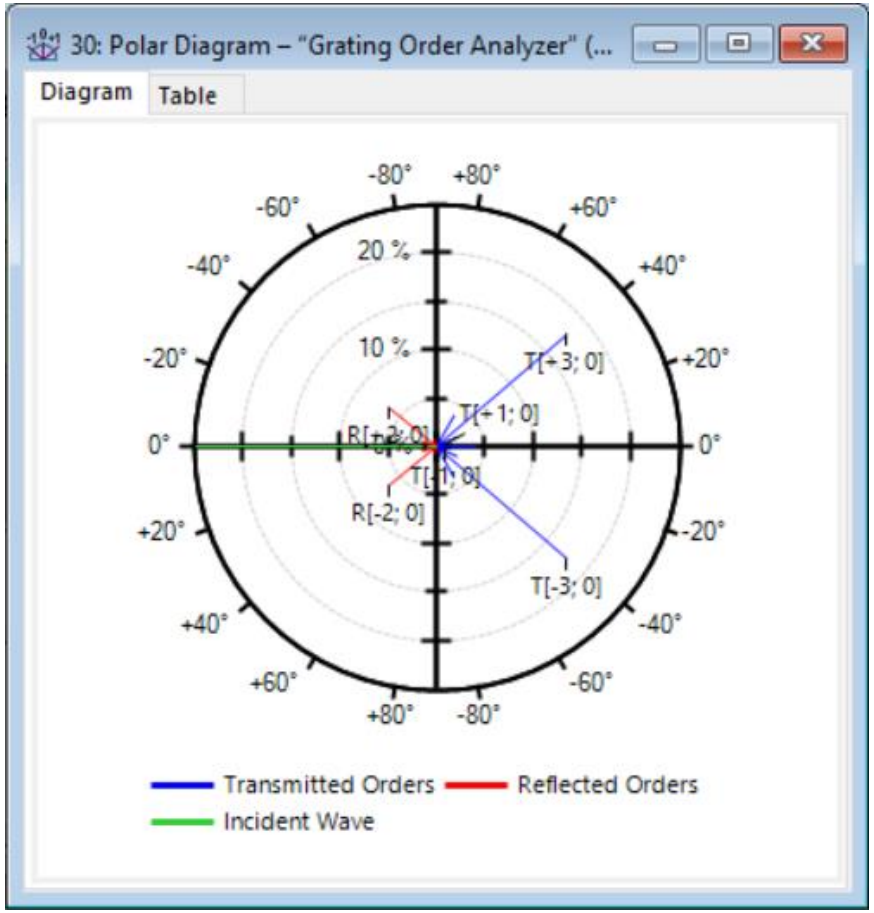
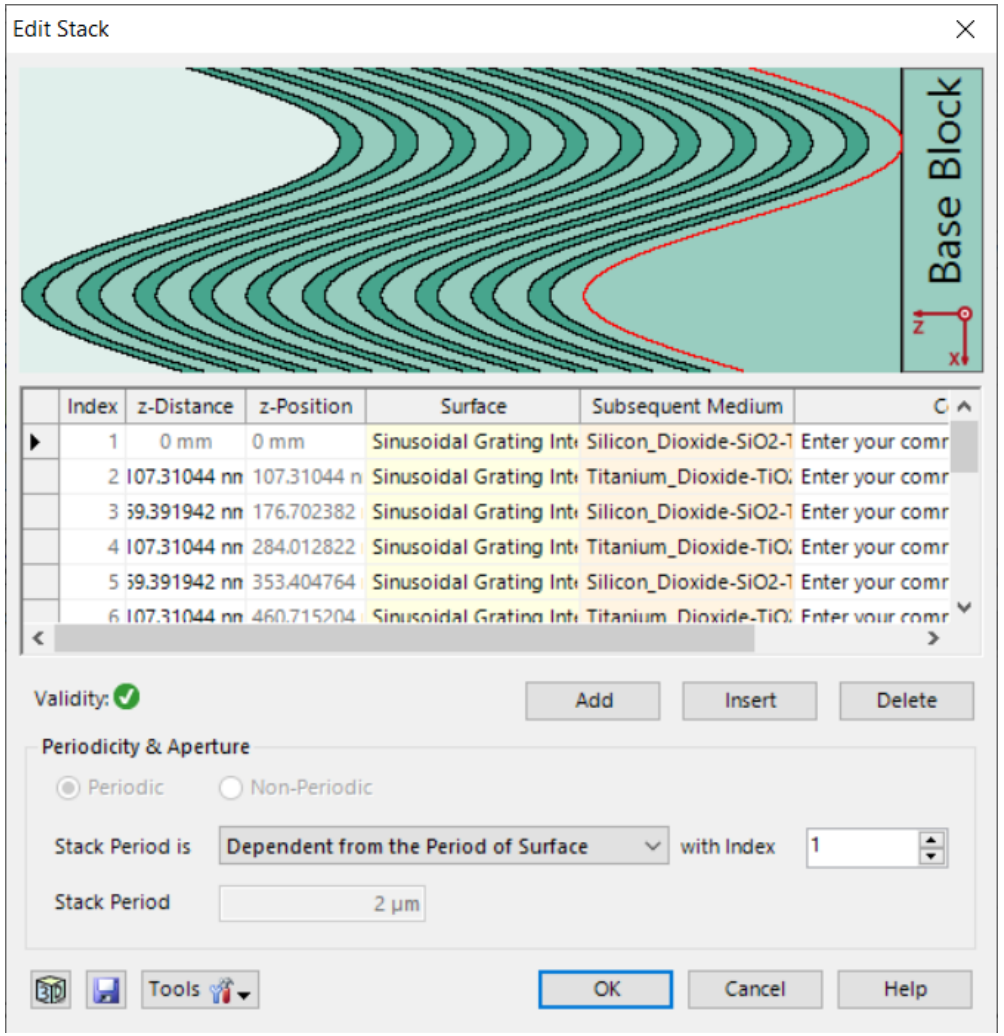
Grating Order Analyzer

Abstract



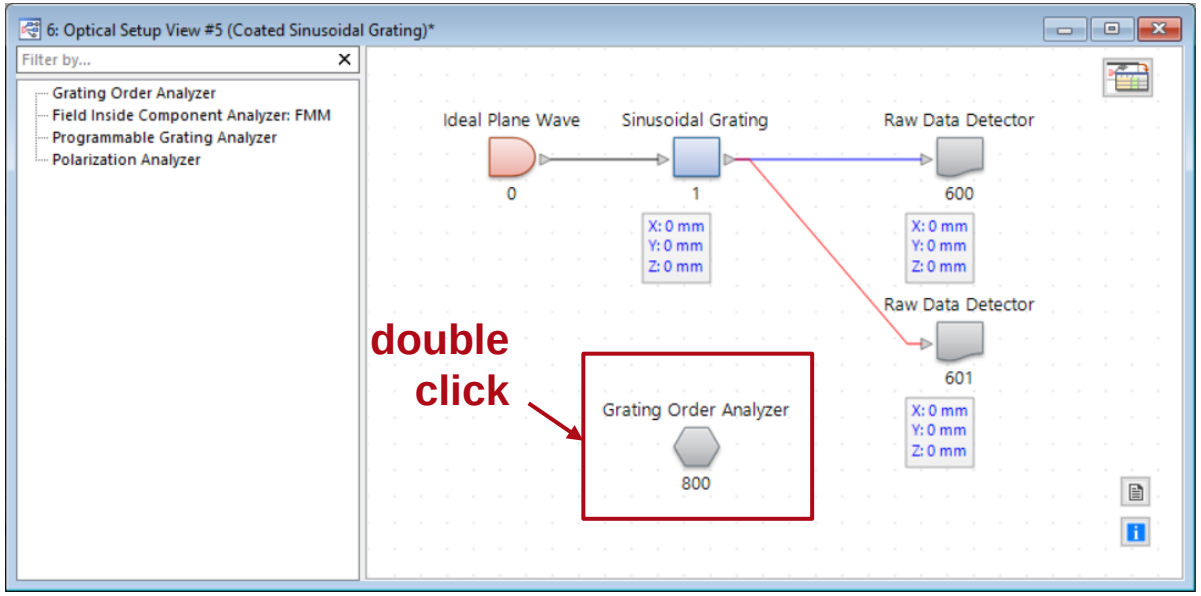
The analysis of the diffraction efficiencies of certain diffraction orders is the typical modeling task for optical grating structures. Due to the small feature sizes and periods regarding the used wavelength of light, the efficiencies must be calculated by rigorous approaches. The well-known FMM or RCWA is one commonly applied algorithm to solve this task and is also available in VirtualLab Fusion. The results of this fully vectorial method are the complex-valued Rayleigh coefficients, which contain all necessary field information per order, from which the corresponding efficiency can be obtained. The Grating Order Analyzer in VirtualLab Fusion helps us to generate and graphically display all this information for complex grating structures (both 1 and 2D-periodic).

Grating Specification



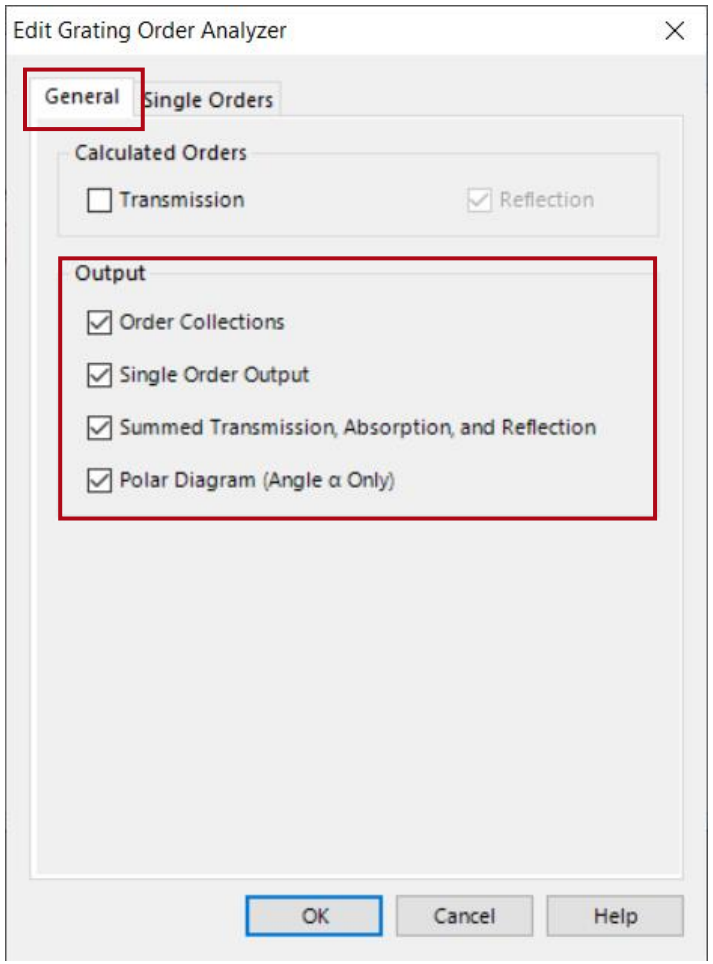
- For the demonstration of the *Grating Order Analyzer* a 1D grating with a sinusoidal grating shape in combination with multiple layers is used.
- The layers are indented to provide high-reflective (HR) function.
- The grating parameters can be specified in the stack that can be accessed in the edit dialog of the grating component.

Grating Order Analyzer Settings



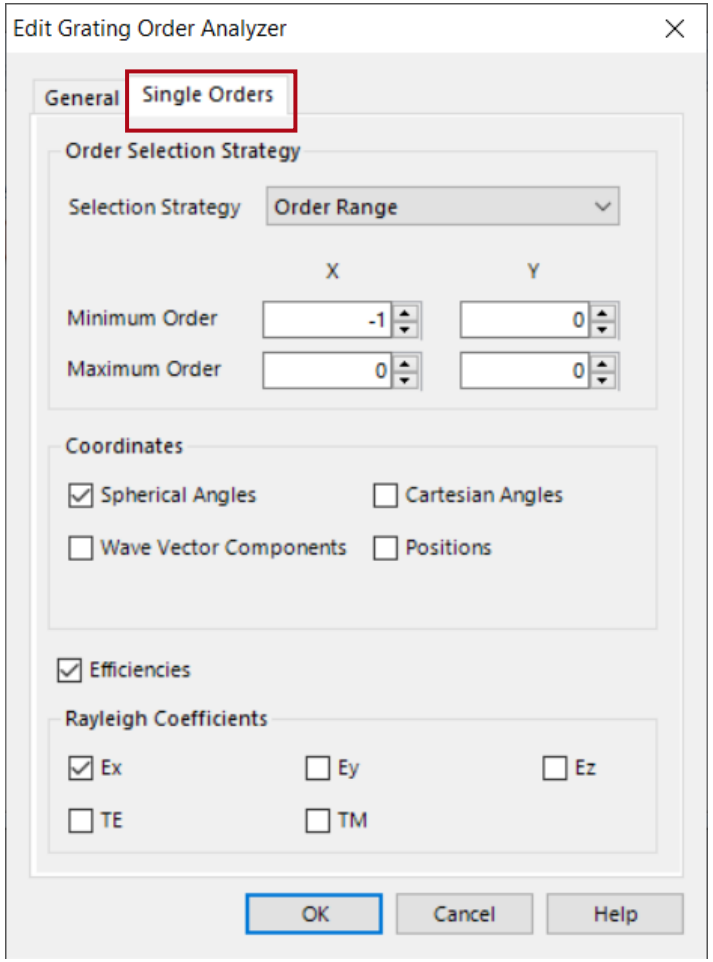
- After the grating structure has been defined, the desired *Grating Order Analyzer* can be applied for calculating the Rayleigh coefficients and the regarding diffracting.
- In addition, various output options are available to display the results.
- This is done through the edit dialog of the analyzer, which is opened by double clicking on the corresponding element in the *Optical Setup View*.

General Settings



- In the *General* tab you can select whether transmission and/or reflection shall be analyzed.
- In addition, you can specify which outputs you would like the *Grating Analyzer* to generate.
  - *Order Collections*: generates a type of document that provides a visual representation of how the field/energy is distributed among the orders, as well as containing the displayed information in numerical form. Order Collections are generated separately for transmission and reflection. More information about the *Order Collection* document can be found in the next slides.
  - *Single Order Output*: activates the additional *Single Orders* tab, to the right of the *General* one. (see next page)
  - *Summed Transmission, Absorption and Reflection*: the corresponding information (i.e., how the energy is distributed among these three effects, without further breaking the results down into the individual grating orders but as aggregate values) will be displayed either in the *Detector* Results tab or as results in a *Parameter Run* or *Parametric Optimization*.
  - *Polar Diagram* (Angle α only): generates another document that provides a visualization of the different appearing grating orders, where the shown angle corresponds to the diffraction angle of the order, and the radius depicts the efficiency. This type of visualization is restricted to a single plane. More information about the Polar Diagram document can be found in the next slides.

Single Orders Settings

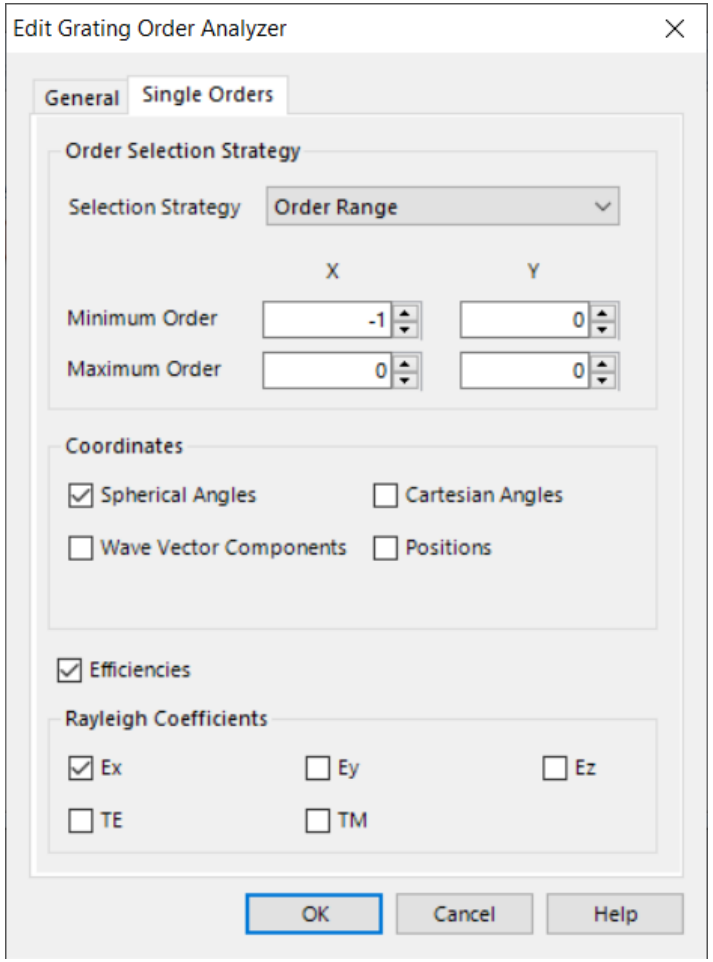


- When the option *Single Order Output* is selected in the *General* tab, the *Single Orders* tab is activated. In it you can select what information about the single orders shall be logged.

- The *Single Order Output* controls whether information about the individual orders (diffraction angles, efficiency, Rayleigh coefficients…) will be delivered (depending on how the simulation is run, either in the *Detector Results* tab or as results in a *Parameter Run* or *Parametric Optimization*).

- This option is very helpful if you would like to use the *Parameter Run* or the *Parametric Optimization* of VirtualLab Fusion to analyze and optimize the grating for specific orders.

Single Orders Settings



Parameter	Description
Order Selection Strategy	The user can define which order(s) shall be evaluated. The user can choose whether to analyze *All* orders, analyze only those orders which have an efficiency *Above a Given Threshold* or calculate only orders in a manually specified *Order Range*. Depending on the selection strategy the user may have to configure additional parameters.
Coordinates	Logging of the coordinates of the orders is also supported. The user can specify whether to show the coordinates in *Spherical Angles*, *Cartesian Angles*, *Wave Vector Components* or *Positions*. For the Position calculation a z-distance between the grating and the screen has to be specified.
Efficiencies	The user can select whether efficiencies shall be logged.
Rayleigh Coefficients	In addition, it is possible to log the Rayleigh coefficients. The user can select to show the coefficients of the diffraction orders according to the xyz-coordinate system (components E_x, E_y, E_z) or TE/TM.

Outputs in Detector Tab

Detector Results

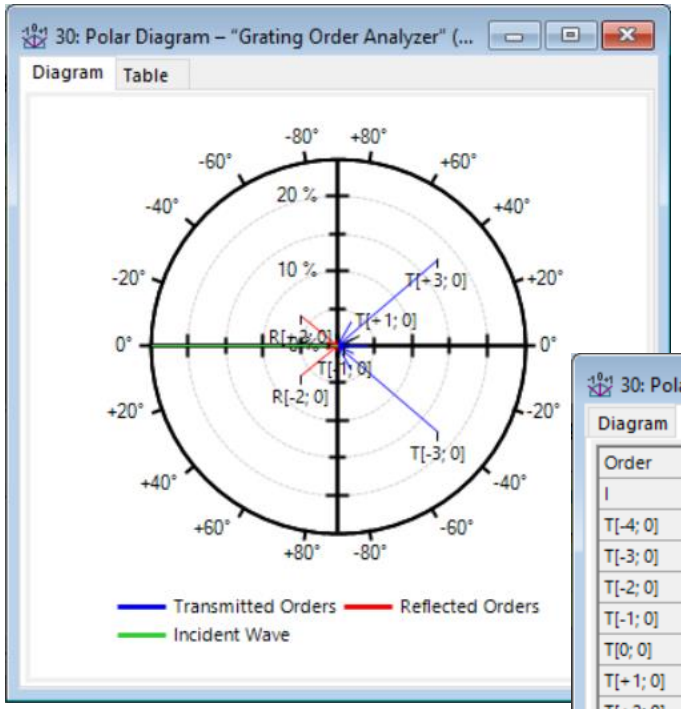
	Date/Time	Detector	Sub - Detector	Result
132	11/16/2021 12:04:25	"Grating Order Analyzer" (# 800)	Overall Reflection Efficiency	46.71935083 %
131			Overall Transmission Efficiency	53.28064917 %
130			Overall Reflection and Transmission Efficiency	100 %
129			Absorption	0 %
128	11/16/2021 12:04:25	"Grating Order Analyzer" (# 800) (Results for Individual Orders)	Spherical Angle Theta R[-1; 0]	18.44015854°
127			Spherical Angle Phi R[-1; 0]	0°
126			Efficiency R[-1; 0]	1.544588438 %
125			Rayleigh coefficient Ex R[-1; 0]	-14.9906794-120.1169758i mV/m
124			Spherical Angle Theta R[0; 0]	0°
123			Spherical Angle Phi R[0; 0]	0°
122			Efficiency R[0; 0]	29.34772296 %
121			Rayleigh coefficient Ex R[0; 0]	538.0671678-62.93609884i mV/m

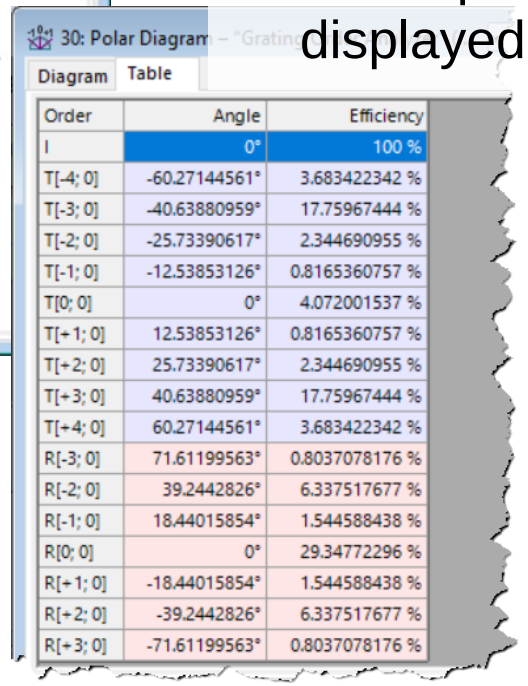
Detector Results | Messages

- If the *Grating Order Analyzer* is processed in the *Optical Setup*, the single order output values are logged in the *Detector Results* tab.

- These values are also available in the *Parameter Run* and the *Parametric Optimization*.

Outputs in Polar Diagram

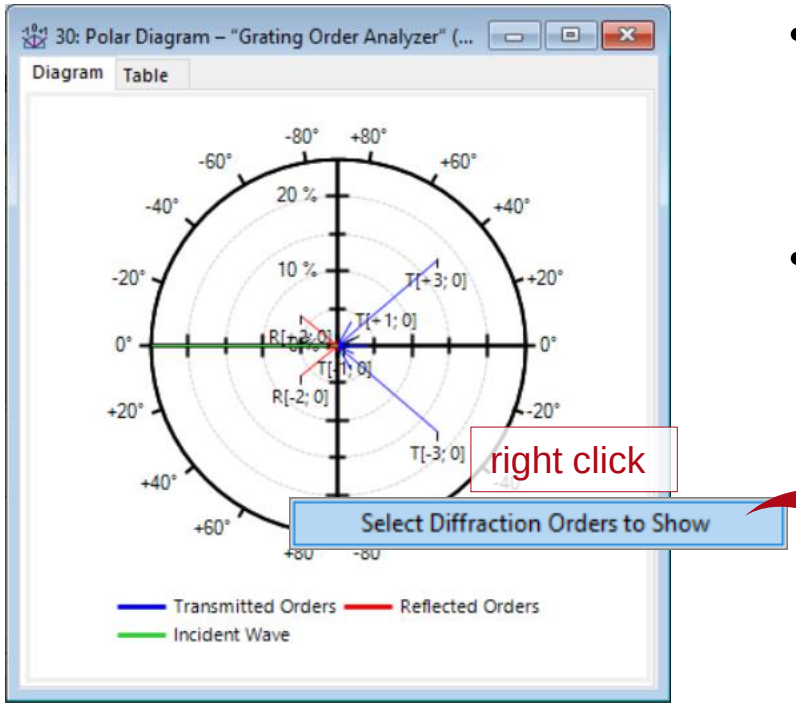




Order	Angle	Efficiency
I	0°	100 %
T[-4; 0]	-60.27144561°	3.683422342 %
T[-3; 0]	-40.63880959°	17.75967444 %
T[-2; 0]	-25.73390617°	2.344690955 %
T[-1; 0]	-12.53853126°	0.8165360757 %
T[0; 0]	0°	4.072001537 %
T[+1; 0]	12.53853126°	0.8165360757 %
T[+2; 0]	25.73390617°	2.344690955 %
T[+3; 0]	40.63880959°	17.75967444 %
T[+4; 0]	60.27144561°	3.683422342 %
R[-3; 0]	71.61199563°	0.8037078176 %
R[-2; 0]	39.2442826°	6.337517677 %
R[-1; 0]	18.44015854°	1.544588438 %
R[0; 0]	0°	29.34772296 %
R[+1; 0]	-18.44015854°	1.544588438 %
R[+2; 0]	-39.2442826°	6.337517677 %
R[+3; 0]	-71.61199563°	0.8037078176 %

- The polar diagram output of the *Grating Order Analyzer* plots the efficiencies of both the reflected and the transmitted orders versus the angles in the x-z-plane.
- It also provides a table of all angles and efficiencies of the displayed orders.

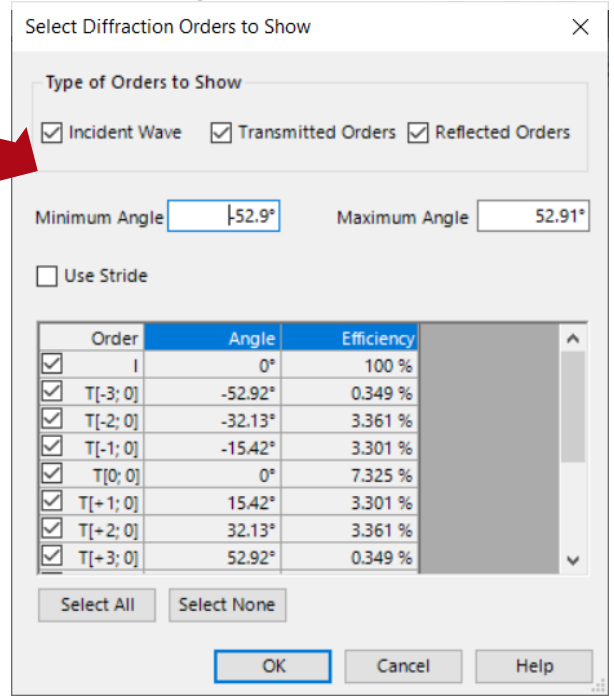
Polar Diagram Settings

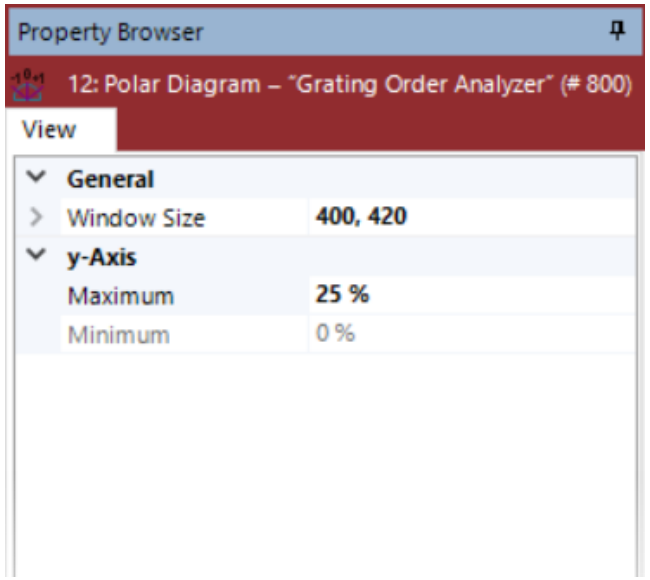


right click

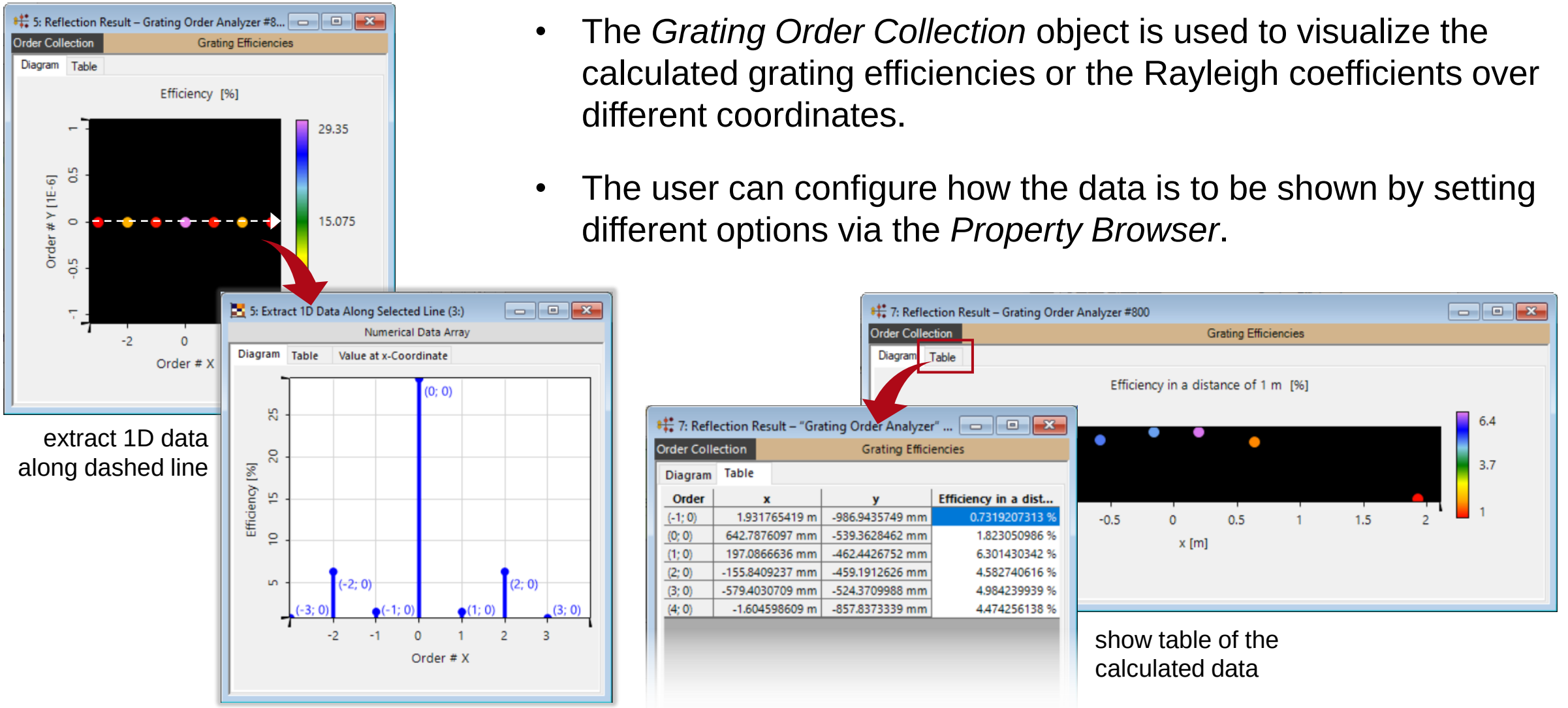
- You can zoom into the polar diagram with the mouse wheel, or through the *Property Browser* or the ribbon menu.

- You can configure which orders are shown by right-clicking on the diagram.





Outputs in Order Collection

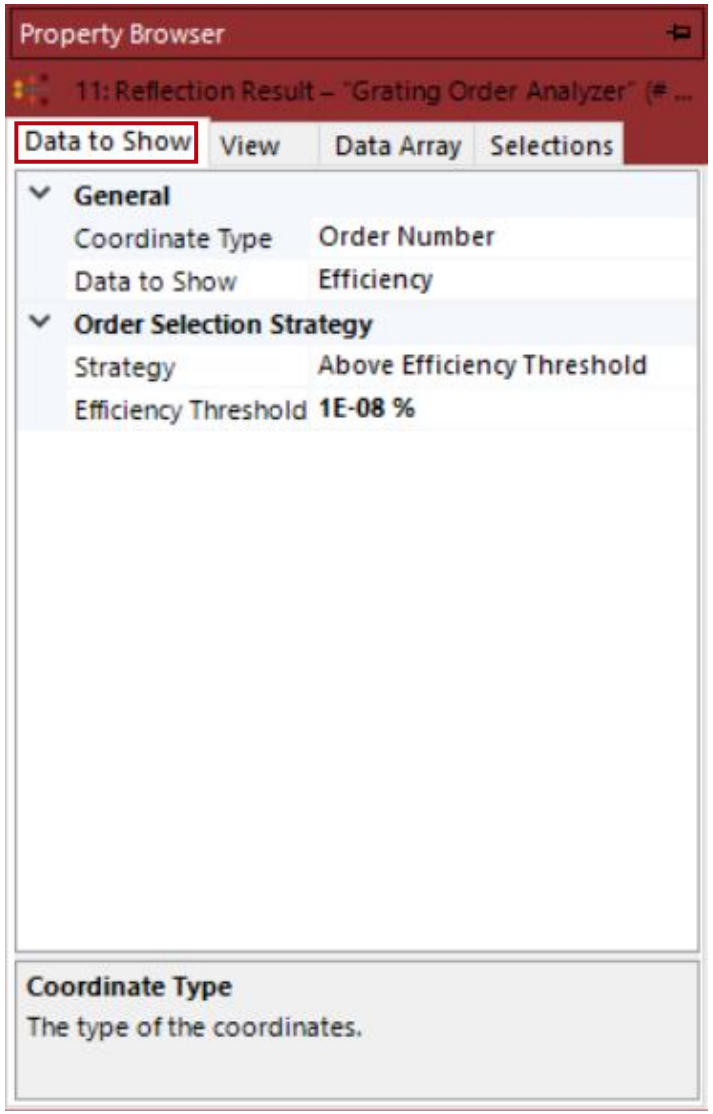


extract 1D data along dashed line

show table of the calculated data

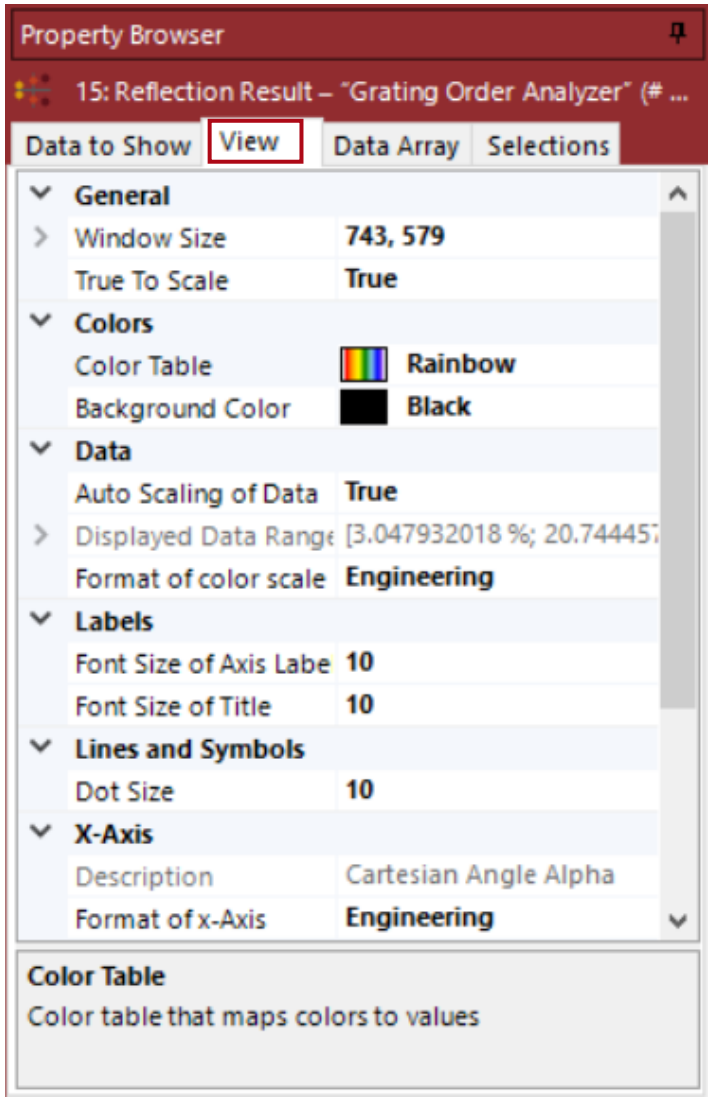
- The *Grating Order Collection* object is used to visualize the calculated grating efficiencies or the Rayleigh coefficients over different coordinates.
- The user can configure how the data is to be shown by setting different options via the *Property Browser*.

Order Collection Settings



Option	Description
Coordinate Type	This property can be used to define the coordinates against which the data will be plotted. Currently the order collection supports the visualization over *Cartesian Angles*, *Spherical Angles*, *Wave Number Vectors* and *Positions*.
Data to Show	It is possible to select the different data values that should be shown. The user can select to display the efficiency or the Rayleigh coefficient over the selected coordinate type. For Rayleigh coefficients E_x, E_y, E_z, TM and TE are supported.
Order Selection Strategy	The user can define which order(s) shall be displayed. In addition, it is possible to define whether to show *All*, show only orders which have an efficiency *Above a Given Threshold* or show only orders in a manually defined *Order Range*. Depending on the selection strategy the user may have to define additional parameters.

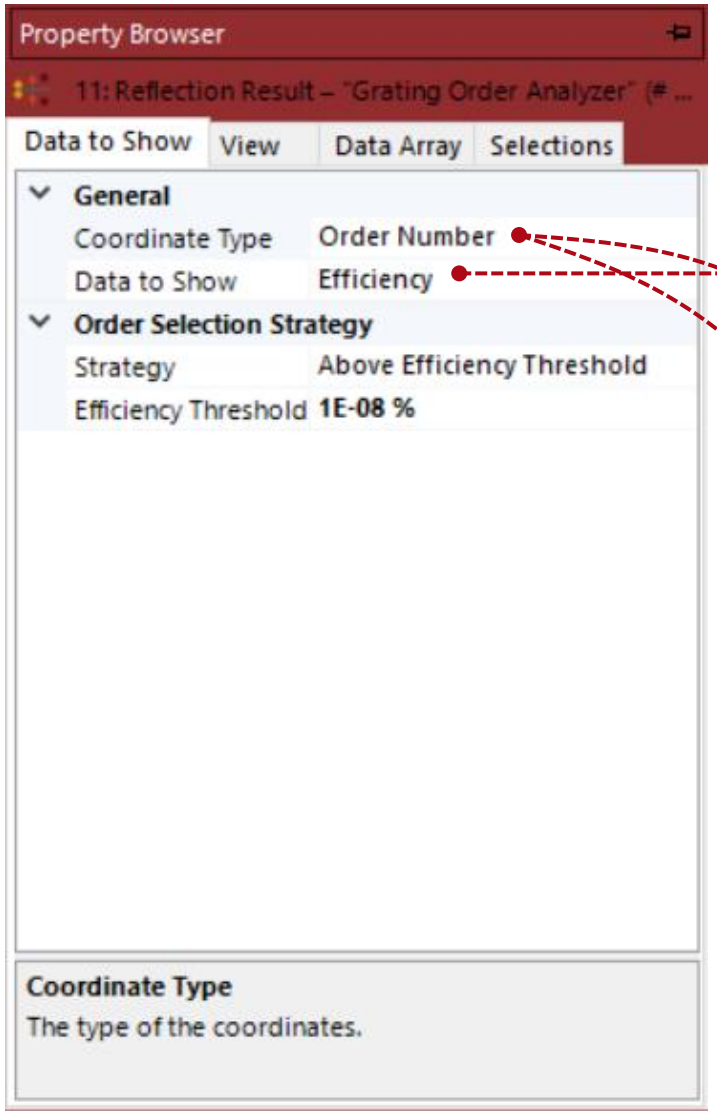
Order Collection Settings



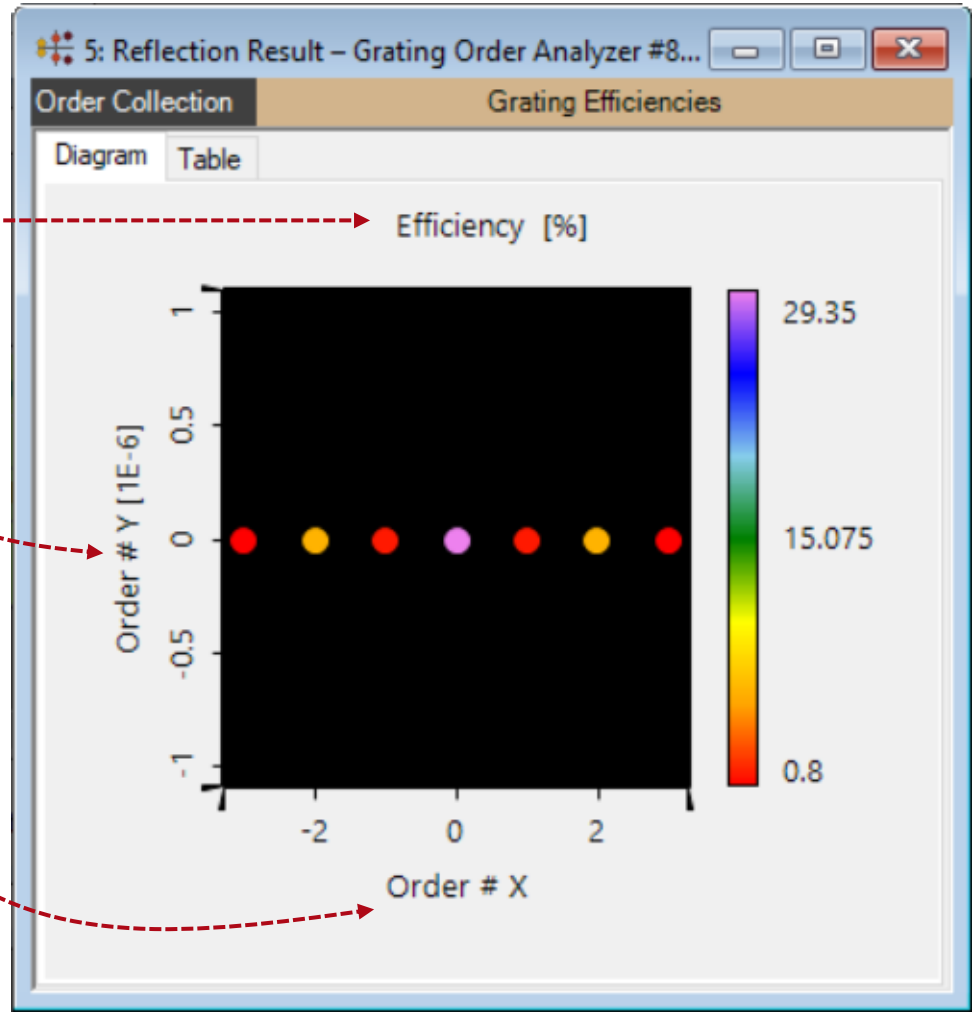
- In the *View* tab of the property browser, the user can further configure how the information is displayed.

- Most important from a visual standpoint are the color settings – it is possible to select the background color for the view, as well as the color lookup table that shall be used to represent the values of the displayed data.

Example of Customized Order Collection Settings

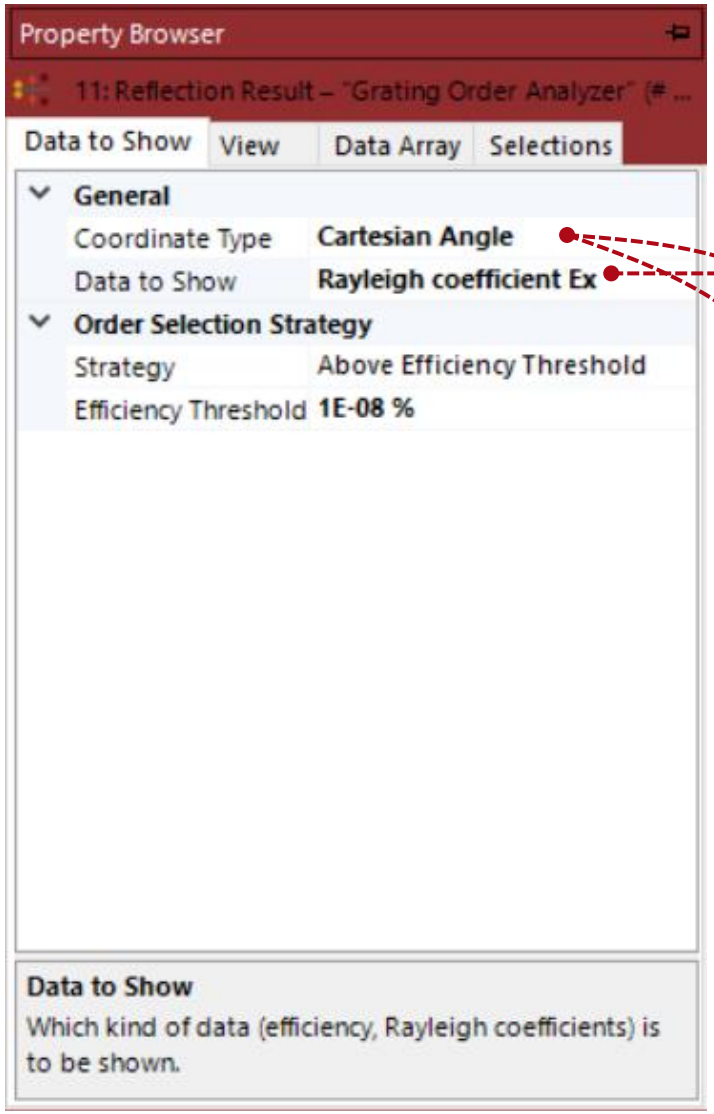


settings

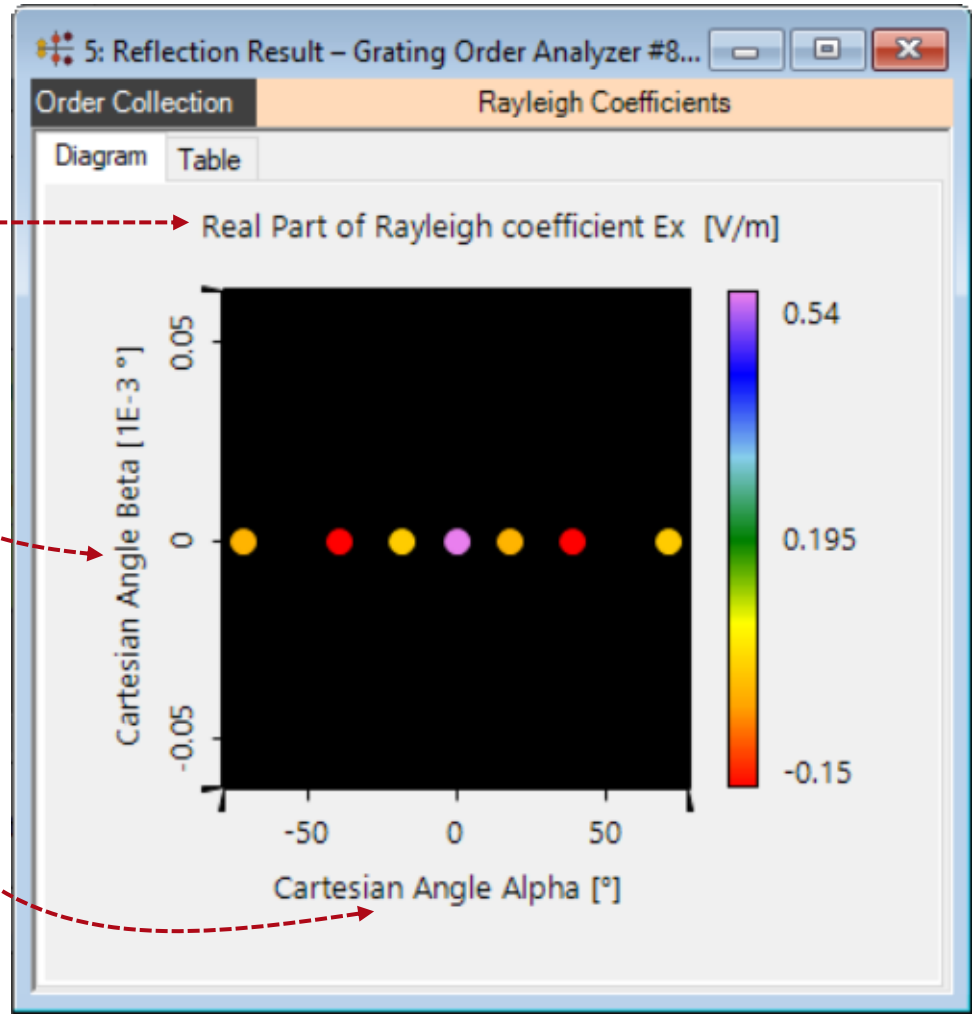


result

Example of Customized Order Collection Settings

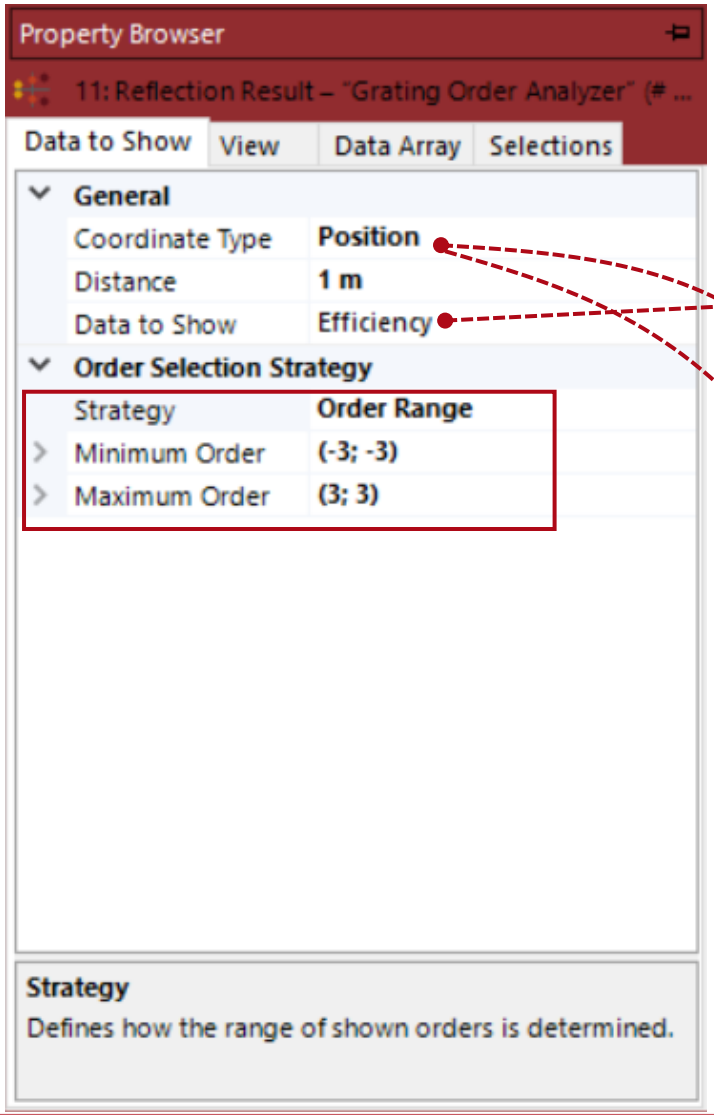


settings

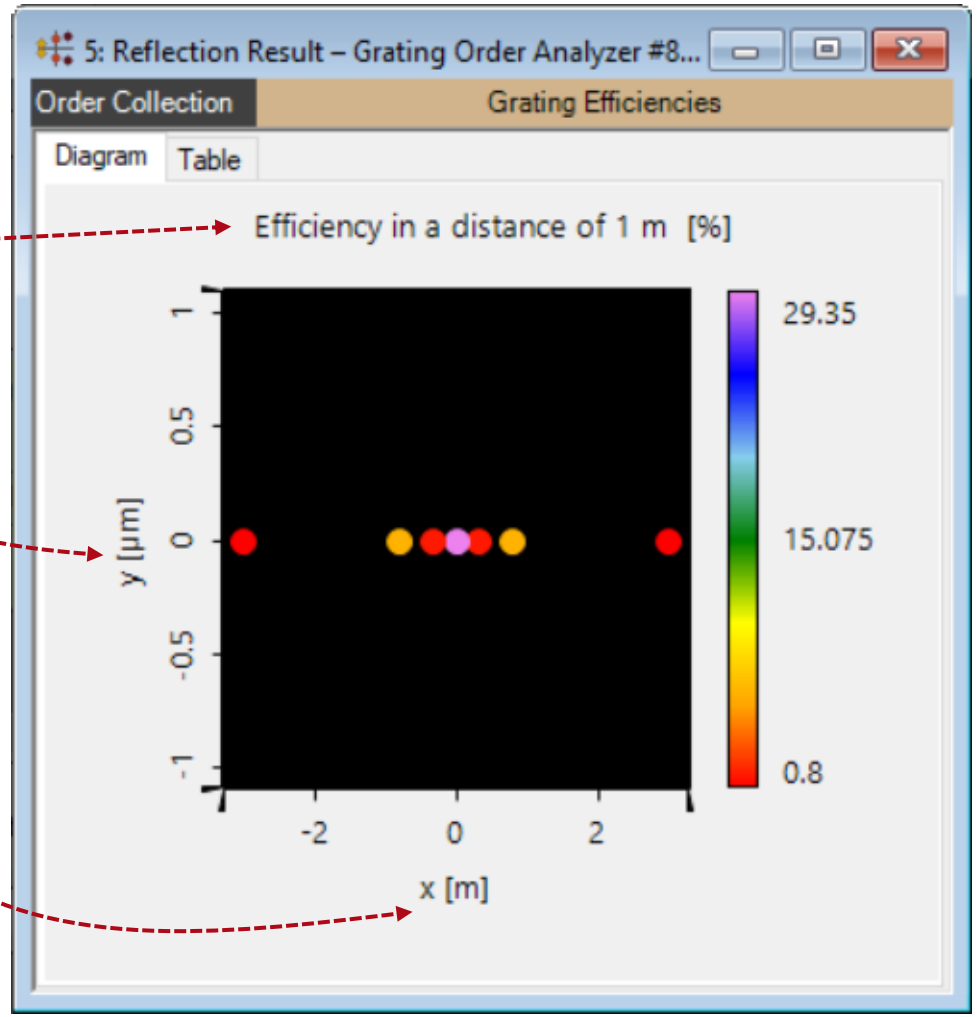


result

Example of Customized Order Collection Settings

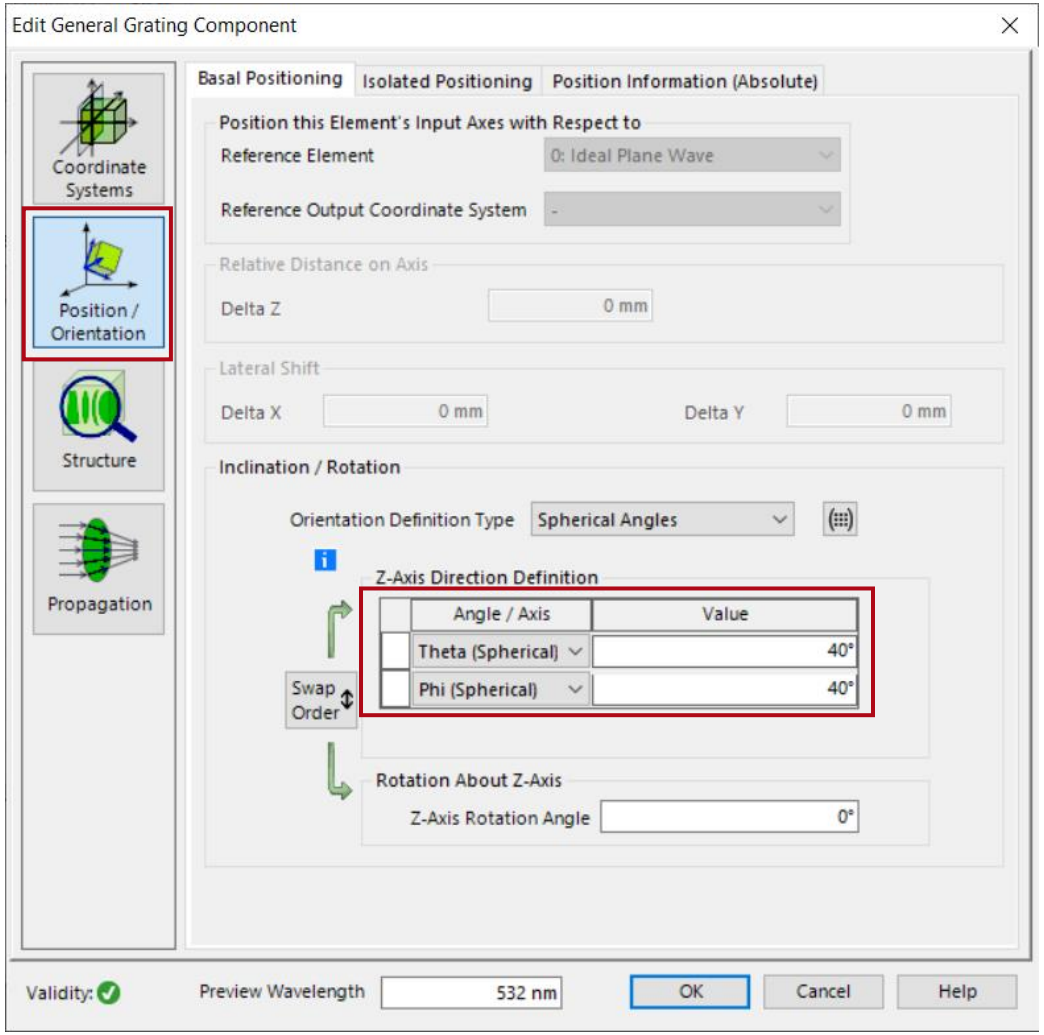


settings



result

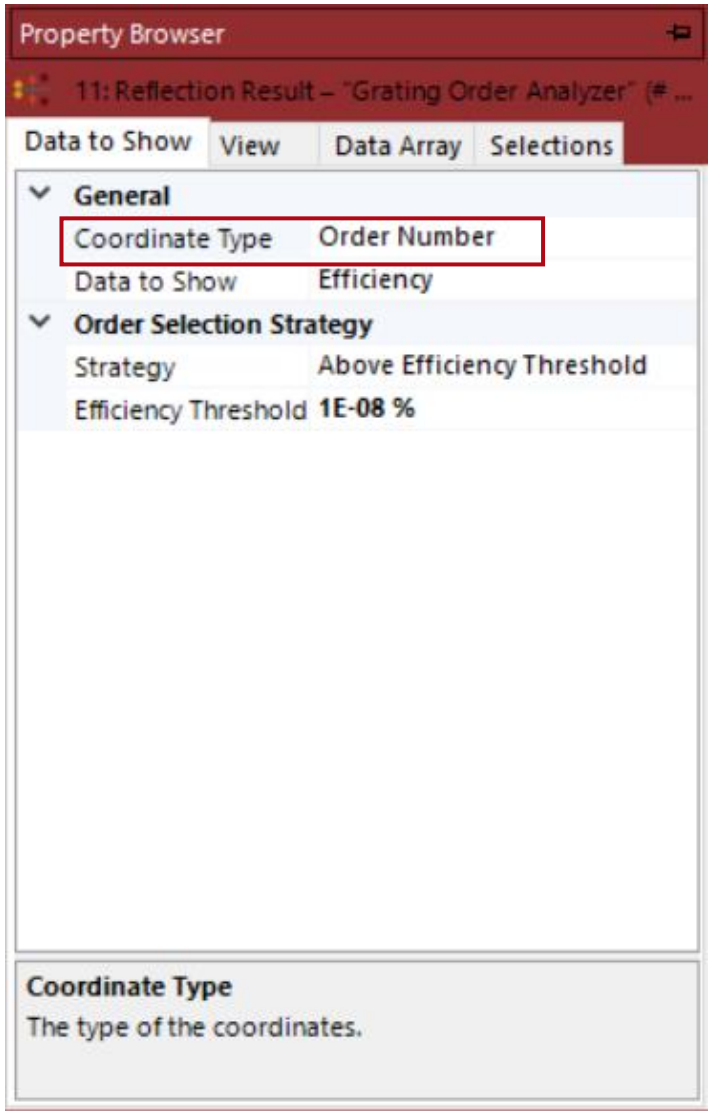
Visualization of Conical Diffraction



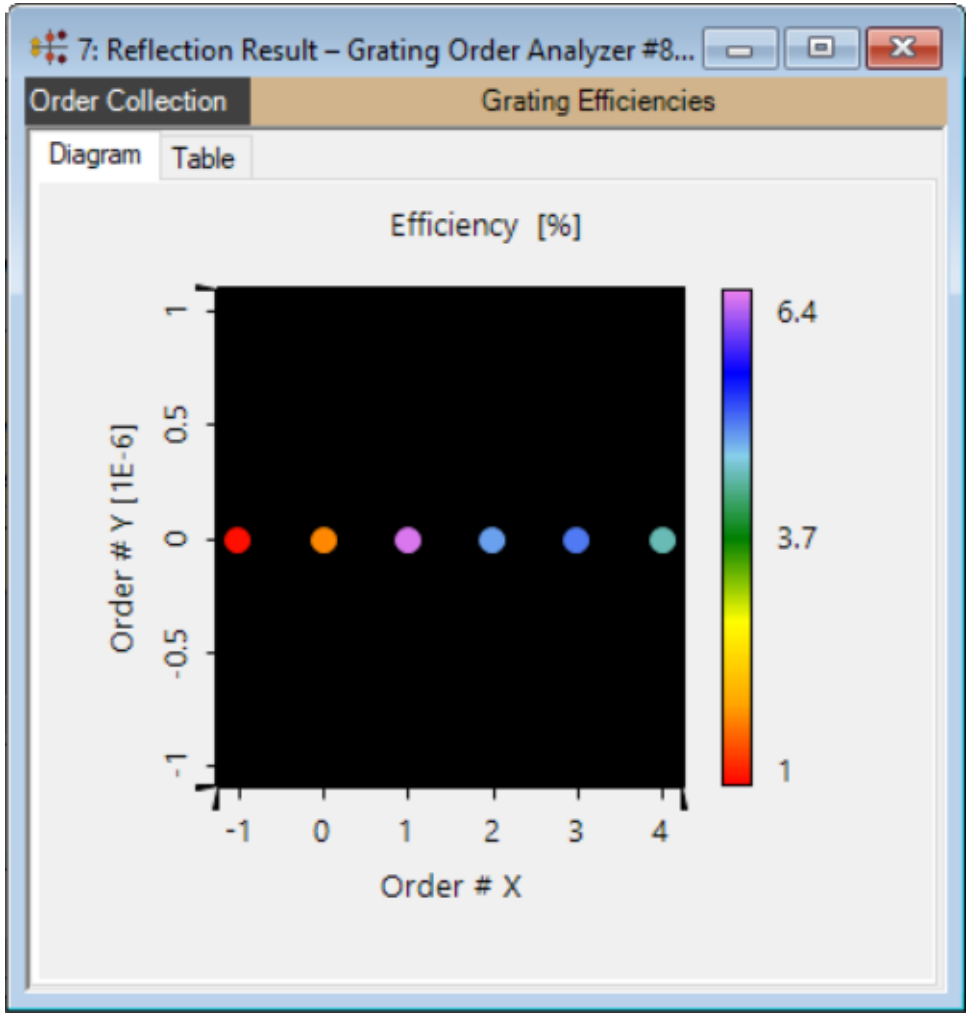
- In the *Position/Orientation* panel of the configuration dialog of the grating, it is possible to alter the orientation of the grating with respect to the source.

- For this use case we use *Theta* = 40° and *Phi* = 40° as an example.

Efficiencies vs Diffraction Order Number

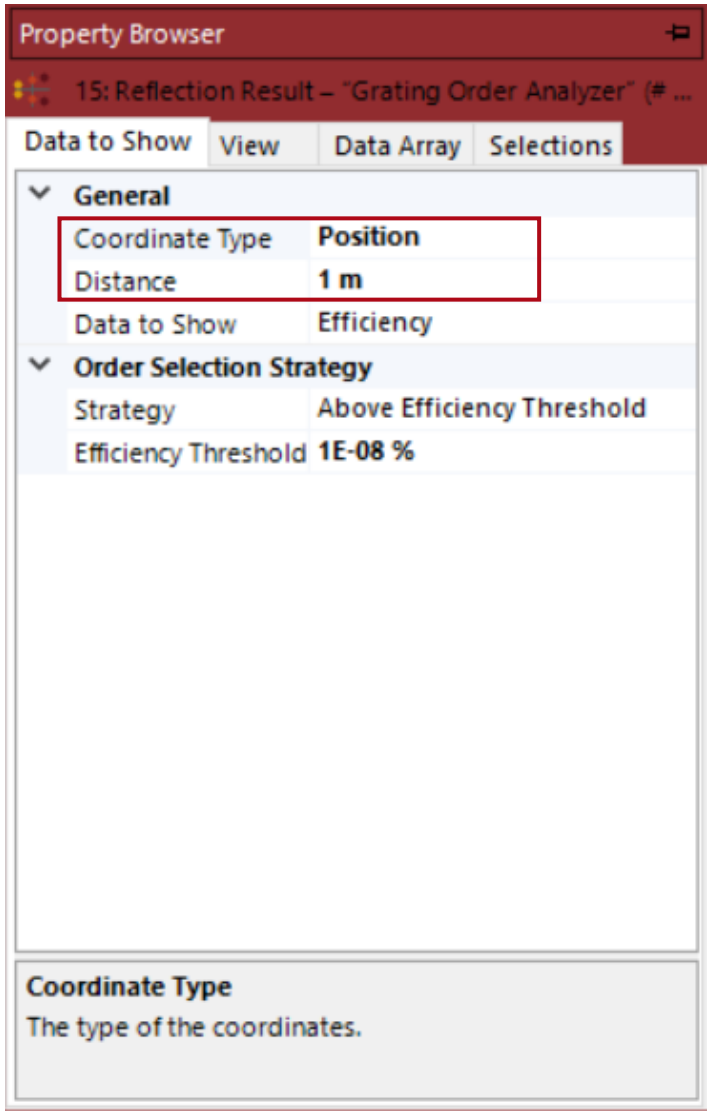


settings

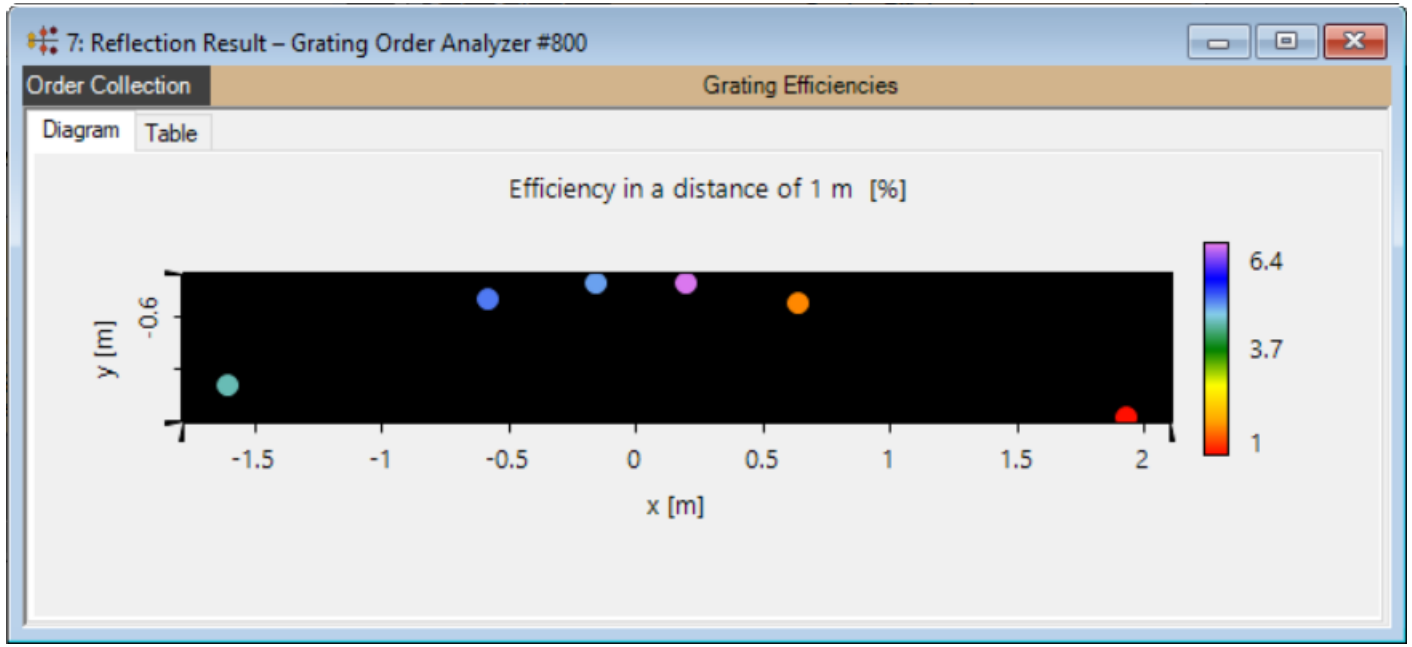


result

Efficiencies vs Diffraction Order Position at Given Distance

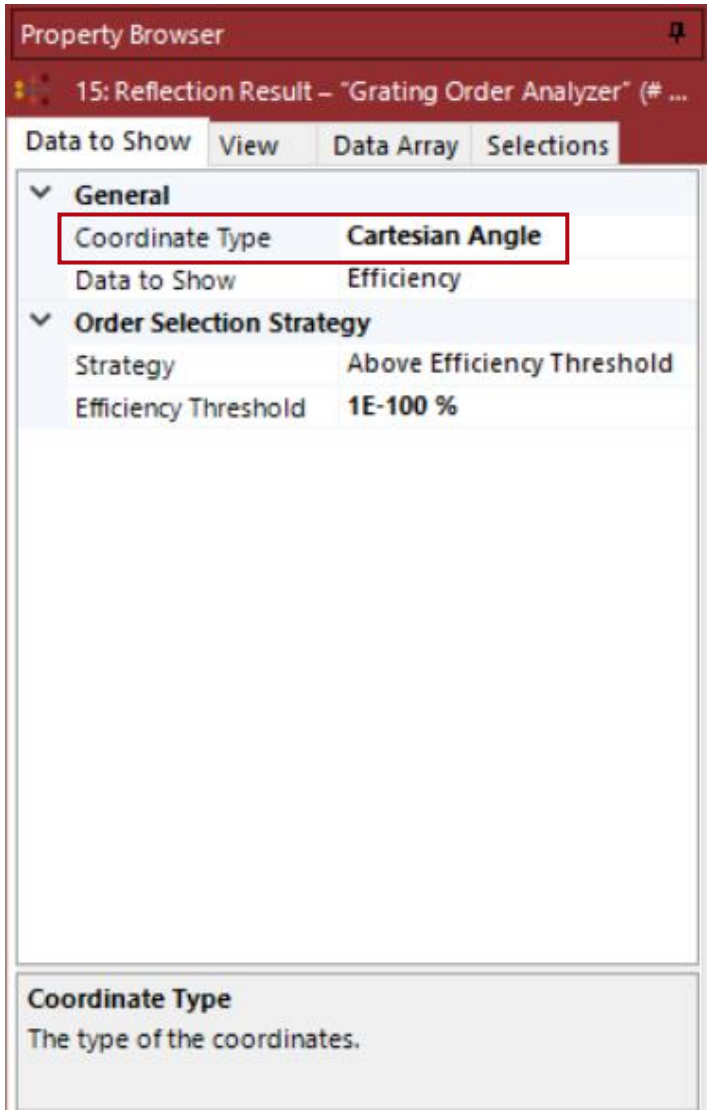


settings

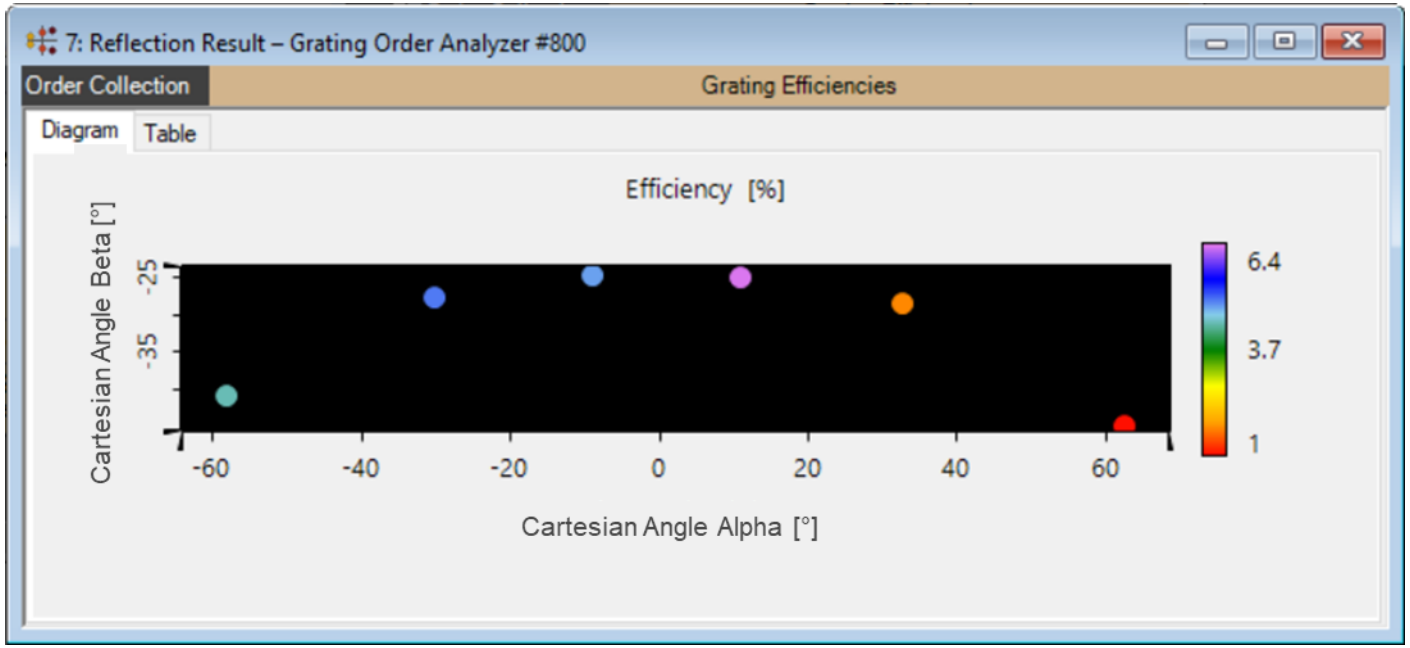


result

Efficiencies vs Diffraction Order Cartesian Angle



settings



result

Document Information

title	Grating Order Analyzer
document code	GRT.0002
document version	2.0
software edition	VirtualLab Fusion Advanced
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	- Analysis of Blazed Grating by Fourier Modal Method - Optimization of Lightguide Coupling Grating for Single Incidence Direction