

UseCase.0086 (2.0)

## **The Grating Order Analyzer**

Introduction to the analysis and display of the diffraction efficiencies and Rayleigh coefficients of gratings

# Requirements & Recommendations

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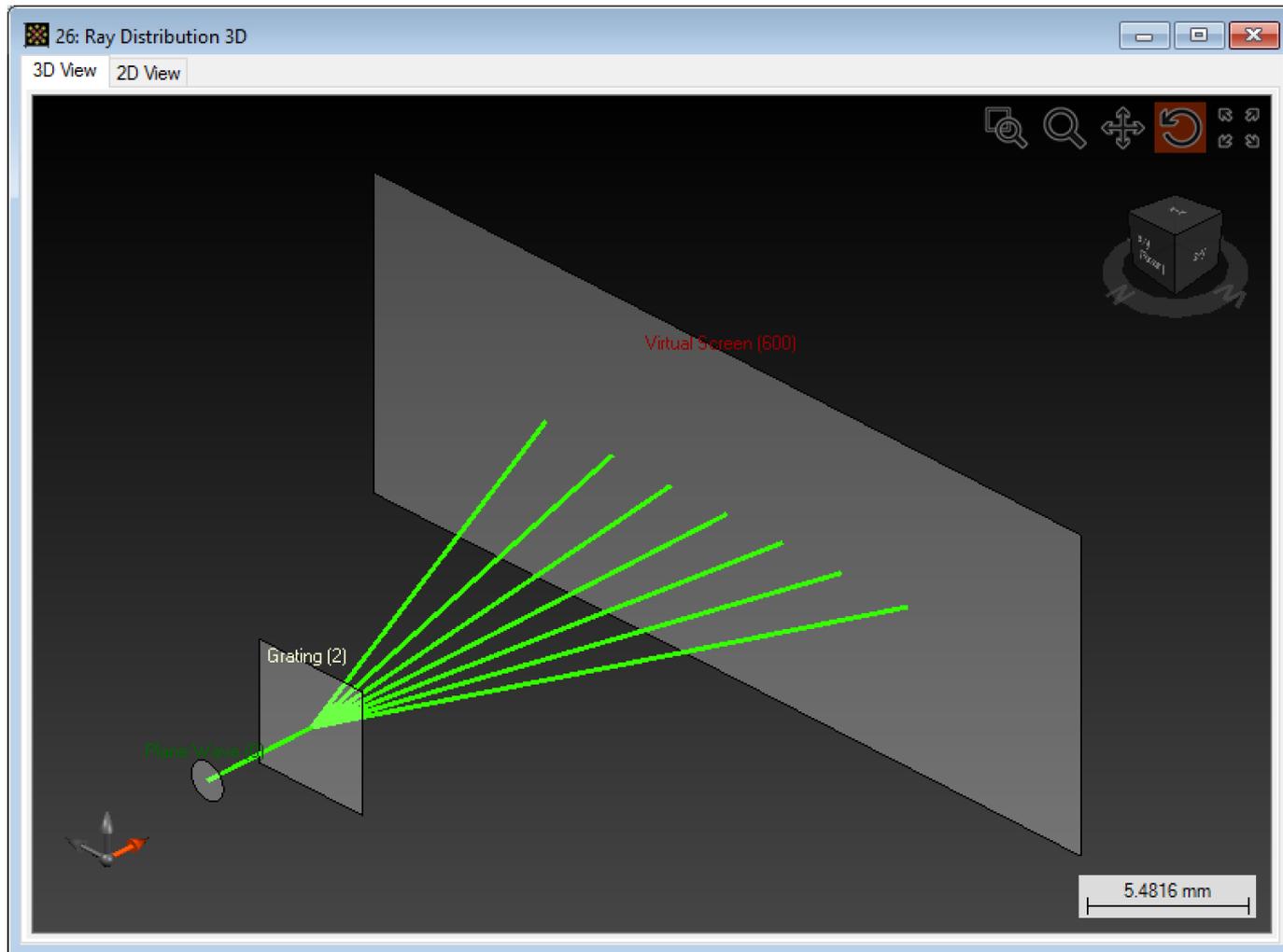
- This use case requires VirtualLab Fusion Build 6.1.0.20 or higher.
- Required Toolboxes:
  - Grating Toolbox
- The trial version of VirtualLab Fusion allows the application of this use case with the following restrictions:
  - The trial version does not support saving of the system description or calculated results.

# Use Case Description

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- The analysis of the diffraction efficiencies of gratings is the typical modeling task with gratings.
- The efficiencies follow from the Rayleigh coefficients.
- Both quantities are given for each of the diffraction orders of a grating.
- VirtualLab Fusion enables the calculation of efficiencies and Rayleigh coefficients by the fully vectorial Fourier Modal Method (FMM).
- This is done by the Grating Order Analyzer, which can display the efficiencies and Rayleigh coefficients of the distinct orders in various ways.
- This use case introduces the Grating Order Analyzer.

# Discrete Orders Generated by a Grating

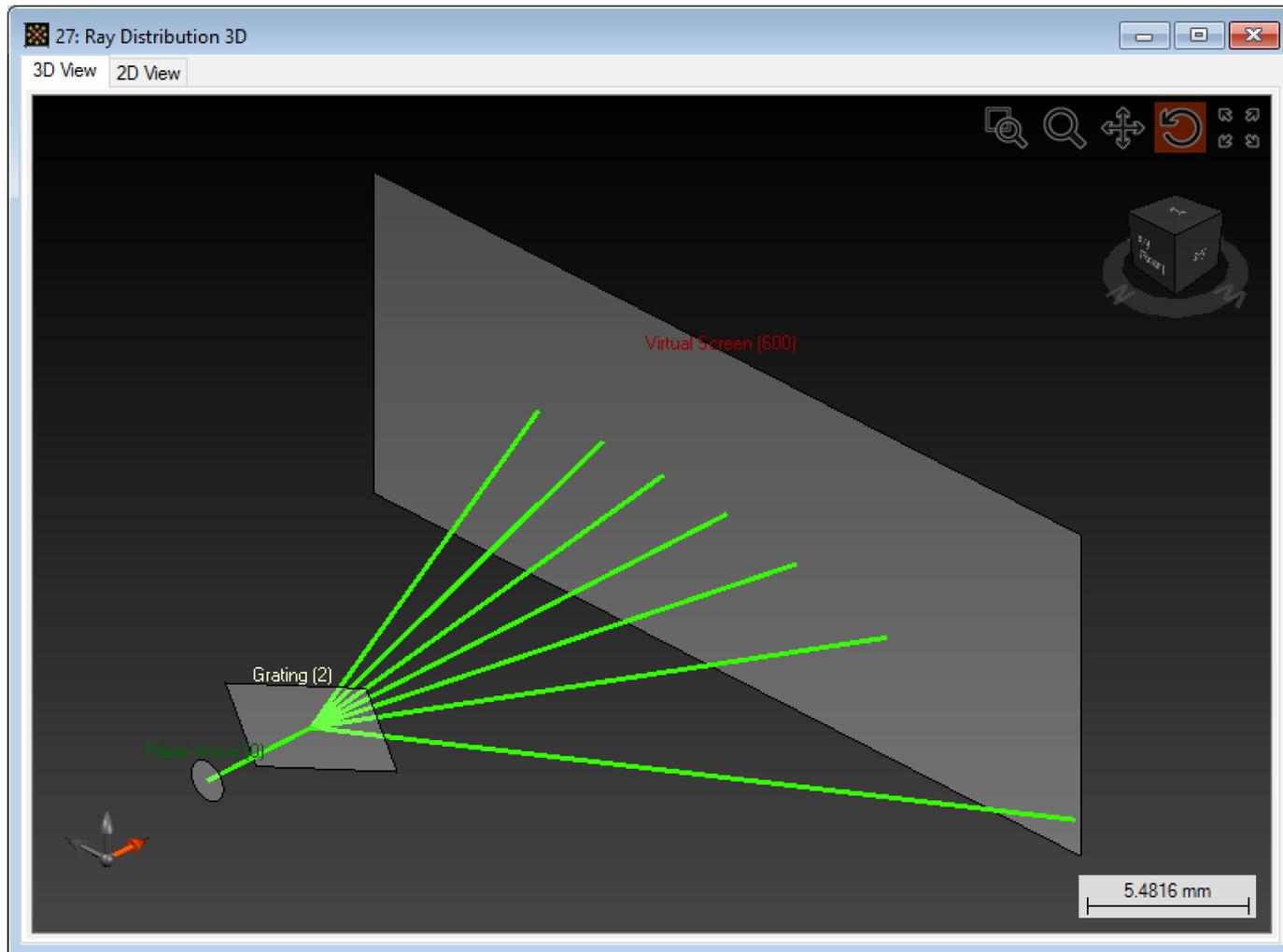


# Grating Orders

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- If a grating is illuminated with a laser beam it generates a set of discrete orders dependent on the period.
- The deflection of the grating orders is defined by the two-dimensional grating equation.
- The grating structure as well as the incident light define the efficiencies of the orders.
- The efficiencies can be calculated by the Fourier Modal method available in VirtualLab.
- If a linear grating is illuminated under an angle (conical incidence) the scattered orders of the grating are in general no longer on a line.
- This is also included in the simulation of grating systems in VirtualLab.

# Conical Incidence on a Grating



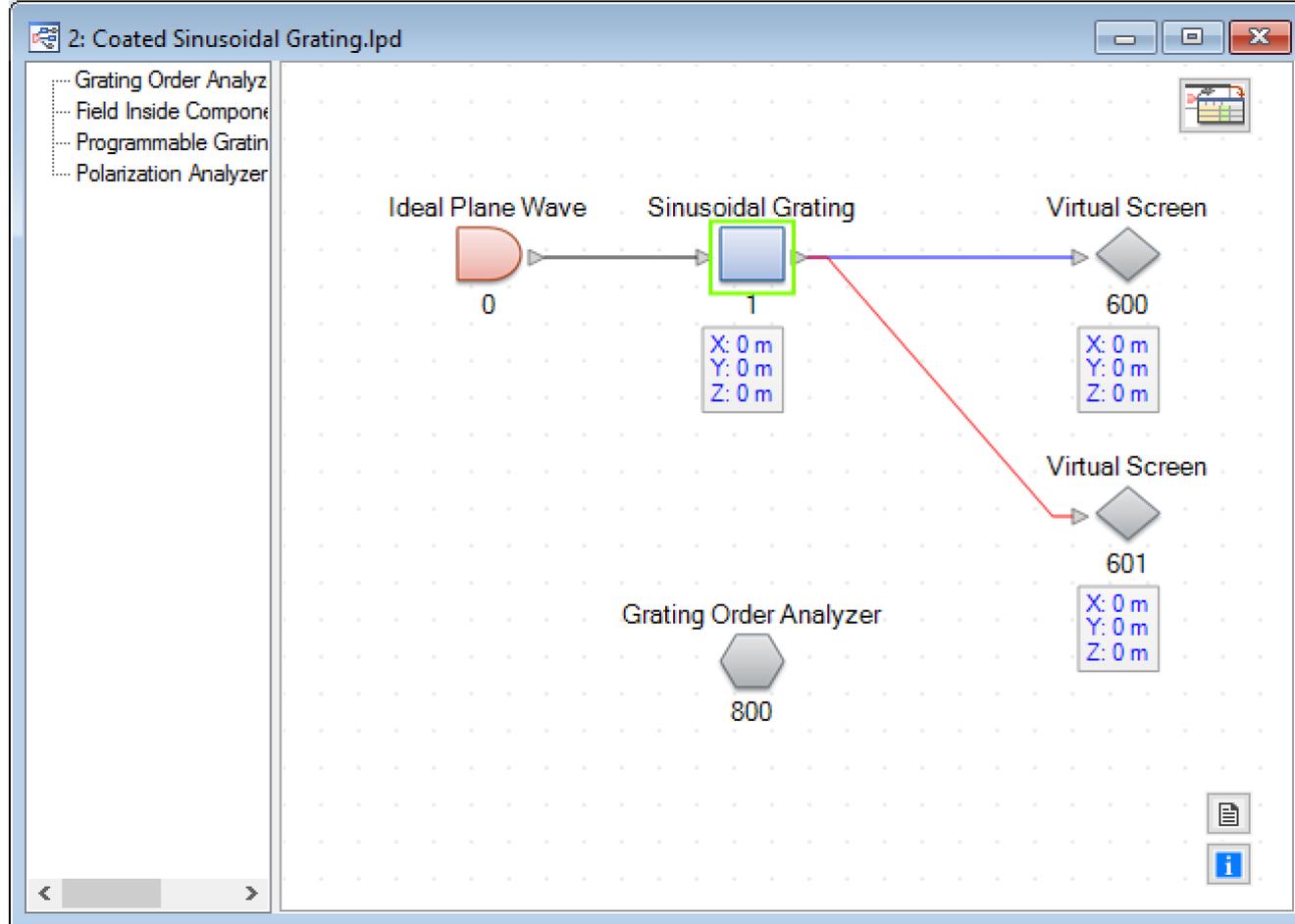
# This Use Case Shows You...

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- ...how to calculate:
  - Direction of diffraction orders (m,n) according to the **2D grating equation**
  - Diffraction efficiencies of the different orders
  - Rayleigh coefficients in TE/TM or x,y,z coordinate system
- ...how to display the quantities in different ways:
  - Tables
  - Polar diagrams
  - Position and efficiency/coefficient of orders in different coordinates including the lateral position
- All calculations can be done dependent on the polarization of the incident wave.
- Linear (1D) and crossed (2D) gratings can be analyzed.

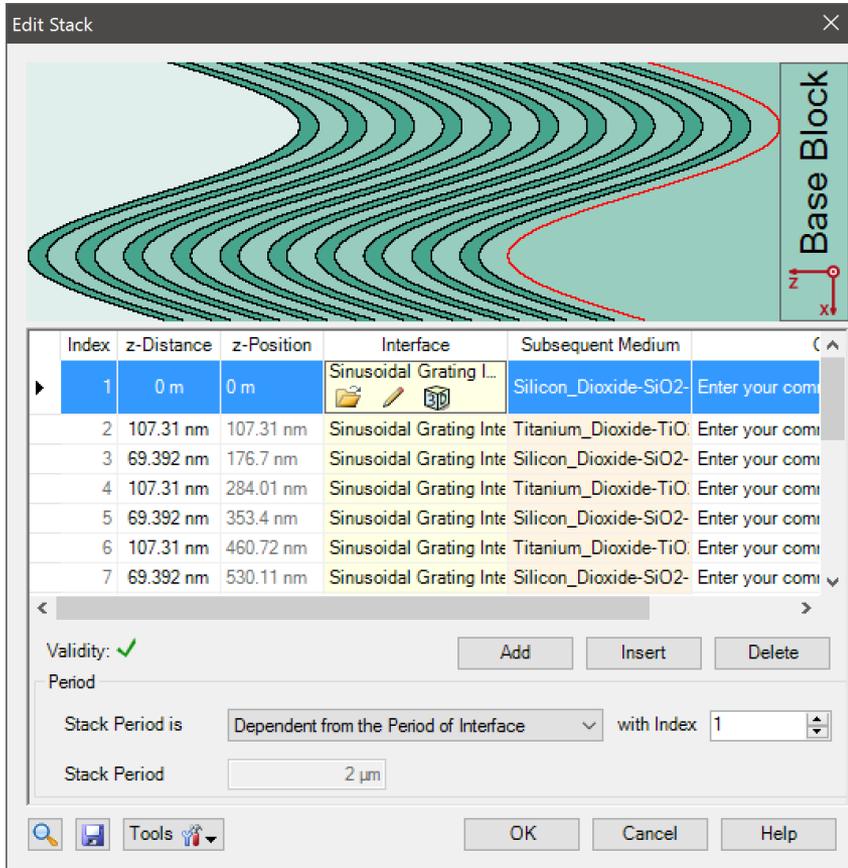
# **Applied VirtualLab Techniques and Tools**

# Sample File



Filename: Coated Sinusoidal Grating.lpd

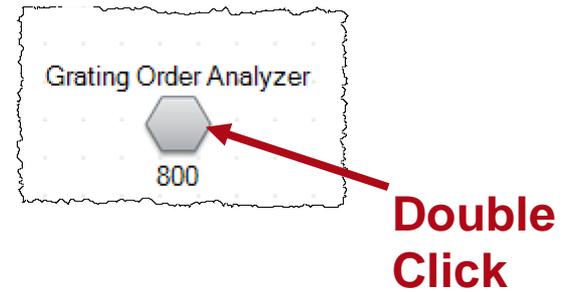
# Grating Specification



- For the demonstration of the Grating Order Analyzer for 1D gratings we use a coated sinusoidal grating.
- The grating parameters can be specified within the stack that can be accessed in the edit dialog of the grating component.

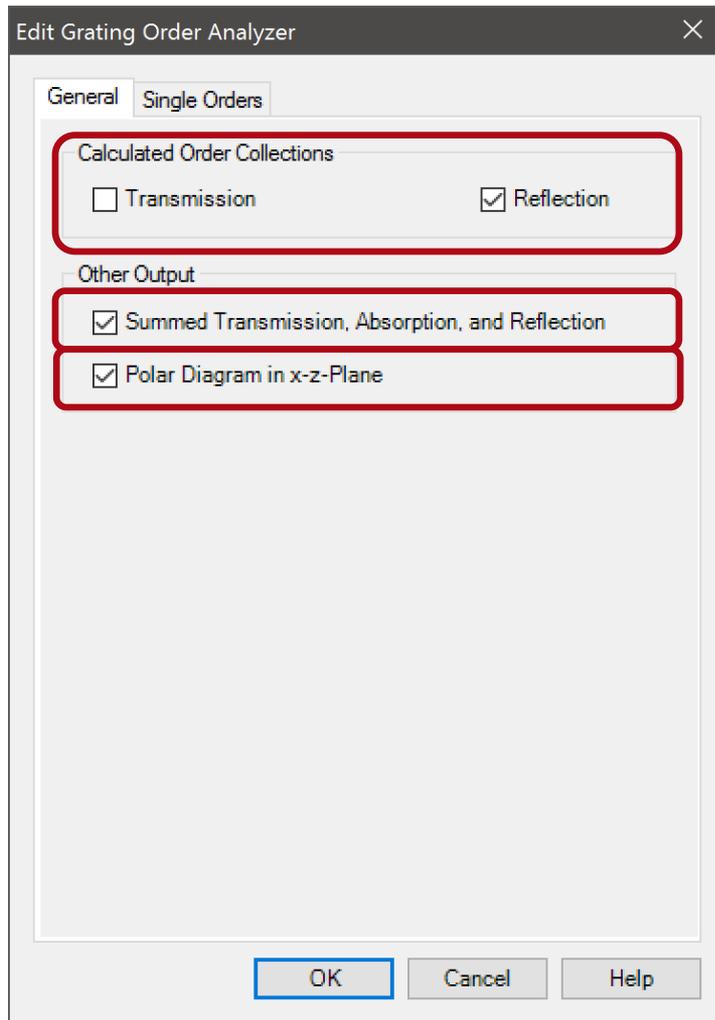
# Grating Order Analyzer

- After the grating structure has been defined you can configure the grating order analyzer.
- Various output options can be specified.
- This is done through the edit dialog of the analyzer which is opened by double clicking on the light path element in the light path view.



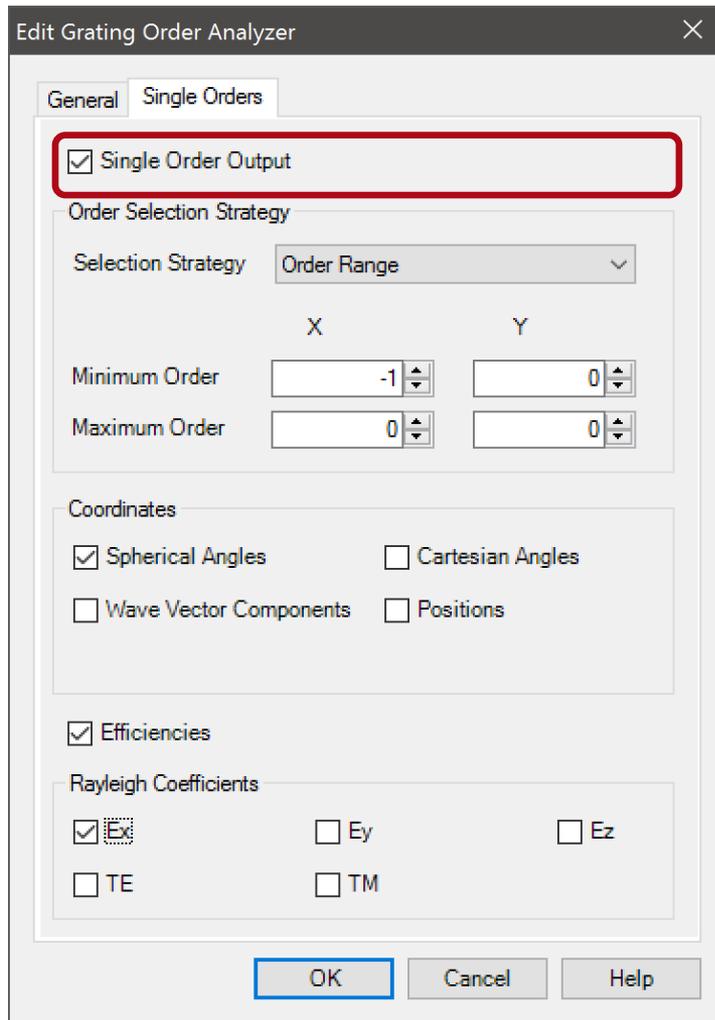
- The options of the analyzer will be explained in the following slides.

# Grating Order Analyzer



- In the *General* tab page you can select whether transmission and/or reflection shall be analyzed.
- In addition you can specify whether you would like to evaluate the summed transmission, absorption and reflection values and whether you would like to show a polar diagram.

# Grating Order Analyzer



- In the *Single Orders* tab you can select whether information for single orders shall be logged.
- This option is very helpful if you would like to use the parameter run or the parametric optimization of VirtualLab to analyze and optimize specific orders of a grating.

# Options for Single Order Output

Parameter	Description
Order Selection Strategy	The user can define which order shall be evaluated. The user can define whether to analyze <b>All</b> orders, analyze only those orders which have an efficiency <b>Above a Given Threshold</b> or calculate only orders in a manually defined <b>Order Range</b> . Depending on the selection strategy the user has to define additional parameters.
Coordinates	Logging of the coordinates of the orders is also supported. The user can specify whether to show the coordinates in <b>Spherical Angles, Cartesian Angles, Wave Vector Components</b> or <b>Positions</b> . 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 coefficient <b><math>E_x</math>, <math>E_y</math>, <math>E_z</math>, TE or TM</b> .



# Grating Order Analyzer – Outputs

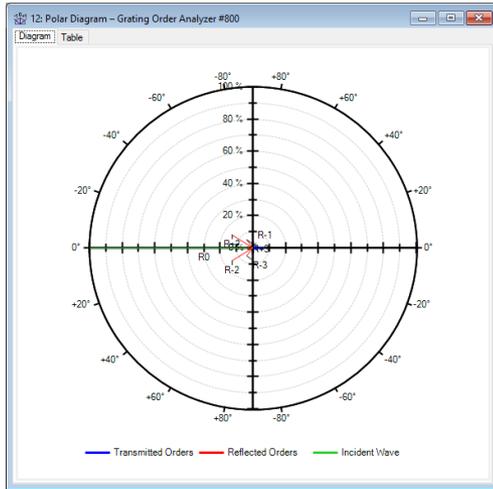
Detector Results				
	Date/Time	Detector	Sub - Detector	Result
14	02/02/2016 09:35:15	Grating Order Analyzer #800 (Results for Individual Orders)	Spherical Angle Theta R[-1; 0]	15.422°
13			Spherical Angle Phi R[-1; 0]	0°
12			Efficiency R[-1; 0]	3.1141 %
11			Amplitude of Rayleigh coefficient Ex R[-1; 0]	173.26 mV/m
10			Phase of Rayleigh coefficient Ex R[-1; 0]	3.0575 rad
9			Spherical Angle Theta R[0; 0]	0°
8			Spherical Angle Phi R[0; 0]	0°
7			Efficiency R[0; 0]	29.639 %
6			Amplitude of Rayleigh coefficient Ex R[0; 0]	544.42 mV/m
5			Phase of Rayleigh coefficient Ex R[0; 0]	1.4436 rad
4	02/02/2016 09:35:15	Grating Order Analyzer #800 (Results for Individual Orders) Grating Order Analyzer #800	Overall Reflection Efficiency	78.661 %
3			Overall Transmission Efficiency	21.339 %
2			Overall Reflection and Transmission Efficiency	100 %
1			Absorption	0 %

Messages **Detector Results**

- If the Grating Order analyzer is processed within the Light Path diagram the single order output values are logged into the detector results tab.
- These values are also available in the parameter run and the parametric optimization.

# Grating Order Output: Polar Diagram

# Polar Diagram

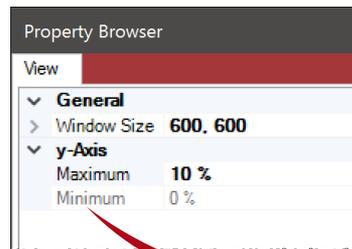
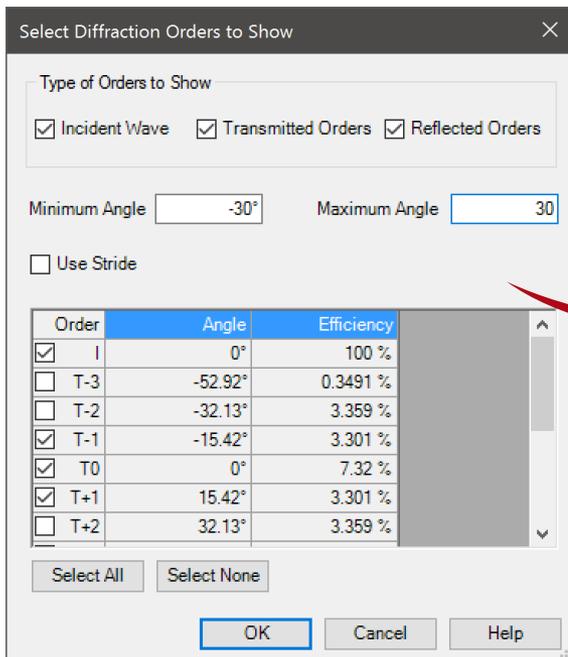


Order	Angle	Efficiency
I	0°	100 %
T-3	-52.919°	0.34913 %
T-2	-32.131°	3.3594 %
T-1	-15.422°	3.3009 %
T0	0°	7.3204 %
T+1	15.422°	3.3009 %
T+2	32.131°	3.3594 %
T+3	52.919°	0.34913 %
R-3	52.919°	6.2033 %
R-2	32.131°	15.194 %
R-1	15.422°	3.1141 %
R0	0°	29.639 %
R+1	-15.422°	3.1141 %
R+2	-32.131°	15.194 %
R+3	-52.919°	6.2033 %

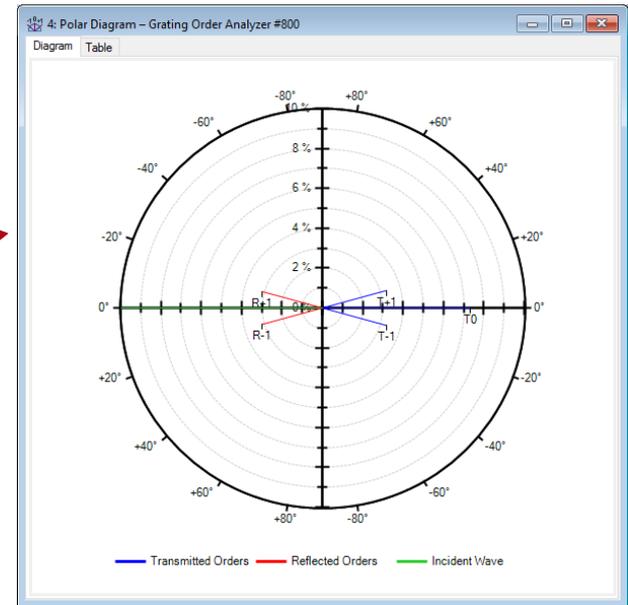
- The polar diagram output of the Grating Order Analyzer plots the efficiencies of both the reflected and the transmitted orders versus the angles in the x-z-plane.
- It also provides a table of all angles and efficiencies of the displayed orders.

# Configuring the Polar Diagram

- You can zoom into the polar diagram with the mouse wheel, the Property Browser and the ribbon.
- You can configure which orders are shown by right-clicking on the diagram.

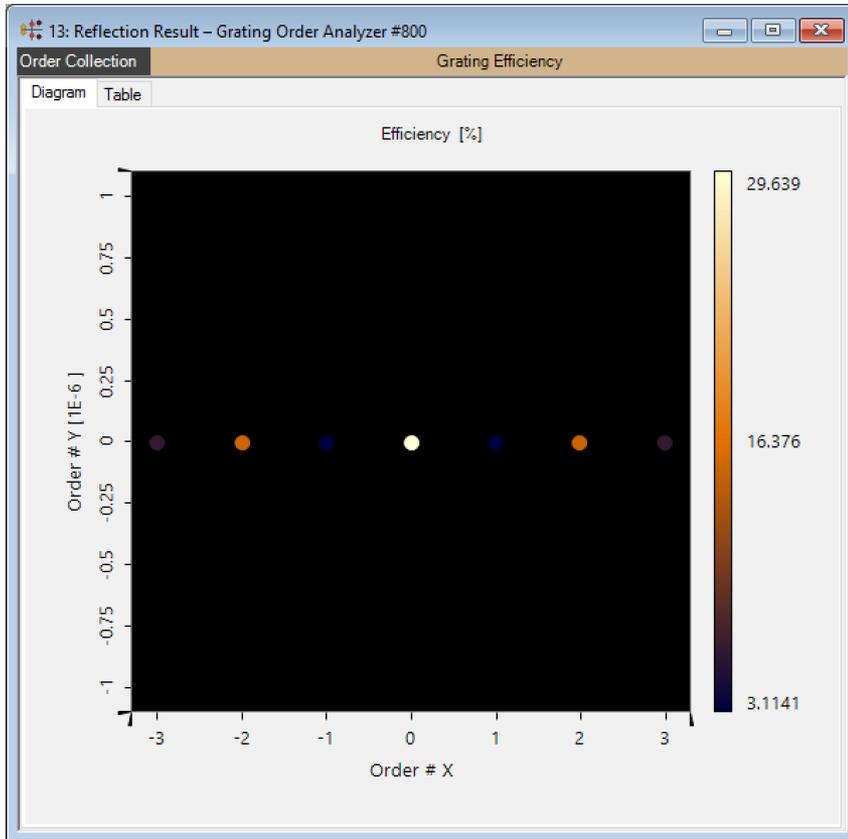


Results in



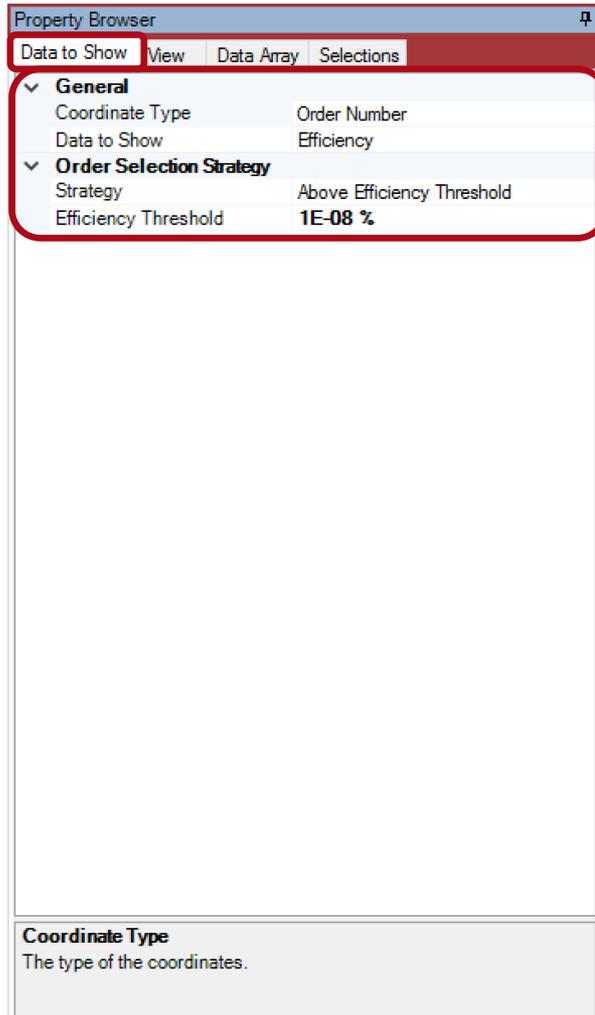
# **Grating Order Output: Order Collection**

# Grating Order Collection



- The Grating Order Collection object is used to visualize the calculated grating efficiencies or the Rayleigh coefficients over different coordinates.
- The user can configure the data that shall be shown by setting diverse options via the property browser.

# Setup of Data to Show

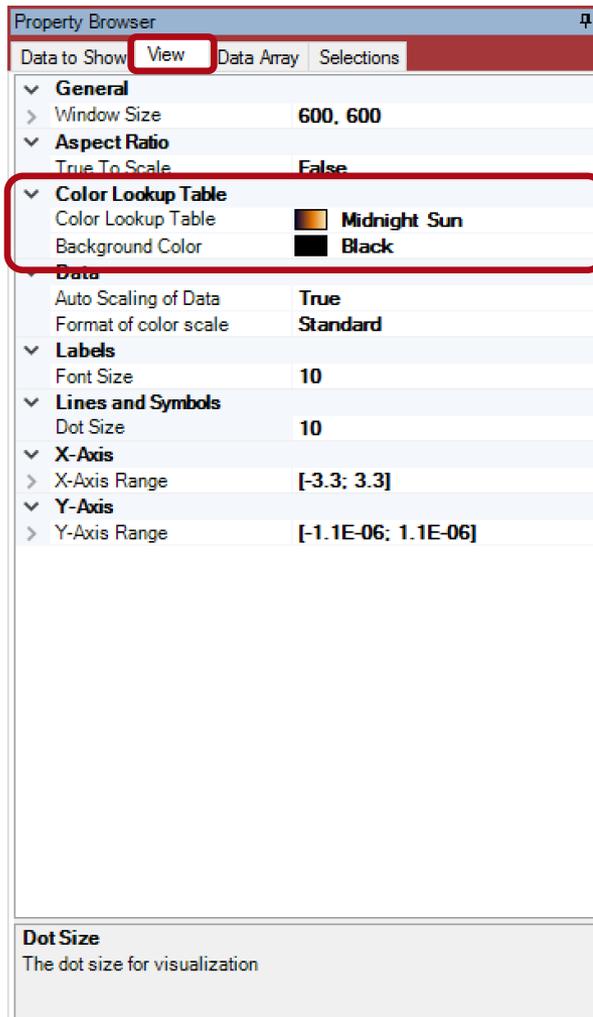


- You can specify via the property browser which data shall be shown over which coordinates.
- In addition the user can select the order to be shown in the diagram.
- These settings are done on the **Data to Show** tab page of the property browser.

# Setup of Data to Show

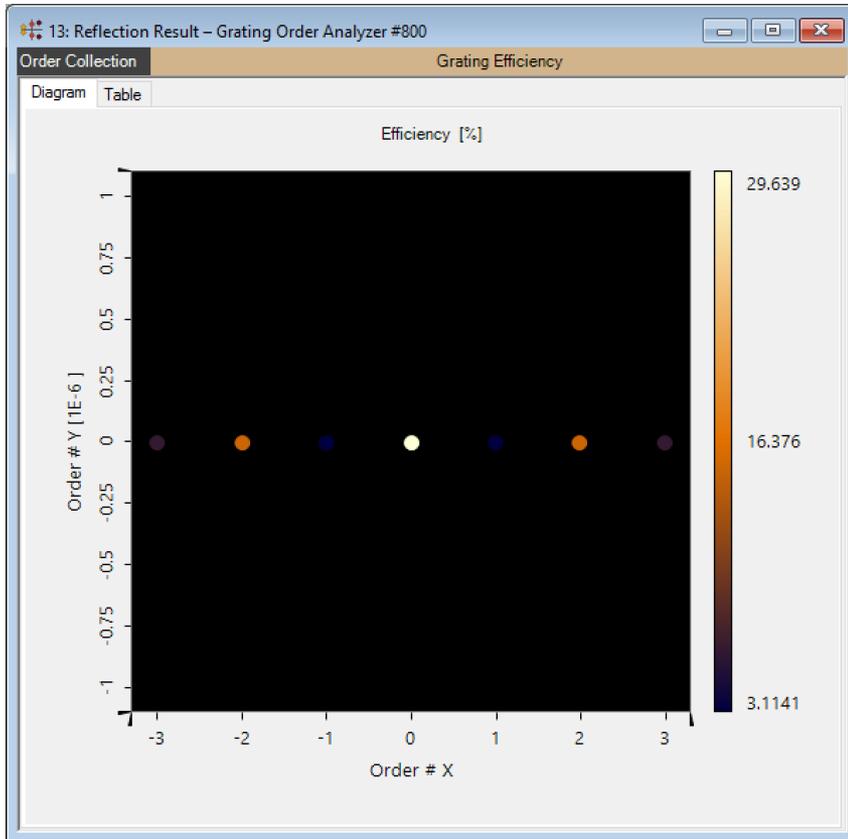
Option	Description
Coordinate Type	This property can be used to define the coordinates over which the data shall be visualized. Currently the order collection supports the visualization over <b>Cartesian Angles, Spherical Angles, Wave Number Vectors</b> and <b>Positions</b> .
Data to Show	It is possible 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 <b><math>E_x</math>, <math>E_y</math>, <math>E_z</math>, TM</b> and <b>TE</b> are supported.
Order Selection Strategy	The user can define which order shall be displayed. The user can define whether to show <b>All</b> , show only orders which have an efficiency <b>Above a Given Threshold</b> or show only orders for a manually defined <b>Order Range</b> . Depending on the selection strategy the user has to define additional parameters.

# Setup of Additional View Settings



- In the **View** tab page of the property browser the user can set up additional view parameters.
- Most important for the customization of the view are the color settings.
- The user can select the background color for the view as well as the color lookup table that shall be used to define the colors for the displayed data values.

# Example of View Customization



Visualization

Property Browser

Data to Show View Data Array Selections

General

Coordinate Type	Order Number
Data to Show	Efficiency

Order Selection Strategy

Strategy	Above Efficiency Threshold
Efficiency Threshold	1E-08 %

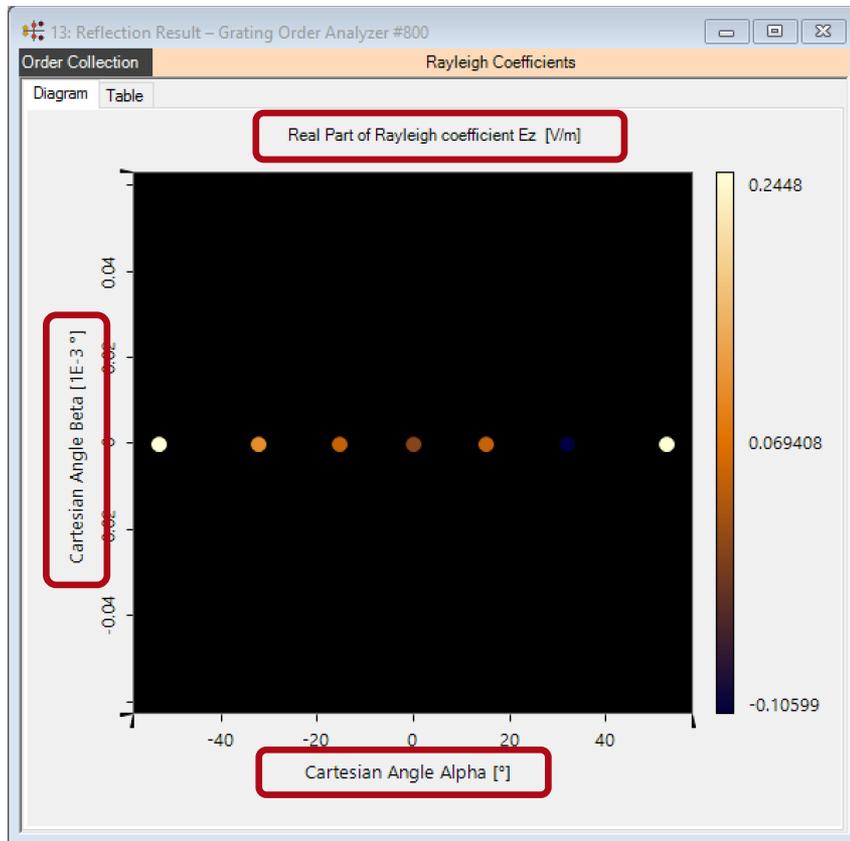
Strategy

Defines how the range of shown orders is determined.

Property Browser VirtualLab Explorer

View Settings

# Example of View Customization



Visualization

The figure shows the "Property Browser" window. The "Data to Show" tab is selected. The "General" section is expanded, showing the following settings:

Coordinate Type	Cartesian Angle
Data to Show	Rayleigh coefficient Ez

The "Order Selection Strategy" section is also expanded, showing the following settings:

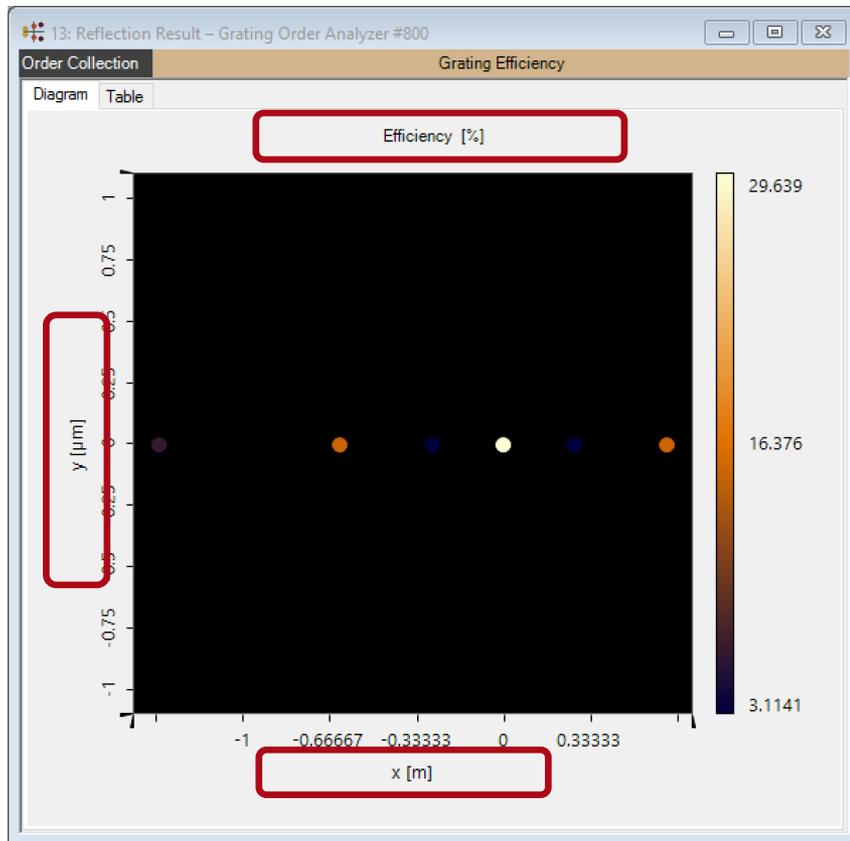
Strategy	Above Efficiency Threshold
Efficiency Threshold	1E-08 %

The "Strategy" section is also visible, with the text: "Defines how the range of shown orders is determined."

At the bottom of the window, the "Property Browser" and "VirtualLab Explorer" tabs are visible.

View Settings

# Example of View Customization



Visualization

Property Browser

Data to Show View Data Array Selections

General

Coordinate Type	Position
Distance	1 m
Data to Show	Efficiency

Order Selection Strategy

Strategy	Order Range
Minimum Order	(-2; -3)
Maximum Order	(3; 3)

Minimum Order

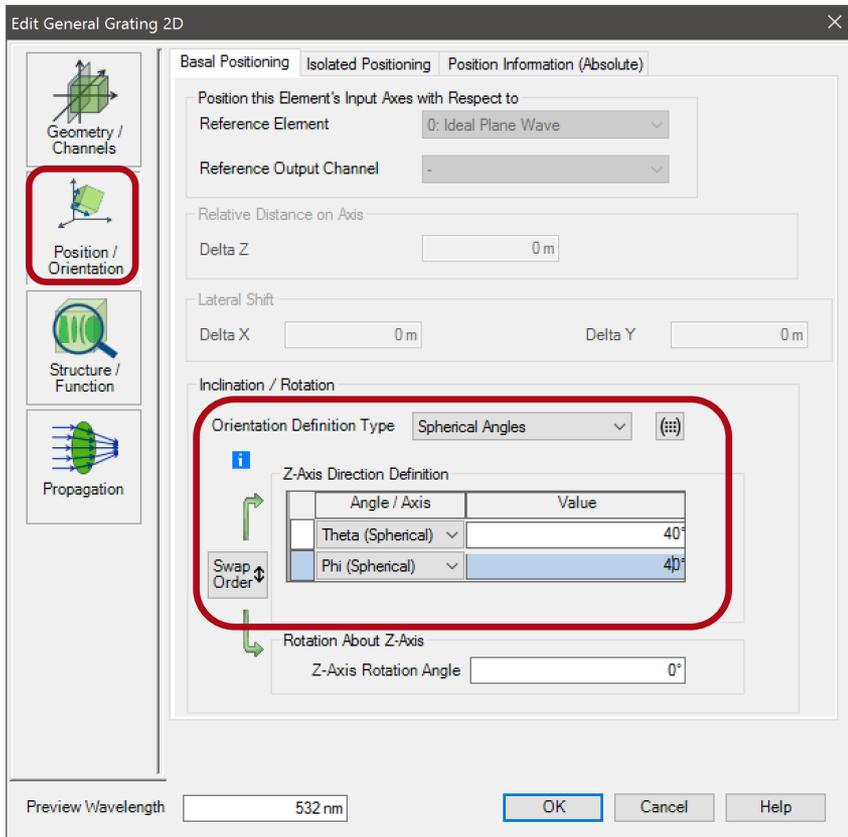
The minimum shown order.

Property Browser VirtualLab Explorer

View Settings

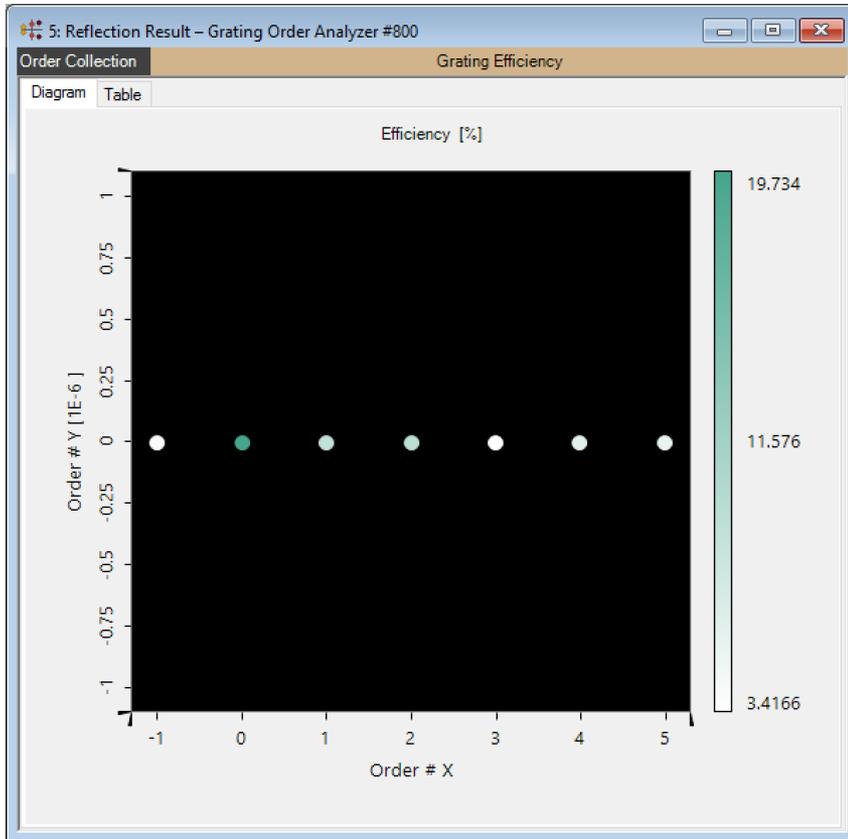
# Visualization of Conical Incidence

# Define Conical Incidence



- Within the positions and orientation definition of the grating the user can define an arbitrary orientation.
- This is done in the *Position / Orientation* tab within the edit dialog of the grating.
- For this use case we use *Theta* = 40° and *Phi* = 40°.

# Result – Grating Efficiencies over Order Number



Visualization

Property Browser

Data to Show View Data Array Selections

**General**

Coordinate Type	Order Number
Data to Show	Efficiency

**Order Selection Strategy**

Strategy	Above Efficiency Threshold
Efficiency Threshold	1E-08 %

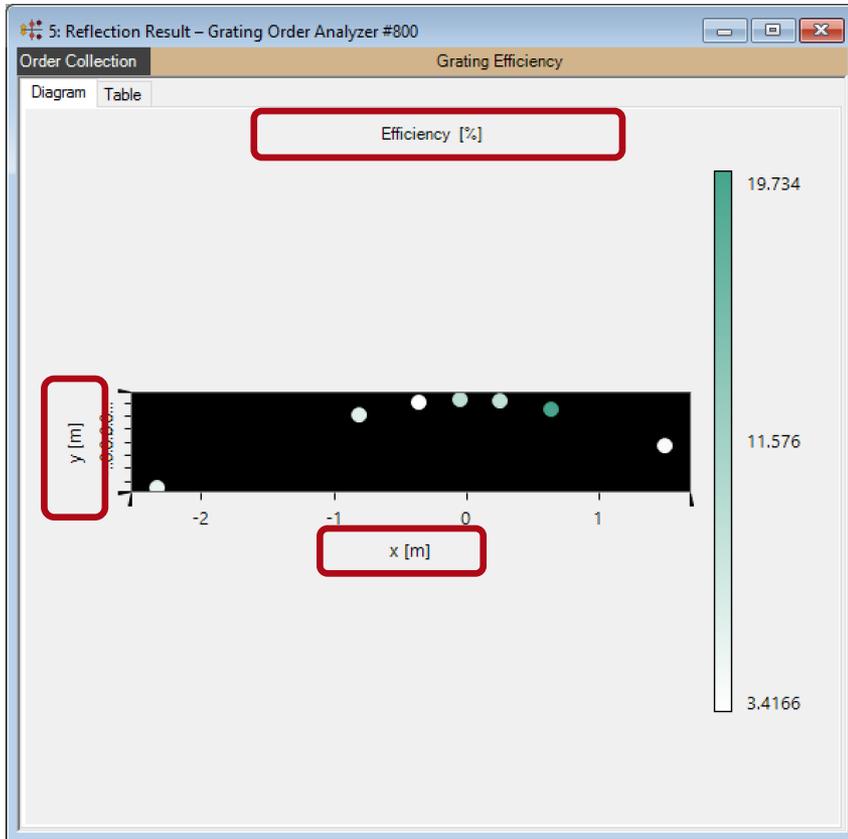
**Strategy**

Defines how the range of shown orders is determined.

Property Browser VirtualLab Explorer

View Settings

# Result – Grating Efficiencies over Order Position



Visualization

Property Browser

Data to Show View Data Array Selections

General

Coordinate Type	Position
Distance	1 m
Data to Show	Efficiency

Order Selection Strategy

Strategy	Above Efficiency Threshold
Efficiency Threshold	1E-08 %

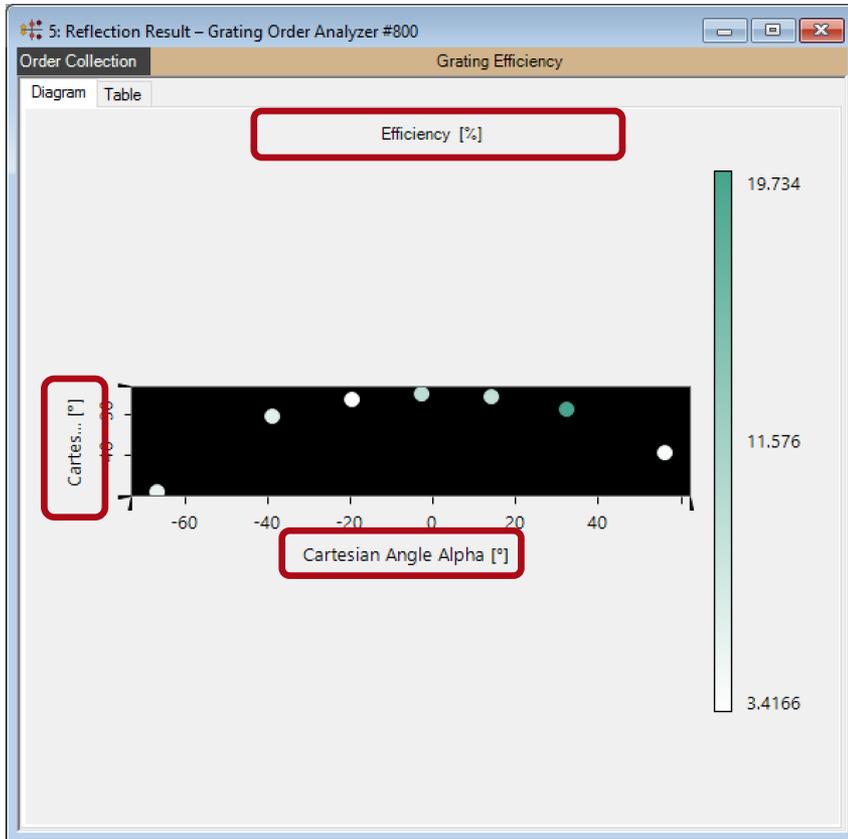
Coordinate Type

The type of the coordinates.

Property Browser VirtualLab Explorer

View Settings

# Result – Grating Efficiencies over Cartesian Angles



Visualization

Property Browser

Data to Show View Data Array Selections

General

Coordinate Type Cartesian Angle

Data to Show Efficiency

Order Selection Strategy

Strategy Above Efficiency Threshold

Efficiency Threshold 1E-08 %

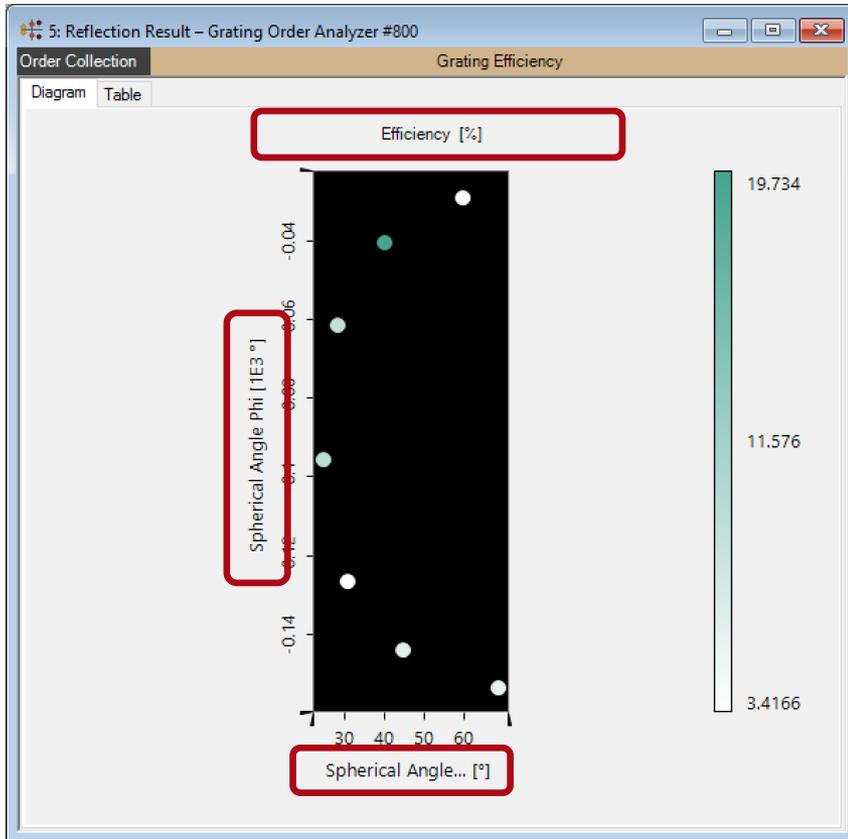
Coordinate Type

The type of the coordinates.

Property Browser VirtualLab Explorer

View Settings

# Result – Grating Efficiencies over Spherical Angles



Visualization

The Property Browser window shows the following settings:

Data to Show	
Coordinate Type	Spherical Angle
Data to Show	Efficiency

Order Selection Strategy	
Strategy	Above Efficiency Threshold
Efficiency Threshold	1E-08 %

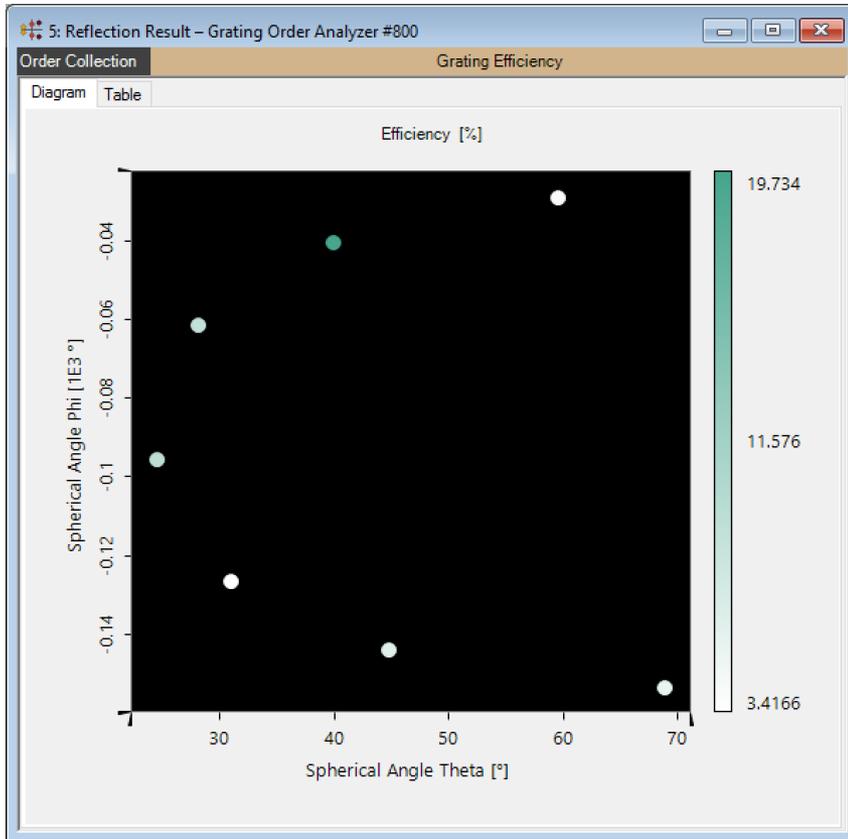
  

**Coordinate Type**  
The type of the coordinates.

Property Browser | VirtualLab Explorer

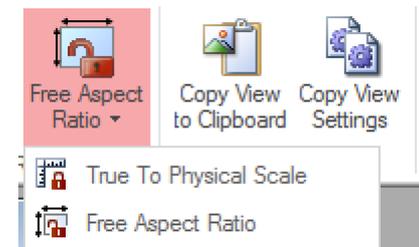
View Settings

# Tips & Tricks: Aspect Ratio



Free Aspect Ratio

- Depending on the coordinate range which is displayed it could be helpful to change the aspect ratio of the data.
- The aspect ratio can be adapted via the property browser or via the corresponding ribbon entry:



In case of questions please do not hesitate to contact us via [\*\*support@lighttrans.com\*\*](mailto:support@lighttrans.com).