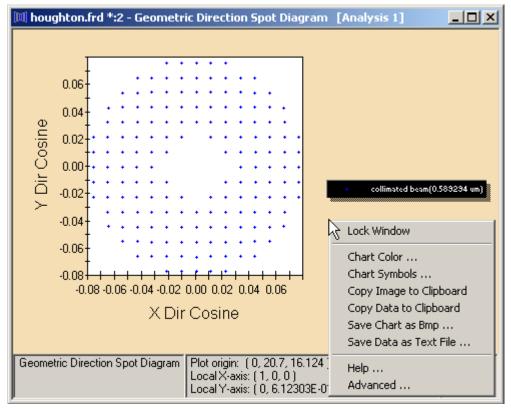
Description How Do I Get There? Dialog box and Controls Application Notes Examples See Also...

Description Directional Spot Diagram

This command generates a ray direction spot diagram based on the rays filtered by one of the available analysis planes. The ray directions are plotted in direction cosines relative to the local X and Y-axes of the analysis plane and *not* relative to the surface with the rays on it (see <u>Examples</u>). Chart crosshairs are available by holding the left mouse button down inside the plot area (see <u>Application Notes</u>)

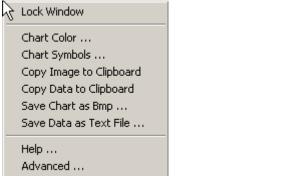
Note The default operation of the spot diagrams and spread plot views in FRED is that they are deleted when a new raytrace is done. A plot view can be locked so it is not deleted when the rays are deleted via a right mouse click pop-up menu.





Direction Spot Diagram

The following commands are available via a right mouse click pop-up menu.



Lock Window

Chart Color ... Chart Symbols ... Copy Image to Clipboard ... Copy Data to Clipboard ... Save Chart as Bmp ... Save Data as Text File ... Help ... Advanced...

Right mouse click menu options

In addition to the graphical ray direction plot, textual information about the number of filtered rays is listed in the output window.

RAY DIRECTION SPOT DIAGRAM:

Rays plotted:	164	
Incoherent power:	0.224938	
RMS:	0.060050	
Power weighted RMS:	0.060050	
-		<u>Power Weighted</u>
	<u>× y</u>	<u>× y</u>
Average:	7.44e-18 -2.285e-5	1.36e-17 -2.285e-5
RMS:	0.042461 0.042461	0.042461 0.042461
Min:	-0.076302 -0.076325	
Max:	0.076302 0.076279	

Direction spot diagram plot information is printed in the output window

How Do I Get There? Directional Spot Diagram

There are three different ways to execute this command:

1. Select Directional Spot Diagram in the Analysis Menu

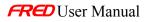
Analyses Window Help	
;≣ Ray St <u>a</u> tus	Shift+F10
😽 Ray Summary	Shift+F11
12 Ray Statistics	Shift+F12
P Paraxial Analysis (first order)	Shift+F3
🗄 🗄 Surface Incident/Absorbed Power	Ctrl+Shift+S
Best Geometric Focus	Shift+F9
= Eiber Coupling Efficiency	Ctrl+Shift+F
🐙 Stray Light <u>R</u> eport	
Generate IES Output	
🔀 Positions Spot Diagram	Ctrl+F9
🎭 Polarization Spot Diagram	Ctrl+Shift+L
🙏 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
www.Directional Spot Diagram	Ctrl+F11
n Yisualization 3D Spot Diagram	43
- 🖙 Irradiance Spread Function	Ctrl+F10
📜 Intensity Spread Function	Ctrl+F12
🖏 Energy Density	Ctrl+Shift+E
~ Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
🔀 <u>C</u> olor Image	
Press the keyboard accelerator ke	vs: Ctrl+F11

- 2. Press the keyboard accelerator keys: Ctrl+F11
- 3. Press the toolbar button:

Dialog Box and Controls Directional Spot Diagram

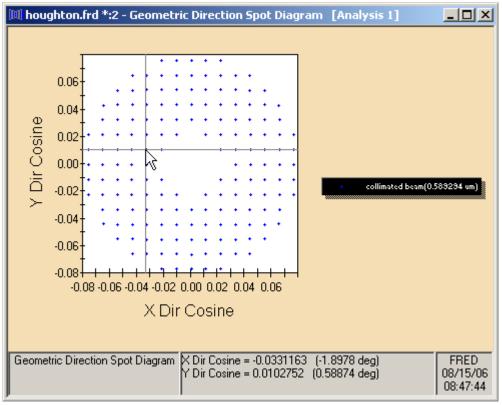
Ġ (houghta	on.frd *) Ray Directions Plot (Spot Dia	gram) ? X
Use This Ar Analysis 1	nalysis Surface:	
List of Avail	able Analysis Surfaces:	
Name	Description	
Analysis 1	image sufface	
	sis Ray Operations	ОК
	e old rays and recreate all active sources ace all active rays	Cancel
E Pi	ot the rays as they are being raytraced	Help

<u>Control</u>	<u>Inputs</u>	<u>Defaults</u>
Use This Analysis Surface:	Lists the analysis surface used to filter rays in the spot diagram.	Highlighted Analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	.Analysis n
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and are traced before the spot diagram is plotted.	Unchecked
Plot the rays as they are being raytraced	If checked, the rays will be plotted when they are raytraced.	Unchecked
OK	Accept Ray Directions Plot and close dialog box.	
Cancel	Discard Ray Directions Plot and close dialog box.	
Help	Access this Help page.	



Application Notes Directional Spot Diagram

Chart crosshairs are available by holding the left mouse button down inside the plot. The plot value under the cursor is reported at the bottom of the chart in both direction cosines and angles (both relative to the local analysis plane X and Y axes).

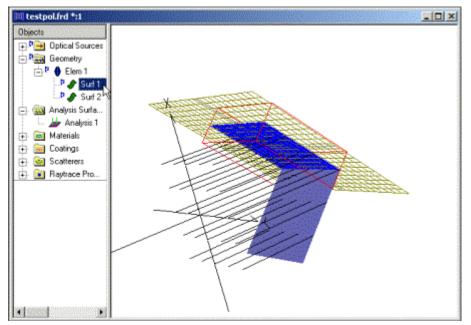


An example of crosshairs

Examples Directional Spot Diagram

The ray directions are reported in direction cosine space relative to the analysis plane. This is illustrated in the example below where there are two surfaces at 90 degrees to one another. There is an analysis plane attached to surface Surf 1 and the ray selection filter for the analysis plane includes rays hitting both surfaces Surf 1 and Surf 2. The direction spot diagram shows all the ray angles at one angle, the angle all the rays have to the analysis plane even though half the rays are on Surf 2.

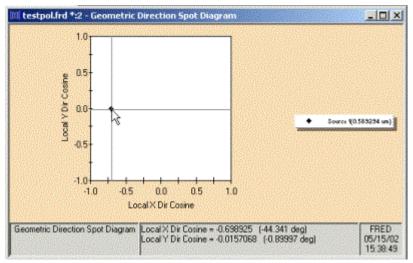




The geometry

Num	Operation	Description
1	AND	Rays on surface "Geometry.Elem 1.Surf 1"
2	OR	Rays on surface "Geometry.Elem 1.Surf 2"

The ray filter for the analysis plane



The resulting direction spot diagram is shown above. Note that the approximate angle is shown with the crosshairs.

Position Spot Diagram

Analyses - Irradiance Spread Function

Description How Do I Get There? Dialog box and Controls Application Notes Examples See Also...

Description Irradiance Spread Function

The <u>Irradiance</u> Spread Function command generates a 3D irradiance plot of the rays filtered by the user-selected Analysis Plane. The irradiance, in units of flux/area, is summed at the center of each pixel and plotted. Incoherent, coherent, and coherent polarized rays can all be summed together based on what rays the analysis plane filters. The summation process follows these steps at each pixel:

- Step 1. The <u>coherent polarized</u> rays at each discrete wavelength are summed coherently using their electric field vectors. Each coherent polarized ray's electric field is decomposed into X, Y, and Z components. All the X components are summed coherently, all the Y components are summed coherently, and all the Z components are summed coherently. The X, Y, and Z components summations are all summed incoherently. Then all the discrete wavelengths are summed incoherently.
- Step 2. The coherent unpolarized rays are coherently summed at each discrete wavelength. Then all the discrete wavelengths of coherent rays are summed incoherently.
- Step 3. The incoherent rays are summed incoherently.
- Step 4. All three summations are summed together for each pixel.

Note: If the wavelength of two coherent sources differs by any amount at any decimal place, they are summed incoherently.

If the source is <u>coherent</u>, then a complete coherent irradiance pattern is calculated from a relatively small number of rays using <u>gaussian</u> beamlet propagation. The coherent summation calculation accurately includes diffraction effects as long as the coherent rays have been propagated through the optical system meeting two rules at every surface. First, the gaussian beamlets must be significantly smaller than the apertures that they go through and second, the beamlets should be small relative to the local curvature of the optical surface. The diffraction effects of apertures are calculated by sampling the aperture with gaussian beamlets. If the beamlets are not small compared to the aperture, then the sampling will be inaccurate. If the beamlets are large relative to local surface curvature changes, then the gaussian beamlet may not maintain its quadratic curvature on refraction or reflection.

If the source is incoherent, then the irradiance plot does not include diffraction. The incoherent irradiance pattern is simply a binning of the incident rays into the bins or grids defined by the analysis plane. In addition to providing an irradiance pattern based on the binning of the incoherent rays, this command also provides an auxiliary spread function chart (fourth panel in the window) showing the number of the rays in each bin or alternatively an estimated percent error for each bin based on the number of rays in each bin.

Coherent and incoherent examples are shown below with exactly the same analysis plane and source definition. The only change made was setting the source coherent in the first case and incoherent in the second case. Note that the peak is significantly lower and broader in the coherent case than in the incoherent indicating that the system performance is limited by diffraction.

Note: The spread function and spot diagram windows are deleted if anything in the FRED document is altered unless the spread function or spot diagram windows have been locked.

How Do I Get There? Irradiance Spread Function

There are three different ways to execute this command:

1. Select Irradiance Spread Function in the Analysis Menu

	· · · , · ·
Analyses Window Help	
🔚 Ray St <u>a</u> tus	Shift+F10
😸 Ray Summary	Shift+F11
12Ray Statistics	Shift+F12
P Paraxial Analysis (first order)	Shift+F3
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S
Best Geometric Focus	Shift+F9
≒ Fiber Coupling Efficiency	Ctrl+Shift+F
🐙 Stray Light <u>R</u> eport	
Generate IES Output	
🙀 Positions Spot Diagram	Ctrl+F9
🍋 Polarization Spot Diagram	Ctrl+Shift+L
🙏 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
🕎 Directional Spot Diagram	Ctrl+F11
🐢 Visualization 3D Spot Diagram	
Irradiance Spread Function	Ctrl+F10
൙ Intensity Spread Function	ر Ctrl+F12
🖏 Energy Density	Ctrl+Shift+E
~ Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
<mark>∕∕</mark> ⊆olor Image	
Press the keyboard accelerator key	vs: Ctrl+E10

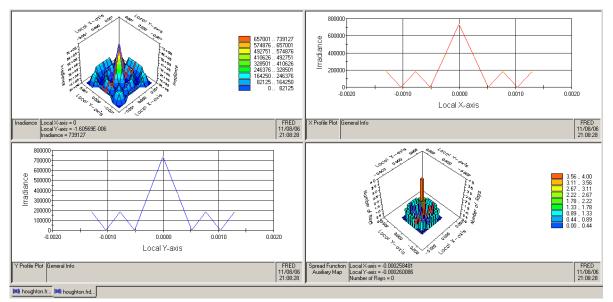
- 2. Press the keyboard accelerator keys: Ctrl+F10
- 3. Press the toolbar button:

Dialog Box and Controls Irradiance Spread Function

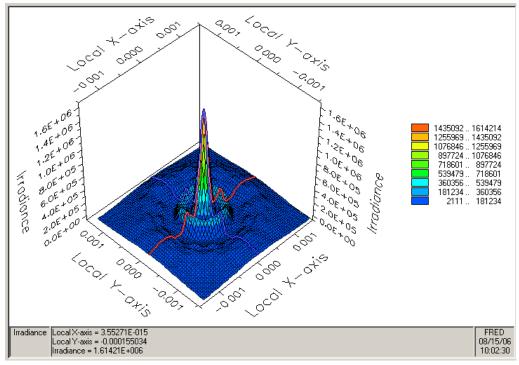
<mark> (</mark> houghta	n.frd *) Irradiance Distribution (positional power di	stribution) ? ×
Analysis 1.	halysis Surface:	
Name	able Analysis Surfaces: Description image surface	
Delete Raytra	is Ray Operations old rays and recreate all active sources ice all active rays of the rays as they are being raytraced	OK Cancel Help

<u>Control</u>	Inputs	<u>Defaults</u>
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid analysis surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Irradiance Distribution and close dialog box.	
Cancel	Discard Irradiance plot and close dialog box.	
Help	Access this Help page.	

Application Notes Irradiance Spread Function



Incoherent irradiance pattern is shown in the first panel and the number of rays per bin is shown in the auxiliary spread function chart in the fourth panel for the Houghton sample.



Coherent irradiance pattern for the Houghton sample

Chart crosshairs are available by holding the left mouse button down inside the plot. The irradiance and location under the cursor is reported at the bottom of the chart in position (relative to the local analysis plane X and Y axes).



In both the coherent and incoherent cases, the following commands are available in the first panel via a right mouse click pop-up menu.

 Perspective View
Show Ceiling
Show Floor
Axes Labels
Chart Color
Chart Color Levels
Copy Data to Clipboard
Copy Image to Clipboard
Save Chart to Bmp
Save Data to Text File
Read Data from File
Show Statistics
Scale Data
Smooth/Modify Data
Encircled/Ensquared Data
Fourier Transform (FFT)
Combine Datasets
Show in Visualization View
Lock Window
Help
Advanced

Perspective View Show Ceiling Show Floor Axes Labels... Chart Color... Chart Color Levels... Copy Data to Clipboard... Copy Image to Clipboard... Save Chart to Bmp... Save Data to Text File... Read Data from File... Show Statistics... Scale Data... Smooth / Modify Data... Encircled/Ensquared Data... Fourier Transform (FFT)... Combine Datasets... Show in Visualization View... Lock Window Help... Advanced...

First panel right mouse click menu options

In the incoherent case only, the following commands are available in the auxiliary spread function chart (second panel) via a right mouse click pop-up menu.

 Show Ray Count Show Relative Error
Lock Window
Chart Color
Chart Color Levels
Copy Image to Clipboard
Copy Data to Clipboard
Save Chart as Bmp
Save Data as Text File
Help
Advanced

The spread function auxiliary chart right mouse click menu options in the 2nd panel (incoherent spread functions only) Show Ray Count Show Relative Error Lock Window Chart Color ... Chart Color Levels ... Copy Image to Clipboard ... Copy Data to Clipboard ... Save Chart as Bmp ... Save Data as Text File ... Help ... Advanced...

	A	B	C	D	E	F	G	H	I	L	K
2360											
2361	IRRADIANCE	DISTRIBUT	TION:			(houghton	n.frd)				
2362	0.023290	sec total	time				1				
2363						-			1		
2364	8				# Rays						
2365			# Rays		Not Inclu	ded	1				
2366	Ray Type		Included		(Errors)		Time (sec)				
2367	Incoherent		0		8		8				
2368	Coherent U		8		8		8				
2369	Coherent F	olarized:	164		8		0.023249				
2370											
2371	Totals		164		8		0.023249				
2372											
2373	Total Powe	r:		1.854667			entire analy		ne)		
2374				95798.93	(over th	e entire a	analysis plan	ne)			
2375	Valid Aver	age Irradi	iance:	95798.93	93 (over valid pixel area only)						
2376					1		1				
2377	Length uni	ts are:	in								
2378						1	1				
2379	Min/Max		Irradiance		<u>X</u>		<u>Y</u>		Row		Colur
2388	Maximum:		1136897.752526		8		8		6		6
2381	Minimum:		33.64182627426		-0.002		0.002		1		11
2382											
2383	Widths/Hei	ghts	<u>X width</u>		Y height		Width (pixe	(15)	Height (pi	xels)	
2384	Analysis P	lane:	0.0844		8.8844		11		11		
2385	Single Pix	el:	0.8004		8.0084	1	1		1		
2386							1				
2387	Areas		Area		Pixel Cou	nt	3				
2388	Analysis p	lane:	1.936e-5		121						
2389	Valid pixe		1.936e-5		121	1	1				
2390	Single pix	el:	1.6e-7		1						
2391											
2392	Local Coor	dinates	X		Y		Row		Column		
2393	Lower left	corner:	-0.0022		-0.8022	1	0.5		0.5		A REAL PROPERTY AND ADDRESS OF
2394	Upper righ	t corner:	0.0022		0.0022		11.5		11.5		
2395					1		1				termine the second second second second
-	and the second state of th										

In addition to the graphical irradiance plots, textual information about the filtered rays, the analysis plane, and the irradiance profile is output to the output window.

Irradiance plot information printed in the output window for every irradiance plot

Examples Irradiance Spread Function

None.

See Also.... Irradiance Spread Function

> The data in the chart can be <u>saved to a text data file</u>. A modified chart style can be saved and made the <u>default</u> file.

Analyses - Intensity Spread Function

Description How Do I Get There? Dialog box and Controls Application Notes See Also...

Description Intensity Spread Function

The <u>Intensity</u> Spread Function command generates a 3D intensity plot of the rays filtered by the analysis plane selected by the user. The intensity, Watts/steradian, is summed at the center of each pixel and plotted. A <u>steradian</u>, [sr], is a measure of solid angle. Incoherent, coherent, and coherent polarized rays can all be summed together incoherently based on what rays the analysis plane filters. It is important to note that unlike the irradiance calculations, the summation process for intensity is entirely incoherent and does not include diffraction.

Note: The intensity calculation is incoherent.

The intensity pattern is simply a binning of the incident rays into the bins or grids defined by the analysis plane. In addition to providing an intensity pattern based on the binning of the incoherent rays, this command also provides an auxiliary spread function chart (fourth panel in the window) showing the number of the rays in each bin or alternatively an estimated percent error for each bin based on the number of rays in each bin.

Note: The spread function and spot diagram windows are deleted if anything in the FRED document is altered. Locking the window prevents its deletion.

How Do I Get There? Intensity Spread Function

There are three different ways to execute this command:

1. Select Intensity Spread Function in the Analysis Menu



<u>A</u> nalyses <u>W</u> indow <u>H</u> elp	
🔚 Ray St <u>a</u> tus	Shift+F10
- 🤝 Ray <u>S</u> ummary	Shift+F11
12 Ray Statistics	Shift+F12
Paraxial Analysis (first order)	Shift+F3
😤 Surface Incident/Absorbed Power	Ctrl+Shift+S
Sest Geometric Focus	Shift+F9
📜 Eiber Coupling Efficiency	Ctrl+Shift+F
🐙 Stray Light <u>R</u> eport	
Generate IES Output	
Positions Spot Diagram	Ctrl+F9
🎭 Polarization Spot Diagram	Ctrl+Shift+L
🙏 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G
🕎 Directional Spot Diagram	Ctrl+F11
🐢 Visualization 3D Spot Diagram	
👾 Irradiance Spread Function	Ctrl+F10
達 I <u>n</u> tensity Spread Function	Ctrl+F12
🖏 Energy Density	^{NV} Ctrl+Shift+E
전 Coherent Scalar <u>W</u> ave Field	Ctrl+Shift+W
- 🔀 <u>C</u> olor Image	

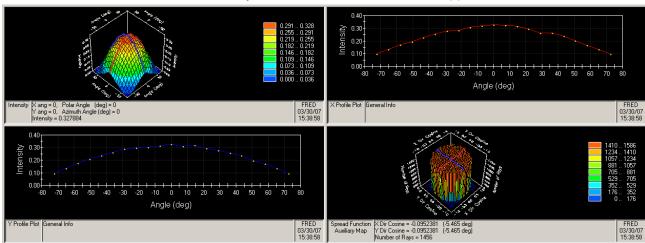
- 2. Press the keyboard accelerator keys: Ctrl+F12
- 3. Press the toolbar button:

Dialog Box and Controls Intensity Spread Function

🕻 (houghton.frd *) Intensity Distribution (directional power distribution) 🎦 🗙							
Analysis 1.	nalysis Surface: Iable Analysis Surfaces:						
Name	Description image surface						
E Delete	sis Ray Operations e old rays and recreate all active sources ace all active rays ot the rays as they are being raytraced	OK Cancel Help					

<u>Control</u>	Inputs	<u>Defaults</u>						
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram.	Highlighted Analysis Surface						
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First surface in list						
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked						
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked						
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Grayed out, unchecked						
OK	Display Intensity Distribution and close dialog box.							
Cancel	Discard Intensity Distribution and close dialog box.							
Help	Access this Help page.							

Application Notes Intensity Spread Function

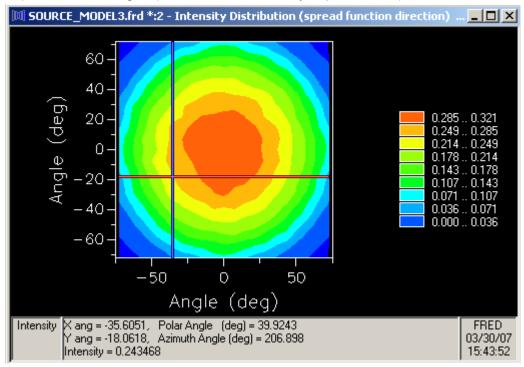


The chart below shows an intensity calculation from an illumination application.

Incoherent intensity pattern is shown in the first panel and the number of rays per bin is shown in the auxiliary spread function chart in the fourth panel for a Lambertian angular distribution.

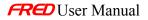


Chart crosshairs are available by holding the left mouse button down inside the plot. The intensity and location under the cursor is reported at the bottom of the chart in both xy-angles and in polarazimuthal angles (relative to the local analysis plane X axis).



An example of crosshairs

The following commands are available in the first panel via a right mouse click pop-up menu.



~	Perspective View
~	Isotropic
	Flat Pixel Cell View
	Show Ceiling
	Show Floor
	Axes Labels
	Chart Color
	Chart Color Levels
	Copy Data to Clipboard
	Copy Image to Clipboard
	Save Chart to Bmp
	Save Data to Text File
	Read Data from File
	Show Statistics
	Scale Data
	Smooth/Modify Data
	Encircled/Ensquared Data
	Fourier Transform (FFT)
	Combine Datasets
	Show Direction Cosine Space
•	Show Angle Space
	Show Direction Cosine Angle Space
	Show Direction Tangent Angle Space
	Show in Visualization View
	Lock Window
	Help
	Advanced

Perspective View Isotropic Flat Pixel Cell View **Show Ceiling** Show Floor Axes Labels... Chart Color... Chart Color Levels... Copy Data to Clipboard Copy Image to Clipboard Save Chart as Bmp... Save Data to Text File... Read Data from File ... Show Statistics... Scale Data... Smooth / Modify Data... Fourier Transform (FFT)... Combine Datasets... Show Direction Cosine Space Show Angle Space Show Direction Cosine Angle Space Show Direction Tangent Angle Space Show in Visualization View...

Lock Window Help Advanced...

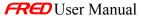
First panel right mouse click menu options

The following commands are available in the auxiliary spread function chart (fourth panel) via a right mouse click pop-up menu.

 Show Ray Count Show Relative Error
Lock Window
Chart Color Chart Color Levels Copy Image to Clipboard Copy Data to Clipboard Save Chart as Bmp Save Data as Text File
Help Advanced

The spread function auxiliary chart right mouse click menu options in the 2nd panel

Show Ray Count Show Relative Error Lock Window Chart Color ... Chart Color Levels ... Copy Image to Clipboard ... Copy Data to Clipboard ... Save Chart as Bmp ... Save Data as Text File ... Help ... Advanced...



	A B	C	D	E	F	G	H	I	J K
293	INTENSITY DISTRIBUT				(SOURCE_M	ODEL3.frd)			
294	Analysis Surf:	Analysis							
295									
296									
297	<u>Ray type</u>		<u># rays</u>						
298	Incoherent Rays:		500000						
299	Coherent Unpolarized	d :	0						
300	Coherent Polarized:		ß						
301	Total:		500000	(3.51 secs)				
302	Errors:		0						
303									
304	Length units are:	MM							
3 05									
306	Integrated Power:		0.950476	(over the	entire a	nalysis are	a)		
307	Total Average Inten	sity:	0.307494	(over the	entire a	nalysis are	a)		
308	Valid Average Inten	sity:	0.309646	0.309646 (over non-zero (valid) pixels only)					
3 0 9									
310	Min/Max	<u>Intensity</u>		<u>X</u>		<u>Y</u>		Row	<u>Column</u>
311	Maximum:	0.320647		7.224720		6		12	11
312	Minimum:	0.004434		-72.24720		-50.57304		1	4
313									
314	Widths/Heights	<u>X width</u>		<u>Y heiqht</u>		Width (pix	els)	Height (pixels	5)
315	Analysis Surface:	151.7191		151.7191		21		21	
316	Single Pixel:	7.224720		7.224720		1		1	
317									
318	Areas	Area		Pixel Cour	<u>it</u>	1		1	
319	Analysis surface:	23018.69		441					
320	Valid pixels:	21765.97		417					
321	Single pixel:	52.19659		1					
322									
323	Local Coordinates	X		Y		Row		Column	
324	Lower left corner:	-75.85957	-	-75.85957		0.5		0.5	
325	Upper right corner:	75.85957		75.85957		21.5		21.5	

In addition to the graphical intensity plots, textual information about the filtered rays, the analysis plane, and the intensity profile is output to the output window.

Intensity information is printed in the output window for every intensity plot

3. As of version 6.40, the Intensity Spread function default display mode is angle space. Conversions to other spaces are available on the popup menu.

<u>See Also....</u> Intensity Spread Function

The data in the chart can be saved to a text data file.

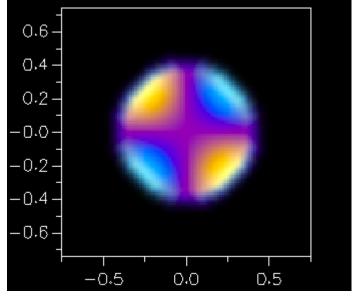
A modified chart style can be saved and made the default file.



Analyses - Color Image

Description How Do I Get There? Dialog Box and Controls Application Notes See Also...

Description Color Image



Calculates and displays an RGB spatial map of a user-selected Analysis Surface.

How Do I Get There? Color Image

There are two different ways to execute this command:

1. Menu



<u>Analyses</u> <u>Window</u> <u>H</u> elp		
I≣ Ray St <u>a</u> tus Shift+F10		
🤝 Ray <u>S</u> ummary	Shift+F11	
12 Ray Statistics	Shift+F12	
P Paraxial Analysis (first order)	Shift+F3	
🐣 Surface Incident/Absorbed Power	Ctrl+Shift+S	
Pest Geometric Focus	Shift+F9	
= Eiber Coupling Efficiency	Ctrl+Shift+F	
🚚 Stray Light <u>R</u> eport		
Generate IES Output		
Not the second s	Ctrl+F9	
🎭 Polarization Spot Diagram	Ctrl+Shift+L	
📩 Gaussian Ray Size Spot Diagram	Ctrl+Shift+G	
🕎 Directional Spot Diagram	Ctrl+F11	
🌮 Visualization 3D Spot Diagram		
Geometric <u>O</u> PD Map…		
Irradiance Spread Function Ctrl+F10		
🕽 Intensity Spread Function	Ctrl+F12	
🖏 Energy Density	Ctrl+Shift+E	
전 Coherent Scalar Wave Field Ctrl+Shift+W		
🔀 <u>C</u> olor Image		
2. Toolbar Button - 🚺		

Dialog Box and Controls Color Image

nage plane		
ist of Available Analys	is Surfaces:	
Name	Description	
image plane small area image plan	e	
Pre-Analysis Ray Ope	rations	OK
🗖 Delete old rays ar	nd recreate all active sources	
🔲 Delete old rays ar	nd recreate all active sources	Cancel

<u>Control</u>	Inputs / Description	<u>Defaults</u>
Use This Analysis Surface:	Lists the analysis surface used to filter the rays in the spot diagram	Highlighted analysis surface
List of Available Analysis Surfaces:	Lists the available analysis planes for use as the ray filter.	First valid analysis surface
Delete old rays and recreate all active sources	If checked, then the old rays are deleted, new rays are created, and they are traced before the spot diagram is plotted.	Unchecked
Raytrace all active rays	If checked, then the existing rays are raytraced and the spot diagram is generated.	Unchecked
Plot the rays as they are being raytraced	If checked the rays will be plotted when they are raytraced.	Unchecked
OK	Plot Irradiance Distribution and close dialog box.	
Cancel	Discard Irradiance plot and close dialog box.	
Help	Access this Help page.	

Application Notes Color Image

• The Color Image feature calculates the XYZ chromaticity coordinates for each pixel of the Analysis Surface. Those coordinates are converted into RGB values and displayed in the Chart Viewer.

• The Color Image Chart View presents four (4) panes; an RGB spatial map of color on the Analysis Surface, two cross-sectional profiles of the spatial map, and a chromaticity diagram. As the cursor is moved in the spatial map, a cursor in the chromaticity diagram indicates the XY chromaticity coordinate corresponding to the specific pixel where the spatial map cursor is positioned.

• The Chart View allows data to be displayed as RGB, Greyscale, Luminosity, or either of the three RGB components alone. Right-click in the Chart to invoke this menu:

Isotropic	Isotropic
Axes Labels	Axes Labels
Chart Color	Chart Color
Copy Image to Clipboard	Chart Color
Save Chart as Bmp	Copy Image to Clipboard
 Show Color (RGB) 	Save Chart to Bmp
Show Grayscale	Show Color (RGB)
Show Red Component	Show Greyscale
Show Green Component	Show Red component
Show Blue Component	Show Green Component
Show Luminosity (Y)	Show Blue Component
Adjust Image Brightness	Show Luminosity (Y)
Show in Visualization View	Adjust Image Brightness
	Show in Visualization View
Lock Window	Lock Window
Help	Help
Advanced	Advanced

See Also.... Color Image

Adjust Image Brightness

Help - Menu commands

The Help menu offers the following commands:

Help Topics	Brings up this help file.
Tutorials	
Keyboard Map	Shows a listing of which commands do what in FRED.
Frequently Asked Questions	
Script Language Reference	
Tip of the Day	Bring up the Tip of the Day dialog box.
Open the Photon Engineering Website	Opens a web browser turned to <u>http://www.photonengr.com</u> .
License Authorization	Brings up the License Authorization dialog
Demo Version	Displays a message box describing the Demo Version of FRED.
About	Brings up the About dialog box.

Help - Keyboard Map - Accelerator Keys

This page has two accelerator keys tables.

- 1. By command.
- 2. By accelerator key

There is also a set of accelerator keys that work with the different graphs available in FRED. They are listed <u>here</u>.

Accelerator Keys By Command

Command	Accelerator Key	
	Visualization View	Tree View
Open the help file	F1	F1
Switch to the Tree View / OpenGL View	F6	F6
Bring up a context menu	Shift+F10	Shift+F10
Close the file	Ctrl+F4	Ctrl+F4
Create a new optical system	Ctrl+N	Ctrl+N
Create a new macro	Ctrl+Shift+N	Ctrl+Shift+N
Open a file	Ctrl+O	Ctrl+O
Save the file	Ctrl+S	Ctrl+S
Print a file	Ctrl+P	Ctrl+P
Go to the command line	Ctrl+I	Ctrl+l
Switch between open documents	Ctrl+Tab	Ctrl+Tab
Import an IGES or STEP file	Ctrl+Shift+J	Ctrl+Shift+J
Import a CodeV, Zemax or OSLO lens prescription	Ctrl+Shift+I	Ctrl+Shift+I
Import an ASAP output file	Ctrl+Shift+K	Ctrl+Shift+K
Cut an element	none	Ctrl+X



Copy an element	none	Ctrl+C
Paste an element	none	Ctrl+V
Rename a selected element in Tree View	none	F2
Switch to trackball mode	F5	none
Switch to magnify mode	F7	none
Select an object	F8	none
Toggles between orthographic and perspective views	F9	none
View all objects in the scene	F10	none
Orbit the camera	Ctrl+F5	none
Translate the camera	Ctrl+F7	none
Rotate the camera	Ctrl+F8	none
Create a Positions Spot Diagram	Ctrl+F9	Ctrl+F9
Create an Irradiance Spread Function	Ctrl+F10	Ctrl+F10
Create a Directional Spot Diagram	Ctrl+F11	Ctrl+F11
Create an Intensity Spread Function	Ctrl+F12	Ctrl+F12
Toggle animation mode for continuous scene rotation	Shift+F5	none
Translate the scene	Shift+F7	none
Rotate the scene	Shift+F8	none
Perform a Best Focus Analysis	Shift+F9	Shift+F9
Create a Ray Summary	Shift+F11	Shift+F11
Display Ray Statistics	Shift+F12	Shift+F12
Delete existing rays	Ctrl+Shift+F5	none



and trace all optical sources		
Trace and draw all optical sources	Ctrl+Shift+F7	none
Create rays for all traceable optical sources but don't trace or draw them	Ctrl+Shift+F8	none
Delete all existing rays	Ctrl+Shift+F9	none
Edit the properties of the background grid	Ctrl+Shift+F12	none
Switch to looking towards the positive X direction	Ctrl+1	none
Switch to looking towards the positive Y direction	Ctrl+2	none
Switch to looking towards the positive Z direction	Ctrl+3	none
Switch to looking towards the negative X direction	Ctrl+4	none
Switch to looking towards the negative Y direction	Ctrl+5	none
Switch to looking towards the negative Z direction	Ctrl+6	none

Accelerator Keys By Key

Accelerator Key	Command or Key	
	Visualization View	Tree View View
F1	Opens the help file	Opens the help file
F2	none	Allows for renaming the

		selected element
F3		
F4		
F5	Switches to trackball mode	none
F6	Switches to the Tree View	Switches to the OpenGL View
F7	Switches to Magnify mode	none
F8	Switches to Select Object mode	none
F9		
F10	View All objects in the system (zoom out)	none
F11		
F12		
Ctrl+1	Switch to looking towards the positive X direction	none
Ctrl+2	Switch to looking towards the positive Y direction	none
Ctrl+3	Switch to looking towards the positive Z direction	none
Ctrl+4	Switch to looking towards the negative X direction	none
Ctrl+5	Switch to looking towards the negative Y direction	none
Ctrl+6	Switch to looking towards the negative Z direction	none
Ctrl+F1		
Ctrl+F2	none	Allows for renaming the selected element
Ctrl+F3		



Ctrl+F4	Asks if you want to save and closes the file	Asks if you want to save and closes the file
Ctrl+F5	Orbits the camera	none
Ctrl+F6		
Ctrl+F7	Translates the camera	none
Ctrl+F8	Rotates the camera	none
Ctrl+F9	Positions Spot Diagram	Positions Spot Diagram
Ctrl+F10	Irradiance Spread Function	Irradiance Spread Function
Ctrl+F11	Directional Spot Diagram	Directional Spot Diagram
Ctrl+F12	Intensity Spread Function	Intensity Spread Function
Shift+F1	Opens the help file	Opens the help file
Shift+F2	none	Allows for renaming the selected element
Shift+F3		
Shift+F4		
Shift+F5	Toggles animation mode for continuous scene rotation	none
Shift+F6	Switches to the Tree View	Switches to the Visualization View
Shift+F7	Translates the scene	none
Shift+F8	Rotates the scene	none
Shift+F9	Performs a Best Focus Analysis	Performs a Best Focus Analysis
Shift+F10	Prints out the Ray Status	Prints out the Ray Status
Shift+F11	Ray Summary	Ray Summary
Shift+F12	Ray Statistics	Ray Statistics
Ctrl+Shift+F1		
Ctrl+Shift+F2		



Ctrl+Shift+F3		
Ctrl+Shift+F4	Closes the file and asks if you want to save	Closes the file and asks if you want to save
Ctrl+Shift+F5	Deletes existing rays and trace all optical sources	none
Ctrl+Shift+F6	Switches between open documents	Switches between open documents
Ctrl+Shift+F7	Traces and draws all optical sources	Traces and draws all optical sources
Ctrl+Shift+F8		
Ctrl+Shift+F9		
Ctrl+Shift+F10		
Ctrl+Shift+F11		
Ctrl+Shift+F12		

2D and 3D Graph Accelerator Keys

The following keystrokes are available when viewing graphs. You can use the middle mouse button instead of the left + right button combination, if your mouse driver has not mapped the middle button to something else.

Accelerator Key Combination	Command		
	2-D Graph	3-D Graph	
Both mouse buttons	nothing	rotate the graph freely	
Both mouse buttons + Ctrl		zoom into or out of the graph	
Both mouse buttons + Shift		shift the graph left, right, up, or down	
Ctrl + Left mouse button + drag		Zoom in on a portion of the graph	
Shift + Left mouse button + drag		Zoom in on a portion of the graph and display axes values	
R		Return the camera to its original (unzoomed, unshifted) view of the graph	
Both mouse buttons + X	nothing	Rotate the grid about the X axis	
Both mouse buttons + Y	nothing	Rotate the grid about the Y axis	
Both mouse buttons + Z	nothing	Rotate the grid about the Z axis	

Help - About Command (Help menu)

Description How Do I Get There?

Description About FRED (Help menu)

Use this command to display the copyright notice and version number of your copy of FRED.

How Do I Get There? About FRED (Help menu)

From the Help menu, choose About FRED...

<u>H</u> elp	
E	elp Topics
Т	utorials
K	eyboard Map
E	requently Asked Questions
S	cripting •
I	ip of the Day
I	est Flight (Adobe Acrobat Format)
G	pen the Photon Engineering Website
Q	heck for Updates
Ŀ	jcense Authorization
ρ	bout the <u>D</u> emo Version
8	bout FRED

Help - Script menu commands

The Script menu offers the following commands:

Run	Runs the current script.
Debug Run Start	Begins the current script in the script debugger, stopping at any breakpoints.
Debug Step Into	Advances into the next execution statement
Debug Step Over	Advances over the next execution statement
Debug End	Ends the script debugging session.
Toggle Debug Breakpoint	Sets a debug breakpoint on the current line if one does not

	exist, or removes one if it does exist.		
Clear All Debug Breakpoints	Removes all debug breakpoints from the script.		
Associate With FRED Document	Associates the script with a FRED document that is open.		

Run command

Description

How Do I Get There?

Description - Run command

Use this command to Run a FRED Script.

How Do I Get There? - Run command

There are three ways to execute this command:

- On the Script Toolbar, press this button:
 Use the keyboard shortcut Ctrl+B.
- 3. From the Script menu, choose "Run".

<u>Script View Tools Window Help</u>

▶ <u>R</u> un	Ctrl+B
_heck Syntax K	
Compile And Save	
∎↓ Debug Run <u>S</u> tart	Ctrl+Shft+B
The Debug Step Into	Ctrl+Q
Pebug Step Over	Ctrl+Shft+Q
🗙 Debug End	Ctrl+Alt+Q
• Toggle Debug Breakpoint	Ctrl+K
🝨 Clear All Debug Breakpoints	Ctrl+Shft+K
Associate with FRED Document	,



Debug Start command

Description

How Do I Get There?

Description - Debug Start command

Use this command to begin running a FRED Script in the debugger. This command differs from the Run command in that it pauses the script at a breakpoint, if one exists. This command is only available when a Script is active.

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How Do I Get There? - Debug Start command

There are three ways to execute this command:

- 1. On the Script Toolbar, click this button:
- 2. Use the keyboard shortcut Ctrl+Shift+B.
- 3. From the Script menu, choose "Debug Run Start".

Script View Tools Window Help

<u>R</u> un <u>C</u> heck Syntax Compile And Save	Ctrl+B
<mark>≣↓</mark> Debug Run <u>S</u> tart	Ctrl+Shft+B
🚹 Debug Step Into	Ctrl+Q
→ Debug Step <u>O</u> ver	Ctrl+Shft+Q
🗙 Debug End	Ctrl+Alt+Q
• Toggle Debug Breakpoint	Ctrl+K
🝨 Clear All Debug Breakpoints	Ctrl+Shft+K
Associate with FRED Document	

Debug Step Into command -

Description How Do I Get There?

Description - Debug Step Into command

Use this command to execute the next line of script code, then pause again. If the next line is a call to a function or subroutine you have written, this command will advance to the first



line of that function or subroutine. This command is only available if the script is being run in the debugger.

{*}

How Do I Get There? - Debug Step Into command

There are three ways to execute this command:

- 1. On the Script Toolbar, click this button:
- 2. On the Script menu, choose "Debug Step Into".

<u>S</u> cript	⊻iew	<u>T</u> ools	<u>W</u> indow	Help		
• <u>R</u> u	▶ <u>R</u> un Ctrl+B					
⊆ŀ	neck Sy	ntax 🛛				
Co	om <u>p</u> ile /	And Sav	/e			
≣ ↓ De	ebug Ri	un <u>S</u> tari	t		Ctrl+Shft+B	
{*}	Pebug Step Into I Ctrl+Q					
{} ⁺ De	ebug St	:ep <u>O</u> ve	er		Ctrl+Shft+Q	
imes D6	🗙 Debug End Ctrl+Alt+Q					
<u>I</u> oggle Debug Breakpoint Ctrl+K						
🐤 Clear All Debug Breakpoints Ctrl+Shft+K						
Associate with FRED Document						

3. Use they keyboard shortcut Ctrl+Q.

Debug Step Over command

Description How Do I Get There?

Description - Debug Step Over command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected.

How Do I Get There? - Debug Step Over command

There are three ways to execute this command:

- 1. Toolbar:
- 2. Menu: Script->Debug Step Over

<u>Script</u> <u>View</u> <u>T</u> ools <u>W</u> indow <u>H</u> elp					
▶ <u>R</u> un Ctrl+B					
<u>C</u> heck Syntax					
Compile And Save					
≣↓ Debug Run <u>S</u> tart	Ctrl+Shft+B				
The Debug Step Into	Ctrl+Q				
Pebug Step Over	Ctrl+Shft+Q				
🗙 Debug End 📈	Ctrl+Alt+Q				
🔶 Toggle Debug Breakpoint	Ctrl+K				
🜪 Clear All Debug Breakpoints	Ctrl+Shft+K				
Associate with FRED Document					
3. Keyboard Shortcut: Ctrl+S	Shift+Q				

Debug End command

Description

How Do I Get There?

Description - Debug End command

Use this command to end a script debugging session. This command is unavailable if a script is not running.

How Do I Get There? - Debug End command

There are two ways to execute this command:

- 1. On the Script Toolbar, click this button:
- 2. From the Script menu, choose "Debug End".



<u>Script View Tools Win</u>	dow <u>H</u> elp			
▶ <u>R</u> un	Ctrl+B			
⊆heck Syntax				
Compile And Save				
■↓ Debug Run Co <u>n</u> tinue	Ctrl+Shft+B			
🔁 Debug Step Into	Ctrl+Q			
↓ Debug Step Over	Ctrl+Shft+Q			
X Debug End Ctrl+Alt+Q				
<u>T</u> oggle Debug Breakpoint Ctrl+K				
🝨 Clear All Debug Breakpoints 👘 Ctrl+Shft+K				
Associate with FRED Document				

Toggle Breakpoint command

Description How Do I Get There?

Description - Toggle Breakpoint command

Use this command to copy selected data onto the clipboard. This command is unavailable if there is no data currently selected.

How Do I Get There? - Toggle Breakpoint command

There are three ways to execute this command:

1. On the Script Toolbar, click this button:

2. From the Script menu, choose "Toggle Debug Breakpoint".

<u>Script View Tools Window Help</u>

🕨 <u>R</u> un	Ctrl+B
<u>C</u> heck Syntax	
Compile And Save	
≣↓ Debug Run <u>S</u> tart	Ctrl+Shft+B
The Debug Step Into	Ctrl+Q
Debug Step Over	Ctrl+Shft+Q
🗙 Debug End	Ctrl+Alt+Q
<u>T</u> oggle Debug Breakpoint	Ctrl+K
🍨 Clear All Debug Breakpoints	^K Ctrl+Shft+K
Associate with FRED Document	t
lice the keyboard charter	it Ctrl I

3. Use the keyboard shortcut Ctrl+K.

Clear All Breakpoints command

Description How Do I Get There?

Description - Clear All Breakpoints command

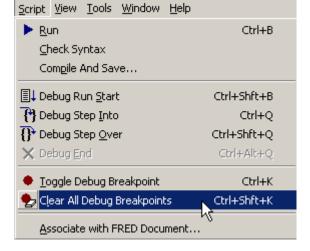
Use this command to remove all breakpoints in the current script.

How Do I Get There? - Clear All Breakpoints command

There are three ways to execute this command:

- 1. On the Script Toolbar, click this button:
- 2. On the Script menu, choose "Clear All Debug Breakpoints".

Þ



3. Use the keyboard shortcut Ctrl+Shift+K.



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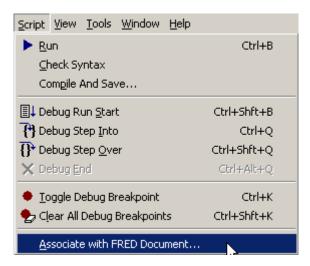
Associate With FRED Document

Description How Do I Get There?

Description - Associate With Document

Associates a FRED script with an existing FRED document.

How Do I Get There? - Associate With Document



Output Window Cut

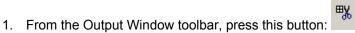
Description How Do I Get There?

Description Output Window: Cut

This command takes the current selection in the text output window and cuts it to the Windows clipboard. The selected area remains selected. If nothing is selected, nothing gets cut.



There are three ways to execute this command:



- 2. Use the Ctrl+Shift+X keyboard shortcut.
- 3. From the edit menu, select "Output Window Cut".



Example 1 - MTF Calculations in FRED

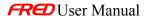
Description Geometry & Sources Setting up the Calculation MTF Comparison 1 MTF Comparison 2

Description - MTF Calculations in FRED

This help article describes how to perform a Modular Transformation Function in FRED.

Geometry & Sources - MTF Calculations in FRED

MTF Calculations can be performed on any system that has a coherent source. In this example, we use the file mtflens.frd, found in the Complete Systems Samples directory (C:\Program Files\Photon Engineering\FRED <version number>\Samples\Complete Systems, by default). It consists of a coherent source, a BK7 lens, and a focal plane. The lens is shifted in the Z direction by 1, while the focal plane is shifted in Z by 94.591622 units relative to surface 2 of the lens.



_

🛟 (mtí	flens.frd) Location				? <u> </u>
Name					
	etry.Subassembly 1.detector			[OK
Descr	iption:				Connect
				-	Cancel
					Apply
				Ī	Help
Locati	ion:				
		Action	Parameters (r	ight mouse-	click for pop
	Starting Coordinate System	n			
0	Geometry.Subassembly 1.	Lens 1.Surface			
	Occurrent of the second bill		Z 94,591622		
1	Geometry.Subassembl 💌	Shiπ in Z dir 💌	94.591022		
ш					
	ations On The Above Location				
Express In This Coordinate System:					
	Simplify				

The detector location

(🚰 (mtflens.frd) Edit Lens	? _ 🗆 🗙			
Parent: Subassembly 1	OK			
Name: Lens 1	Close			
Description: simple BK7 singlet: r1=60 mm, r2=-300 mm, ct=4 mm	Apply			
	Help			
Basic Parameters Parameter Type: Front Radius: Back Radius: Thickness Radii 60 -300 4 4	\$5:			
Lens Aperture Specification Materials X Semi-ape: Y Semi-ape: 10 10 Advanced Settings Air				
Location of the Lens (at front surface vertex) (right mouse-click for pop-up menu)				
Reference Coordinate Action Parameters (right mouse-click for popup Starting Coordinate System				
Derived Properties (computed from the basic parameters entered above) Focal: 97.1303972707 Front Prin: 0.4412128517 Wavlen(um): 0.5892938				
Bend: 0.666666666666666666666666666666666666	Update			

The lens specification

Polar	ization	1.	Wavelengths Visualization) OK
Source	Positions/D)irections	Location/Orientation Power Coh	
Ray Position:	3			
Туре:	Grid Plane (re	etangular array	of points arranged on a plane)	Apply
Parameters:		Parameter	Description	Help
	X Num Rays	41	Number of rays across X	
	YNum Rays	41	Number of rays across Y	
	X Semi-Ape	5	X Semi-aperture	
	Y Semi-Ape	5	Y Semi-aperture	
	Aperture	Elliptical 📘	The aperture shape	-
Ray Directior Type:		on (plane wave)	•
Parameters:		Parameter	Description	
	X Component	0	X component of ray direction	
	Y Component	: 0	Y component of ray direction	
	Z Component	1	Z component of ray direction	

The source position & direction

Setting up the Calculation - MTF Calculations in FRED

MTF Comparison 1- MTF Calculations in FRED

MTF Comparison 2 - MTF Calculations in FRED





Example 2 - Fluorescence in R6G

This example demonstrates the methodology of simulating fluorescence in FRED. Fluorescence is implemented through the wavelength attribute *g_w* associated with a scripted Scatter model. This attribute permits the wavelength of individual rays to be altered according to a user-programmed probability distribution. The ability to alter the wavelength assignment of individual rays is a key architectural feature of FRED. Indeed, the scripting language offers increased capability in wavelength manipulation. The power of FRED allows the user to carry out accurate color simulations for a wide range of physical phenomena; fluorescence being just one example.

The example has four parts:

Setting up the Problem Add a Source Add Geometry Add a Scatter Model Running the Simulation

Setting Up the Problem

This simulation involves 0.486 μ m light from an Ar⁺ ion laser incident upon a host layer impregnated with Rhodamine 6G dye.

Add a Source

Let this source have a gaussian width of 0.075 mm,



ouresce	ence.frd *)	Edit Optical S	iource: "arg	jon	ion"			_ 🗆 ×
	olarization		Wave				ualization	ОК
Source	' <u> </u>	ons/Directions	Loc	atior	n/Orientation	Power	Coherence	Cancel
	Power: 1				Direction Apodiz	ation		Apply
Туре:					Туре:			Help
Gaussia Paramet		(useful for Ga	ussian t 💌		Uniform Unit Ap Parameters:	odization (equi	valent to no 💌	
i aramet		Description			No Data Requ	ired		
X width		X semi-width	of 1/e^2 (1					
Y width	0.075	Y semi-width						
X pos	0	X offset of Ga	aussian ce					
Y pos	0	Y offset of G	aussian ce					

and a wavelength of 0.486 $\mu m.$



(flourescence.frd *) Edit Optical Source: "argon ion"	_ <u> </u>
Source Positions/Directions Location/Orientation Power Polarization Wavelengths Visu	Coherence OK ualization Cancel
Wavelength List (right mouse-click for menu) Wavelength Apodization Type: Uniform Unit Apodization Parameters: No Data	n (optional) Apply

Add Geometry Add now a plane surface to represent the film of Rhodamine 6G:



🗳 (flourescence.frd *) Edit Surface: "fluorescent film"	<u> </u>
Scatter Visualization Glue Grating Auxiliary Data Modifiers SURFACE Aperture Location/Orientation Materials Coating/RayControl	OK Cancel
Logical Parent: .rhodamine 6G Name: fluorescent film	Apply
Description:	Help
Traceable (this surface can be raytraced) Use for trimming only (never raytrace)	
No data	

Set the Coating to "Transmit", the Raytrace Control to "Allow All", and make the scattered rays have a different color.

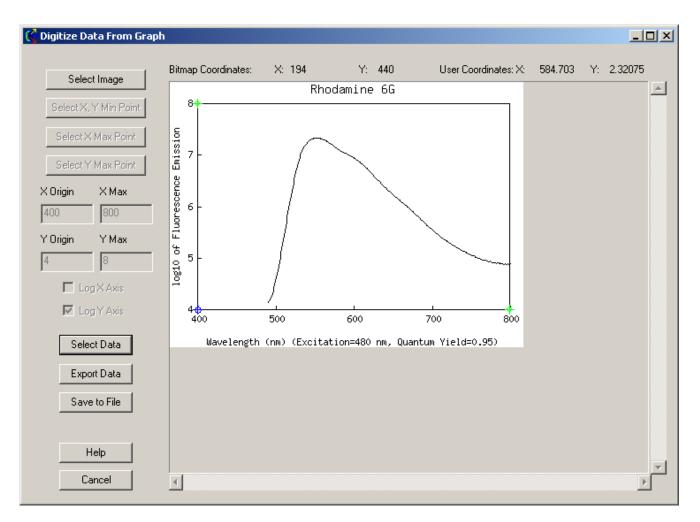


📢 (flourescence.fr	d *) Edit Sur	face: "fluorescer	nt film"				_ 🗆 ×
Scatter SURFACE	Visualization Aperture	Glue Clue	Grating ntation	Auxiliary Auxiliary Materials		Modifiers ng/RayControl	OK Cancel
Ray Colors Change color	Coating Assigned:	Transmit		100% Trans	smissive C	Coating	Apply
of rays that intersect this surface:	List of Available Coatings:	Name Absorb Reflect Transmit	100% Refle 100% Trans	bing Coating ctive Coating missive Coatir		Assign	Help
	- Raytrace C	Standard Coating	96% Transn	hitting, 4% Ref		ireate New	
	Assigned:	Allow All	Description	Allow all ray	compone		
	List of Available Raytrace	Halt All Transmit Specular Reflect Specular	Halt all ray of Allow transm	components hitted specular ted specular ra		Assign	
Scatter	Controls:	Allow All		components	_	ireate New	

Add a Scatter Model

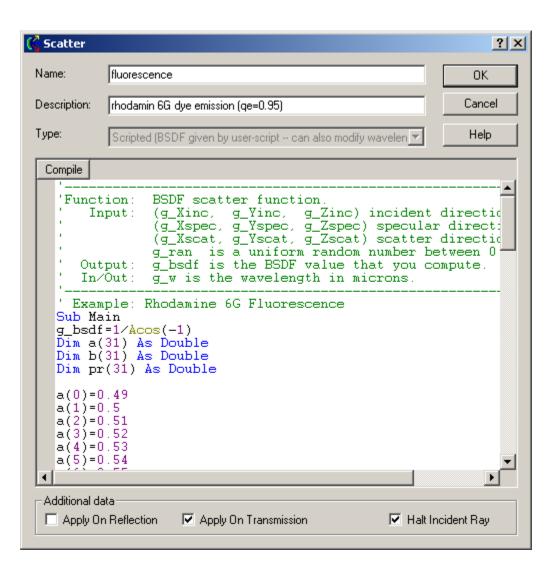
In order to complete the fluorescence surface definition, data for Rhodamine 6G must be inserted into a FRED scripted scatter model. FRED's Coating digitizer is convenient method of transforming graphic images into numerical data sets. Shown here is a bitmap image of the Rhodamine 6G emission spectra loaded into the digitizer.

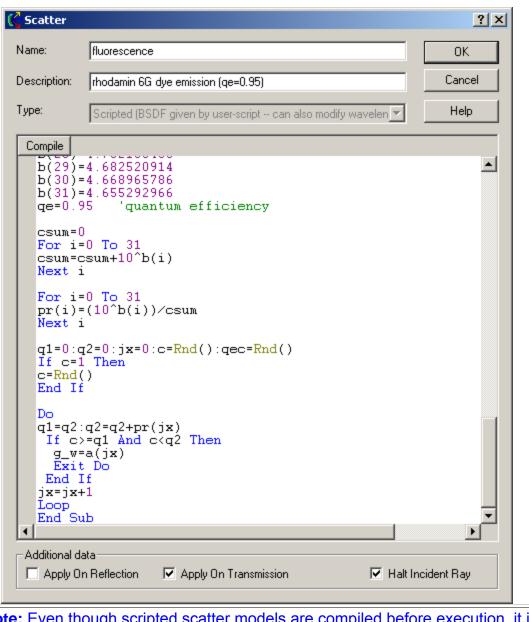




The data from the digitized file can then processed and included in a scripted Scatter model shown here in part:

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Note: Even though scripted scatter models are compiled before execution, it is recommended that datasets included within them should be kept compact so as to have minimal impact on raytrace speed.

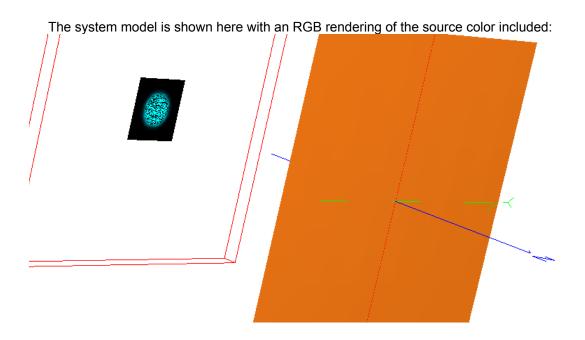
This scatter model is assigned to the film surface and scatter into a small angle around specular is chosen as the Scatter Direction:



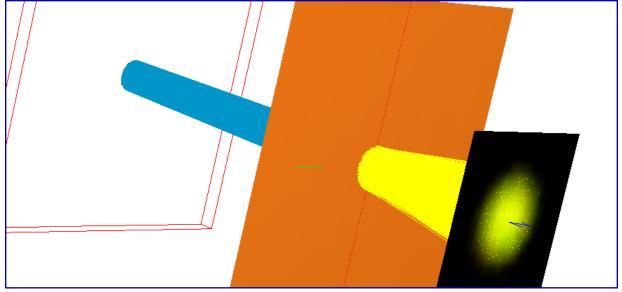
📢 (flouresco	ence.frd *) Edit Surf	ace: "fluorescent film"			_ 🗆 🗙
SURFAC Scatter	E Aperture Visualization	Location/Orientation	Materials Auxiliary	Coating/RayCont Data Addifie	ers i
Note: Che ⊢Scatter-	cked items are active,	unchecked items are ignored	during the raytrac	e	Cancel Apply
Assigner	d Scatter Properties: scence (rhodamin 6G Virection Region(s) of In amp 1	> Remove Edit/View Create New	Available Scatter Name Black Lambertia White Lambertia Harvey Shack fluorescence fluorescence2	Description n 4% Lambertia n 96% Lambert Polished surf rhodamin 6G	an Help
(Importan	ice Sampling Specifi	cations (for Scatter)		?×	
Description:			Can		
Туре:	Scatter rays into a giv	en direction	▼ He	lp	
Valu	le	Description			
Other Data	al Coordinate Syste 💌 🔲 Reverse Ray Di e Scale Factor: 1		ector ector rection vector tter Rays: 1		

A detector surface is also created to catch the transmitted fluorescence and to accommodate an Analysis Surface.

Running the Simulation



The image below shows a Color Image calculation at the detector implemented with the *Show in Visualization View* feature of the Chart Viewer. This rendering is an RGB representation of the spectral content of fluorescence as described by the digitized data. Anyone who has operated a dye laser will recognize the familiar yellow color of this common laser dye.





Example 3 - Color Separation by Polarization

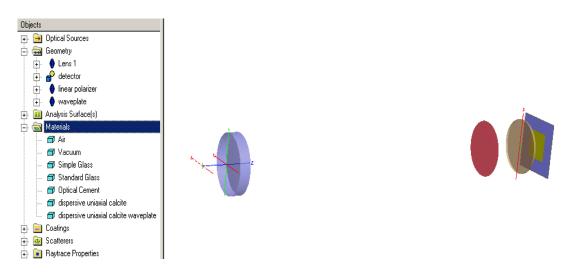
Description How Do I Get There?

Description - Color Separation by Polarization

This example illustrates the spatial separation of color resulting from passage through birefringent optical elements. Polarized white light is incident upon a simple lens made from calcite, a uniaxial crystal. The converging bundle continues through a waveplate and a polarizing element and is captured on a screen. The Color Image feature in FRED is used to display the spatially distributed spectra.

Example - Color Separation by Polarization

Start by setting up the geometry. Included here are a plano-convex calcite lens followed by a calcite waveplate, a linear polarizer and a collection plane.



Even though there are two orientations of calcite in this model, only one calcite material need be created. The material orientation defined for the lens has its fast axis along global-z:



_

polari	zed_cryst	al_col	ors3_600.f	rd) Edit Material	: "dispersivo	e uniaxial calcite"	
aterial	Absorption	Volu	ime Scatter				OK
Name:	dispe	rsive u	niaxial calcite				Cancel
Descrip	tion:						Apply
							Help
Гуре:	Same	olad Rir	ofringent and	l/or Optically Active	Material		
урс.	Loam	JIEU DII	ennigent ant	or opacally Acave	material		
N=refr	active indi	ces, (G=gyrotrop	ic coefficients, r	ight-click for	menu	
	Х		Υ	Z			
Axis	0		0	1		tal axis vector	
	_			N extraordinary		G extraordinary	_
0	0.425	_	1.6771	1.495	0	0	.]]
1	0.4475	_	1.6732	1.4933	0	0	a
2	0.47	_	1.6699	1.4917	0	0	
3	0.4925	_	1.667	1.4904	0	0	
4	0.515	_	1.6646	1.4893	0	0	
5	0.5375	_	1.6624	1.4883	0	0	
6	0.56	_	1.6605	1.4874	0	0	
7	0.5825	_	1.6588	1.4866	0	0	
8	0.605	_	1.6573	1.4859	0	0	
9	0.6275	_	1.656	1.4853	0	0	
10	0.65	_	1.6547	1.4848	0	0	. 🔽 🔰
•						► F	
- Comm	on Gradien	i Index	Material Par	ameters and Other F	arameters-		
0.011111			# Steps	X Offset	Y Offset	Z Offset	
Stee					- Ulise	Z UIISEL	
Step 0.1	bize	1000		0	0	0	-

The calcite waveplate material is oriented with its fast axis bisecting the global +x & +y directions. The same birefringent material definition used for the lens can also be used for the waveplate by applying a coordinate transformation to the waveplate surfaces through the "Edit/View GRIN/Birefringent Position/Orientation" dialog:



waveplate		
🥜 Surface 1 🖌 Surface 2	✓ Iraceable	
Edge	Never Traceable (for trimming surfaces)	
] 📷 Analysis Surface(s)	Draw O <u>u</u> ter Enclosing Volume Coordinate Axes	
🍌 small area image p 구 词 Materials	Visualization Attributes	
Air Vacuum Simple Glass Standard Glass	<u>P</u> osition/Orientation Parent Coordinate S <u>v</u> stem Sc <u>a</u> le	
 	X Cut	Ctrl+X
🛄 🎁 dispersive uniaxial	Copy	Ctrl+C
-)- 🦲 Coatings	💼 Paste	Ctrl+∀
- 🔂 Scatterers	Delete (all highlighted items)	Del
-)- 💽 Raytrace Properties	Su <u>m</u> mary Report	
	Detailed Report	
	Edit/View Surface	
	Edit/View GRIN/Birefringent Material Position/Orientation.	
	<u>G</u> lue	N
	Draw Surface Trimming <u>V</u> olume	
	Edit/View Array Parameters	
	Delete Array Parameters	
A	Edit/View <u>⊂</u> urve	



	Reference Coordinate	Action	Parameters (right	mouse-click f
	Starting Coordinate System	m		
0	Geometry.waveplate ()			
			X-angle (deg)	
1	Geometry.waveplate 💌	Rotate abc 🖣	90	
	-		Z-angle (deg)	
2	Geometry.waveplate 💌	Rotate abc 🖣	45	

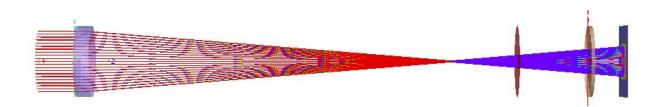
The polarizer has a coating that passes only light polarized along the global x-direction:

(pola	rized_cı	rystal	_colors3	_60	00.frd) Edit Coating	?)
Name:	lin	near po	olarizer			OK
Descrip	tion:					Cancel
Гуре:	F	Polarize	x/Wavepla	ate (Coating (Jones matrix)	Help
	Value				Description	
Туре	X Linear	Polariz	er j	•	Type of polarization coating (applied in transmission	on only)
Coat	Transmit			•	Coating in addition to the polarization coating	
	Amplit	ude	Phase(de	g)		
J00	1	C)		Matrix element J(row,col)	
J10	0	C)		Matrix element J(row,col)	
J01	0	C)		Matrix element J(row,col)	
J11	0	C)		Matrix element J(row,col)	

The source is a coherent, collimated bundle polarized along the global y-direction. The "Synthesize a Color" feature was used to create and weight a range of evenly spaced wavelengths simulating the color "white".

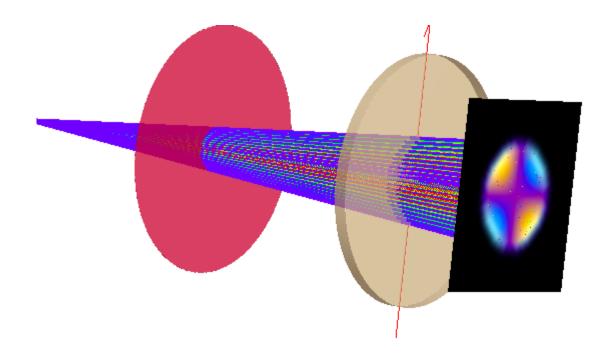
Type:	ype: Collimated source (plane wave)							•	Power: 1	
	Y num 21 Number of rays across the full Y aperture X semi 0.9 X semi-aperture of the collimated beam Y semi 0.9 Y semi-aperture of the collimated beam Shape Elliptical Cross section shape of the beam X dir 0 X-axis component of the propagation direction								Coherence and Coherent Polarized 0 <ellipticity Angle (deg)</ellipticity 	c1: 0
_ Locat	= ion/Orientatior	η <u> </u>				Wavelei	ngth List ——			
	Reference	e Coordinate:	Action	Parameters	(rig		Wavlens (u	m) Weig	jhts Ray Color	
	Starting C	oordinate Syster	n			1	0.425	▼ 0.17	3397	
0	Optical So	ources ()				2	0.4475	- 0.30	4362	
				X	Y	3	0.47	- 0.23	2946 🗾 🔻	
1	Optical So	ources () 🔽	Shift 🔻	0	0	4	0.4925	• 0.11	8920 🗾 🔫	
				Z-angle (deg)		5	0.515	- 0.15	6025	
2	EQUILITIES OF		Rotate abc 🔻	0		6	0.5375	• 0.22	9968	
						7	0.56	- 0.26	4752	
						8	0.5825	• 0.25	5112	
						9	0.605	• 0.20	0036 🗾 🔻	
						10	0.6275	👤 0.11	5097 🗾 🔫	
						11	0.65	👤 0.04	4051 🗾 🔫	
						12		- 1		

Upon tracing the source



and evaluating the rays on the detector using the Color Image feature, the image has the following appearance. This view is obtained by invoking the "Show in Visualization View.." option in the Chart Viewer and setting the detector Visualization Attribute *Opacity* to "Invisible".







Example 4 - Scripting With Libraries

Description <u>1. Cumulative Spot Diagram</u> <u>2. Large Raytrace</u> <u>See Also...</u>

Description Scripting With Libraries

> **FRED**'s script language is the key to effecting specialized, repetitive or complex tasks. This example contains scripts that address two often requested features; the cumulative spot diagram and an efficient method of executing large raytraces. These tasks are implemented here in the compact and efficient form of Basic libraries.

Cumulative Spot Diagram Scripting With Libraries

Spot diagrams, irradiance and intensity calculations require an Analysis Surface. Ray Filter Specifications are applied to an Analysis Surface to restrict which rays are used in the calculation, the default being AND All Rays. While there are nearly fifty Ray Filter Specifications (see <u>Analysis Surface Ray Selection</u>), none of these allow for inclusion of rays that intersect a given surface at one or more points along its path but terminate on some other surface. **FRED** does offer a solution to this dilemma by allowing the user to create temporary buffers that store information as the rays step through the system. When the raytrace finishes, these temporary buffers can be swapped into and out of the main buffer for calculation purposes. Please note that, in **FRED**, only rays in the main buffer can be analyzed.

Executing a cumulative spot diagram in **FRED** requires the following steps: 1) create a temporary buffer for storage; 2) run an Advanced Raytrace stepping the rays incrementally through the system. At each increment, the rays are polled based upon the object they are currently on. Rays on the target surface are stored in the buffer; 3) Upon completion, rays in the temporary buffer are copied to the main buffer and the temporary buffer is deleted. The subroutine SurfAccum has two arguments; cn, the number of single steps needed to finish the raytrace and surfid, the node number of the target surface. This routine should not be used with a totally absorbing surface. It is also recommended that your entire system be enclosed in an absorbing sphere to insure that rays are not overcounted.

Sub SurfAccum (surfid As Long, anode As Long, drawray As Boolean)

Dim rtemp& Dim success As Boolean Dim adv As T_ADVANCEDRAYTRACE Dim fop As T_OPERATION Dim tf As T_RAYFILTEROP InitAdvancedRaytrace adv 'initalize the Advanced Raytrace with default settings

rtemp = AddRayBuffer () 'add a temporary buffer

```
adv.hitcount=1 'step one intersection at a time
adv.traceactivesources=True 'create new rays the first time
adv.draw=drawray
```

'set coordinate system of Analysis surface to snode GetOperation anode, 0, fop fop.parent=surfid SetOperation anode, 0, fop

'set Analysis surface Ray filter spec success = GetAnalysisSurfIthOp (anode, 0, tf) tf.opCode=3:tf.text=GetFullName(surfid) SetAnalysisSurfIthOp anode, 0, tf

count=1 'default count value
stepcount=0 'zero step counter

While count <> 0 'loop until there are no more rays to trace

count=AdvancedRaytrace(adv) 'advance rays one intersection
stepcount=stepcount+1 'number of intersections traced

'loop over all rays. if ray is on the target surface, store ray in the temporary buffer If count<>0 Then For j=0 To GetRayCount()-1 If GetRayEntity(j)=surfid Then CopyRayBufferToBuffer j,0,rtemp End If Next j End If

adv.traceactivesources=False 'set to Trace Existing for remainder of process

Wend

DeleteRays 'empty main buffer before transfer

```
'move rays from temporary buffer to main buffer for analysis
For j=0 To GetRayBufferRayCount(rtemp)-1
CopyRayBufferToBuffer j,rtemp,0
Next j
```

'delete temporary buffer after use (frees RAM) DeleteRayBuffer rtemp Print stepcount, "steps taken. Rays intersecting ", GetName(surfid), " have been transferred to the main buffer for analysis"

End Sub

Warning: Ray buffers use RAM. Delete them after use. Otherwise, memory will not be relinquished until the **FRED** document is closed.

As an alternative to including blocks of code in a working script, save them to a library and gain easy access as if the subroutine were a new FRED command. Follow these steps to create a FRED library:

1) Copy the subroutine lines of code to the clipboard and paste them into a new FRED script.

Save this script as an .frs file to allow for future editing.

The .frl libraries CANNOT be edited directly.

Script1
If GetRayEntity(j)=surfid Then
CopyRayBufferToBuffer j,0,rtemp End If
Next j
Next i
'move rays from temporary buffer to main buffer so they can be analyzed 'main buffer rays are lost (unless you make another buffer to temporarily store them ir
For j=0 To GetRayBufferRayCount(rtemp)-1 CopyRayBufferToBuffer j,rtemp,0 Next j
'delete temporary buffer after use (if not done, this can eat up RAM) DeleteRayBuffer rtemp
Print "Done. Rays that intersected node ", surfid, " have been transferred to the main
End Sub

2) From the Script menu, select Compile and Save..



	<u>Script</u> <u>View</u> <u>Tools</u> <u>W</u> indow <u>H</u> elp							
	▶ <u>R</u> un Ctrl+B							
ł.	⊆heck Syntax							
ļ	Compile And Save							
	□↓ Debug Run <u>S</u> tart	Ctrl+Shft+B						
÷	T Debug Step Into Ctrl+Q							
1	Debug Step Over Ctrl+Shft+Q							
1	🗙 Debug End	Ctrl+Alt+Q						
,	• Toggle Debug Breakpoint	Ctrl+K						
	🝨 Clear All Debug Breakpoints	Ctrl+Shft+K						
i	Associate with FRED Document							

3) Save the file as a Compiled Fred Library (*.frl)

Save Compile	d Script				? ×
Save in: 🛅	temp	•	🔁	📸 🏢 -	
File name:	×.frl			Sav	e
Save as type:	Compiled Script Library Files (*.frl)		•	Cano	el //

To use the subroutines or functions stored in a library, declare a Basic object name and call the library with the **FRED** command <u>GetLib</u>. For example, to use the SurfAccum subroutine from a library named mytoolkit.frl,

Dim mylib As Object Set mylib = GetLib ("C:\Documents and Settings\My Documents\FRED files\mytoolkit.frl")

mylib.SurfAccum 20, 62, True

Large Raytrace Scripting With Libraries

FRED User Manual

Since rays take up space in memory, tracing a large number of rays can be made more efficient by breaking up the task into many smaller traces. In the case when incoherent irradiance or intensity is needed for a large collection of rays, the calculation can be done incrementally and displayed at the end. The following subroutine traces a defined source numloop times accumulating the irradiance at the Analysis Surface with node number anode attached to the surface with node number snode.

Sub largetraceirrad (snode As Long, anode As Long, numloop As Integer, fname As String)

Dim filename\$, rcount&, icount&, xdim&, ydim&, parent&, pwr#, xlim&, ylim&, ck& Dim ana As T_ANALYSIS Dim ent As T_ENTITY Dim temp() As Double Dim irrad() As Double

'load data from the Analysis Surface and transform to local coordinates of measurement surface
LoadAnalysis anode, ana
TransformPosition -1, snode, ana.posX, ana.posY, ana.posZ
TransformDirection -1, snode, ana.AcellX, ana.AcellY, ana.AcellZ
TransformDirection -1, snode, ana.BcellX, ana.BcellY, ana.BcellZ
'number of pixels in x & y
xlim=ana.Amax-ana.Amin
ylim=ana.Bmax-ana.Bmin

'scale source power based upon number of loops
For l=0 To GetEntityCount()-1
If IsSource(l)=True Then
pwr=GetSourcePower(l)
pwr=pwr/numloop
SetSourcePower l, pwr
End If
Next l

t1=Time 'note start time

rcount=0 'zero counter

'loop over rays defined in Source Folder For i=1 To numloop Print "running trace ",i

TraceCreate 'trace with no render to use all available processors

put additional Ray Specification Filters here 'For s=0 To GetRayCount()-1 If xxxxx Then SetRavActive s,True Else SetRayActive s,False End If Next s ***** 'calculate irradiance If i=1 Then icount = Irradiance (snode, snode, ana, irrad()) 'note: irradiance calculated in local coordinates of snode Else icount = Irradiance (snode, snode, ana, temp()) rcount=rcount+icount 'running count of rays used in irradiance calculation 'accumulate irradiance values in irrad() For j=0 To xlim-1 For k=0 To ylim-1 irrad(j,k)=irrad(j,k)+temp(j,k)Next k Next j End If Next i DeleteRays 'delete rays upon completion to free up RAM 'write out irradiance calculation to PlotFile un user Current Directory fileName = CurDir & "\" & fname & ".dat" WriteToPlotFile fileName, ana, irrad() t2=Time 'ending time 'Print begining And ending times Print "end time ", t2 Print "start time ", t1 Print rcount & " rays combined" End Sub

Add these lines to the library and recompile the library as shown above. The subroutine largetraceirrad is implemented in script as follows:



```
Dim mylib As Object
Set mylib = GetLib ("C:\Documents and Settings\My Documents\FRED
files\mytoolkit.frl")
```

mylib.largetraceirrad 17,18,3,"myirradiance"

To view the irradiance data in the Chart Viewer, set focus to the FRED document and select User-defined 3D Chart View from the Tools menu

<u>T</u> ools	<u>R</u> aytrace	<u>3</u> D View	⊆reate	<u>A</u> nalyses	<u>W</u> indow	<u>H</u> elp			
₽	eferences.								
<u>U</u> :	User Defined Scripting Tools								
U	Units and Scaling								
Ec	dit/∀iew GR	IN/Birefrin	gent <u>M</u> at	erial Positio	n/Oriental	tion			
R	eports					•			
B	5DF Data Fi	tting				•			
U:	User-defined 3D <u>C</u> hart View								
D	Determine Scatter Importance Sampling								
<u>A</u>	Analyze Scatter Importance Sampling,								
E	Eorce Immediate Document Update								
Ed	dit/View Pr <u>e</u>	-Update S	icript						
Ed	dit/View P <u>o</u> s	;t-Update	Script						
Pr	e-Update S	Script <u>S</u> tati	us (active	if checked)				
P0	ost-Update	Script S <u>t</u> a	tus (activ	e if checke	d)				
Ed	dit/View <u>G</u> lo	bal Script	Variables						

Right-click in the Chart and load the *.dat file saved by the subroutine:



FRED1:2 - User-defined Plot	
	 Perspective View Isotropic Flat Pixel Cell View Show Ceiling Show Floor Axes Labels Chart Color Chart Color Levels
	Copy Data to Clipboard Copy Image to Clipboard Save Chart to Bmp Save Data to Text File Read Data from File Save Complex Field to File
User-defined Plot General Info	Show Statistics Scale Data

Scripting With Libraries



Chapter 28 – Troubleshooting Driver and Graphic Board Problems

3D View, OpenGL, and Video Board Driver Problems

OpenGL is a software interface to the graphics hardware (video board) that provides a 3D graphics and modeling library that is very fast and portable. Each video board manufacturer supplies its own drivers which implement the software interface. In most cases the drivers work quite well. However, in some cases the OpenGL driver has one or more bugs that can cause unusual behavior in the 3D rendering view of the optical model. A defect in the driver can even cause FRED to hang or crash, even though FRED adheres strictly to the OpenGL standard. Fortunately, there are several ways to deal with a video board and/or OpenGL driver that has problems.

Solutions - 3D View, OpenGL, and Video Board Driver Problems

There are currently four possible solutions to a problem caused by a defective OpenGL driver. <u>Adjust the video board settings</u> via the advanced options on the settings page of the display properties.

Adjust the OpenGL pixel-rendering mode in the FRED preferences. Move the option from Fast to Safe.

<u>Download and install the latest video board drivers</u> for the video board from the video board or computer manufacturer.

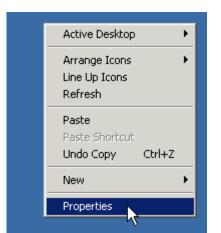
Install a new video board.

The first two options are quick fixes that will allow you to immediately get back to work. However, they may slightly adversely affect the speed and performance of the 3D rendering. The third and forth options are preferred and should be considered if the first two options result in slower 3D View operation.

Adjust the Video Board Settings

With this option you will make a simple adjustment to the Windows operating system. The adjustment will cause the operating system to use the video board in a safer, software-only video mode instead of the most aggressive hardware accelerated mode. Because the adjustment occurs at the operation system level, it will affect all applications that run on your computer. Most users will not notice a difference in performance of their applications, but some high performance applications may have reduced rendering speed. If this results in undesirable behavior in some applications, then we suggest you try the second option discussed below.

Right click anywhere in the desktop and select the Properties option in the pop-up menu. This will open the Display Properties dialog.



Now select the Advanced options in the Settings page of the Display Properties dialog.

Display Properties
Background Screen Saver Appearance Web Effects Settings
Display:
Optiquest Q100 on RV100
Colors True Color (32 bit) 1280 by 1024 pixels
Troubleshoot
OK Cancel Apply

The pages in the Advanced display properties dialog will have different options depending on the video board installed in the computer but five of the pages will be available on all computers with recent windows operating systems: General, Adapter, Monitor, Troubleshooting, and Color Management pages. Select the Troubleshooting page and adjust the Hardware Acceleration slide bar down one step at a time until the FRED visualization problems cease. Typically, you will have to adjust the slide bar down to the lowest first, second, or third setting. This slider adjusts what graphics acceleration processes are handled by the hardware and what processes are handled in software. The Software solution is more robust but slower than the hardware acceleration.

Optiquest Q100 and RV100 Properties	? ×
Color Managem	
Are you having problems with your graphics hardware? These settings control how Windows uses your graphics hardware. Th can help you to troubleshoot display-related problems.	ey
┌─ Hardware acceleration	
Manually control the level of acceleration and performance supplied I your graphics hardware. Use the Display Troubleshooter to assist you making the change.	
Hardware acceleration: None Full	
All accelerations are enabled. Use this setting if your computer has no problems. (Recommended)	
OK Cancel <u>A</u> pply Help	0

Depending on the video card installed in the computer, there may also be an OpenGL Properties page in the Advanced Display properties dialog. If so, the problems may possibly be fixed with the settings on the OpenGL properties page. An example of an OpenGL properties page is shown below. Please consult the video card manufacturer for support on the OpenGL properties page.

Optiquest Q100 and R¥100 Properties
General Adapter Monitor Troubleshooting Color Management
Optimization Preference Quality Performance
OpenGL Settings
Convert 32 bit textures to 16 bit Enable KTX buffer region extension
Enable page flipping Force 16-bit Z-buffer
Disable dithering when alpha blending Wait for vertical sync
Full scene anti-aliasing Full scene anti-aliasing Image: Complexity of the sector of the
Level of Detail
Fuzzy Sharp
OK Cancel Apply Help

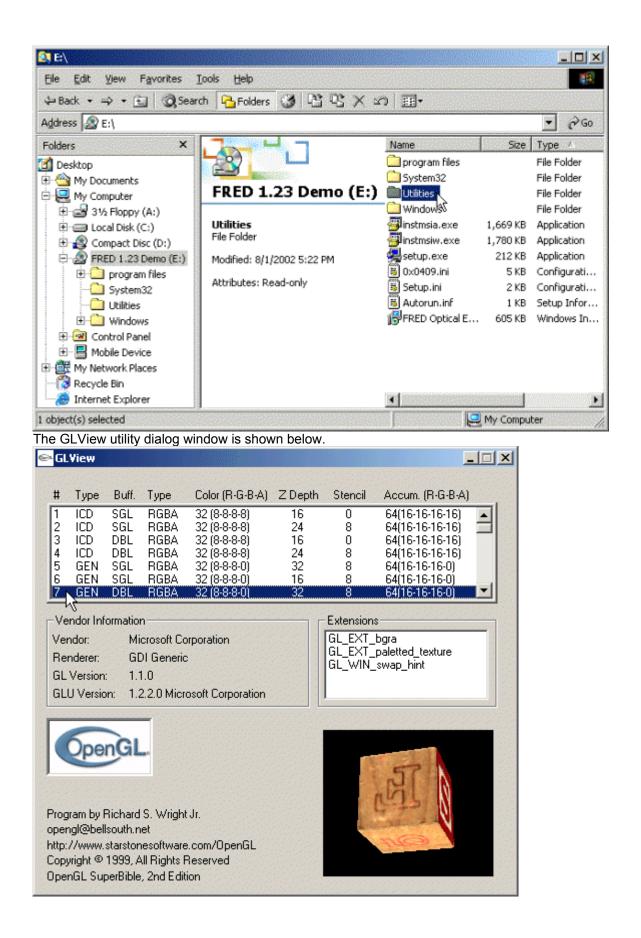
Adjust the OpenGL pixel-rendering mode

This option will change the OpenGL driver mode used by FRED but will not affect the OpenGL driver options for other programs using OpenGL.

This option has two steps. In the first step, a utility is used to determine what OpenGL pixel render mode is stable using the current OpenGL driver and video board. In the second step, the pixel render mode identified in the first step is selected for FRED in the FRED Visualization preferences page.

The utility is called GLView.exe, located on the FRED installation disk in the Utilities folder. The figure below illustrates the location of the utility directory on the installation disk. In this case, the installation disk is for the FRED demo version 1.23.





The GLView dialog lists a number of pixel rendering modes and the attributes for each mode. The ICD types are hardware accelerated modes. The GEN modes are software modes that do not have hardware acceleration. You should choose a mode of type GEN. The mode chosen MUST have a double buffer indicated with DBL in the Buff column. It should also have a type of RGBA. If the mode is a good mode to use, the letter block in the lower left corner will roll smoothly without any flickering. If the mode is not a good one, then the letter block will flicker. The speed that the letter block rolls is a rough indication of how fast the mode will operate.

Some of the modes listed are not available. If the mode is available, then a rolling letter block, **I**, is shown in the window in the bottom left corner of the dialog. If the mode is not available, then a red X, **X**, is drawn instead.

Once a good mode has been identified, make note of the mode number in the left most column. Now close the GLView utility and start FRED, but do not load a FRED file. The mode number should be entered into the pixel rendering mode on the Visualization page of the FRED Preferences dialog. The Preferences are available in the Tools menu.

	Warnings	General	File Locations
Output Window	Visua	lization	Format
Draw local trimming volu	ne when creati	ng a new surfac	e
When creating a new system	, show Coor	dinate Axes 💌	•
OpenGL rendering pixel form	at: 🚺 🗧		recommended)
	17-	-	
-Z Axis	Screen Baci	kground Pri	nter Background
]*
Set Custom Views	C Custom Vi	ew 2 C Cu	stom View 3
Dimensions:	×	Y	Z
	× 0	0	Z 10
Dimensions:	-	Y 0 0	
Dimensions: Camera is located at:	0	-	10

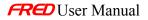
If you later update your video board driver, you may want to update your FRED Preferences by entering an OpenGL pixel rendering mode of 0 (zero). This is the default setting and tells FRED to use the default aggressive rendering mode.



Often there is a new video board driver that has enhanced OpenGL performance available from the video board manufacturer. FRED is using OpenGL extensively but if FRED is having problems with the OpenGL drivers then it is likely that other programs using OpenGL will have troubles with the drivers. In this case the manufacturer may have addressed the problem with an improved driver. Consult the video driver manufacturer's website for updates.

Install a new video board

Please contact Photon Engineering, LLC for a list of video boards that have worked well for other users.



Chapter 29 – How to setup FRED for use with Safenet

Setting up FRED for use with the Safenet hardware key

Description What Is It? Application Notes See Also...

Description - Setting up the software for the SafeNet hardware key

This article details the software installation for the SafeNet hardware key used by FRED.

What Is It? - Setting up the software for the SafeNet hardware key

The SafeNet (formerly Rainbow) Corporation is a vendor of computer security products. Their Sentinel SuperPro software protection is used by the FRED Optical Engineering Software to prevent unauthorized duplication. It is a mandatory component, and must be installed in order to run FRED. It prevents FRED from running on multiple computers at once, but allows multiple instances of FRED to run on the same computer.

FRED launches the SafeNet SuperPro driver installation program automatically at the end of the FRED installation in a "silent" mode. This will automatically install or upgrade the driver unless one of the following conditions is met:

- 4. The version is already installed
- 5. A newer version is installed

The driver cannot coexist with older drivers and is, according to SafeNet, backwards compatible with previous versions.

The installation program briefly displays a dialog with a cancel button as it starts. If you do not wish to run the driver installation, press the spacebar when this dialog appears. This will press the cancel button and stop the driver installation, but will allow the FRED installation to finish.

The installation program installs the drivers for the parallel and the USB key, regardless of which key you received when you purchased FRED. If you wish to remove one of these components, you may do so via the Add/Remove Programs Control Panel applet.

Application Notes - Setting up the software for the SafeNet hardware key

The installation program requires System Administrator privileges to run, as it installs files to the Windows System directory. If, for whatever reason, the SafeNet installation needs to be run without running the FRED installation, it is available on the FRED CD in the "Rainbow Tools" directory. The most recent version is available from the SafeNet website, linked at the bottom of this page.

See Also - Setting up the software for the SafeNet hardware key

SafeNet website SafeNet Network Setup

Setting up FRED for Networks

Description Application Notes See Also...

Description - Setting up FRED for Networks

This article details the software installation for using FRED on a network.

Application Notes - Setting up FRED for Networks

The FRED Network architecture is relatively simple: a PC designated as the "network server" manages FRED "execution licenses" requested by one or more "local" computers running FRED.

When a user launches FRED on a local computer, FRED requests an execution license from the server. If the hardware key is attached to the server and there is a license available, the server grants the request, reduces the number of available licenses by one, and FRED execution continues. If all the licenses are in use, the server denies the request and FRED terminates. When a user exits from FRED, FRED notifies the server which then releases the license.

The network server must have the network hardware key (dongle) connected to it, and it must have the associated dongle software installed. The FRED software itself does not need to be installed on the server.

FRED can be installed on as many local computers as desired. However, only a limited number of users may execute FRED simultaneously. The limiting number is determined by the number of purchased FRED network licenses.

1) PREPARATION OF THE SERVER COMPUTER

- a) Install the SafeNet Sentinel protection software on the host. Run the "Sentinel Protection Installer XXXX.exe" program found in the "SafeNet Tools" subdirectory on the FRED CD to begin the installation. The latest installer program can also be downloaded from the Safe Net website. The installed software is always backward compatible with earlier versions.
- b) Direct the installation procedure to install two items: i) a hardware driver for the hardware key, and ii) a Windows service called "Sentinel Protection Server".
- c) The service must be running on the server so that the user computers can query the hardware key when running FRED. Also, the hardware key must be connected to the server whenever a user computer is running FRED.

d) Communication between the remote and host computers uses a specific port. You should make sure that one of the following ports is open for network communication:

For TCP/IP protocol: UDP port 6001

For IPX/SPX protocol: SAP messages are sent over 361hex

- e) The "SafeNet Tools" subdirectory on the FRED installation CD contains software tools that can be of help to system administrators:
 - i) EndUserSentinelMedic.exe Problem diagnosing tool
 - ii) SPmedic.exe Problem diagnosing tool
 - iii) Monitor.exe
- Allows monitoring of FRED and license usage

2) PREPARATION OF LOCAL COMPUTERS

- b) Install FRED.
- c) You must set an environment variable called NSP_HOST. This environment variable specifies how FRED locates the server computer.
- d) Valid values for the NSP_HOST environment variable are: i) servername/IPadress/IPXaddress the most efficient and fastest access mode for locating the server ii) RNBO SPN BROADCAST broadcast a request over the local subnet to find a server with an available license iii) RNBO SPN LOCAL look for a hardware key on the local computer (stand-alone mode using a local server) iv) RNBO SPN DRIVER look for a hardware key on the local computer (stand-alone mode without a local server) v) RNBO SPN SERVER MODES tries RNBO SPN LOCAL followed by RNBO_SPN_BROADCAST
- e) You can get the NSP_HOST ip address by going to the DOS prompt on the server where the network key is and typing ipconfig on the command line.

See Also - Setting up FRED for Networks

SafeNet website

Chapter 30 - Contact Information

Internet

Web: www.photonengr.com General Information: info@photonengr.com Sales: sales@photonengr.com Tech Support: support@photonengr.com

Address

Mailing Address: Photon Engineering, LLC P.O. Box 31316 Tucson, AZ 85751

Shipping Address: Photon Engineering, LLC 440 S. Williams Blvd, Suite 106 Tucson, AZ 85711

Phone Numbers

Voice: (520) 733-9557 Fax: (520) 733-9609



Chapter 31 - Engineering Services Offered by Photon Engineering, LLC

We have broad-based experience in all phases of optical engineering: specification development, conceptual through detailed optical design of imaging and non-imaging systems, tolerancing, drawings for fabrication, CAD/mechanical design interfacing, customer and vendor interfacing, ghost/stray light analysis, thermal analysis, beam propagation, effects of contamination, "debugging" optical systems, and more. Combined with outstanding communication and presentation skills, Photon Engineering has the breadth and skills to make your project a success! (We've also been known to salvage an existing project in deep trouble from time to time!)

Photon Engineering offers optical engineering consulting services under two "customerfriendly" forms:

"Time and materials" contracts. Under this type of contract, there is no predetermined statement of work; the customer generally has an optical engineering idea/problem he wishes to investigate/solve and we tackle the project from there. We work closely with the customer to understand the idea/problem, select the optimum software and technical approach, and work toward an optimal solution.

Since these contracts tend to be rather loosely structured, we typically ask the customer to issue a purchase order for a not-to-exceed funding level. The specifics, schedule, and cost of each task are negotiated, sometimes on a day-to-day basis, as the work progresses. With frequent reports, discussions and other customer interactions (also sometimes on a day-to-day basis), Photon Engineering acts like a virtual "in-house" engineering resource without the associated overhead.

Fixed price contracts. Under this type of contract, we work to a specific statement of work on a specific schedule for a predetermined cost; all aspects of the contract are negotiated "up front" with the customer prior to beginning any work.

Other business arrangements may be considered. For example, we may accept future royalties as payment for consulting work under the appropriate circumstances. Contact us for more information.

Under any business scenario, Photon Engineering is extremely cost-effective. We keep our overhead low so that we can offer our services at rates affordable to even "start-up" companies.

Photon Engineering will keep your secrets! We routinely sign reasonable non-disclosure agreements intended to protect the proprietary nature of our customer's projects.

Photon Engineering, LLC 440 S. Williams Blvd, Suite 106 Tucson, AZ 85711 520-733-9557 www.photonengr.com



Glossary

curve

A curve is either a collection of points or a functional form defining a line. A curve can then be swept to make a surface.

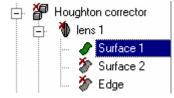
FRED document

All data, i.e. sources, materials, coatings, geometry, ray trace controls, etc. entered into FRED is stored in a document(s).

hierarchical raytrace search

This algorithm searched the FRED geometry nodes starting with a parent node and then working down through the children, grandchildren, etc. until the all progeny nodes have been searched. At each node (parent, child, grandchild, etc.), the algorithm first checks to see if the node is traceable. If the node is not traceable, then skips that node and all of its children and grandchildren. If the node is traceable, then it checks to see if the ray intersects the bounding box for that node. If the ray intersects the bounding box, then the algorithm checks to see if the ray intersects the surface. If the node is a surface, then the algorithm checks to see if the ray intersects the surface. If the node is not a surface, and it has child nodes then it systematically follows the same process for the child nodes. This process continues until all of the nodes under a parent node have been checked. Then the algorithm moves on to the next parent node. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

It is possible to have a traceable surface node that is a child of a non-traceable parent node. Because this algorithm ignores any nodes under a non-traceable node, this algorithm will not trace the surface 1 in the example shown below.



intensity

Intensity is a power per stradian radiometric unit. The SI units for intensity are

irradiance

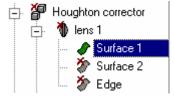
Irradiance is a power per unit area radiometric unit. The SI units for irradiance are

Watts/ meter²

linear raytrace search

This algorithm systematically checks every traceable surface node to determine if the ray interests the bounding surface. If the ray intersects the bounding surface, then the algorithm checks to see if the ray intersects the surface. After the algorithm has determined all the surfaces that the ray intersects, the closest surface is chosen as the next surface intersection. The process then repeats.

This algorithm does not consider and non-surface nodes. It is possible to have a <u>traceable</u> surface node that is a child of a non-traceable parent node. This algorithm will trace the surface 1 in the example shown below.



node

Every entry in the Tree View data structure has a node. Each node has an icon, i.e.

, and a name. There is a hierarchical structure to the nodes. If a node has child nodes, it can be expanded, $\stackrel{\frown}{=}$, or collapsed, $\stackrel{\frown}{=}$, by left mouse clicking on the $\stackrel{\frown}{=}$ or $\stackrel{\frown}{=}$ symbols respectively or by double left mouse clicking on the node name to toggle back and forth.

ray filter

Specific rays can be selected from the ray set based on many criteria including their source, their location, coherence, etc. For example, the Best Focus command has a ray filter for selecting the rays used to find the best focus.

(🕻 (hou	🚰 (houghton.frd *) Best Geometric Focus			
	Coordinate System of the Results:			
Global	Coordinate 9	iystem		<u> </u>
Ray Se	Ray Selection Criteria:			
Num	Operation	Description		
1	AND	All rays		
2	AND		"Optical Sources.co	
3	AND	Rays on surface "(Geometry.image.im	age"
			Cu <u>t</u>	
			⊆opy	
•			Paste	<u> </u>
	OK Cancel Delete Help			
			<u>E</u> dit	
			Insert	
			Append	

Editing, inserting, or appending a record to the ray filter will bring up the Ray Selection Criterion dialog.

Ray Selection Criterion	? <u>-</u> X
Criterion:	
Rays on the specified surface	▼ OK
Surface Name:	
Geometry.image.image	Cancel
Value: Logical Operation	DR Help

rayset

The currently created set of rays in the FRED ray buffer. FRED creates rays (the rayset) from defined sources if one of the following commands are issued by the user: <u>Create All</u> <u>Source Rays</u>, <u>Trace and Render</u>, <u>Trace All Sources</u>, and <u>Advanced Trace</u>. Defining a source dos not create rays. The rayset can be delete use the <u>Delete Existing Rays</u> command. Note, single ray traces have their own separate buffer and are not part of the rayset.

RMS

Root mean sum.

steradian

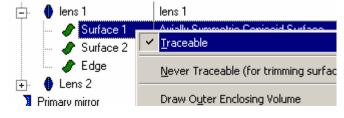
A steradian [sr] is the solid angle subtended by $\frac{1}{4}\pi$ of a the area of a sphere as viewed from the center of the sphere. A hemisphere subtends $2\pi [sr]$ and complete sphere subtends $4\pi [sr]$.

subassembly

A subassembly is a collection of <u>elements</u> and/or custom elements in a FRED <u>document</u>. Note that surfaces and curves cannot be directly entered into a subassembly.

traceable

Only traceable objects are considered when rays are created and/or traced. Sources, parent nodes, element and custom element nodes, and surfaces by default are marked as traceable when they are created. Any source or geometry node can be marked as untraceable via the right mouse click pop-up menu in the Tree View. A node is traceable if when the node is highlighted, "Traceable" is checked in the right mouse click pop-up menu.



An object is not traceable if Traceable is unchecked in the right mouse click pop-up menu.

In addition, untraceable <u>node</u> icons, i.e. $\dot{\boxminus}^{\mathfrak{p}}$ **(**), are colored gray and marked with an $\overset{\boldsymbol{\times}}{\overset{\boldsymbol{\times}}}$.



A count of the traceable and not traceable rays is available in the Ray Status output.

Tree View

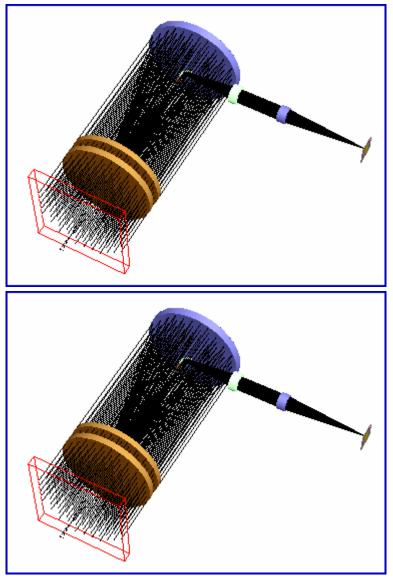
The Tree View is one of the two <u>document</u> views available in FRED. This view is a hierarchical data structure representing the optical model described in FRED. The other view is the <u>Visualization Window</u>.

🔟 houghton.frd *	
Objects	Description
🕞 🚘 Optical Sources	
- 🚅 collimated beam	monochromatic collimated beam
🔲 🚅 poly collimated beam	poly chromatic
📄 🚔 Geometry	
📄 🗗 Houghton corrector	corrector lens
📄 🍈 lens 1	lens 1
🚽 🧼 🥒 Surface 1	Axially Symmetric Conicoid Surface
- 🥒 Surface 2	Axially Symmetric Conicoid Surface
📃 🔤 🥒 Edge	Bilaterally Symmetric Tubular Surface
主 🌒 Lens 2	lens 2
🕂 🗋 Primary mirror	mirror
🕂 🔐 Secondary mirror	secondary
🔁 🌗 Field lens	field lens
📄 🔂 Fold mirror	45 deg fold
🔁 🗗 relay doublet 1	doublet
🔁 🗗 relay doublet 2	doublet
📄 🔂 🔐 image	image
📑 🧰 Coatings	
🕂 💼 Scatterers	
📄 💼 Raytrace Properties	



Visualization Window

The Visualization Window is one of the two <u>document</u> views available in FRED. The other view is the <u>Tree View</u>.





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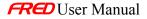
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