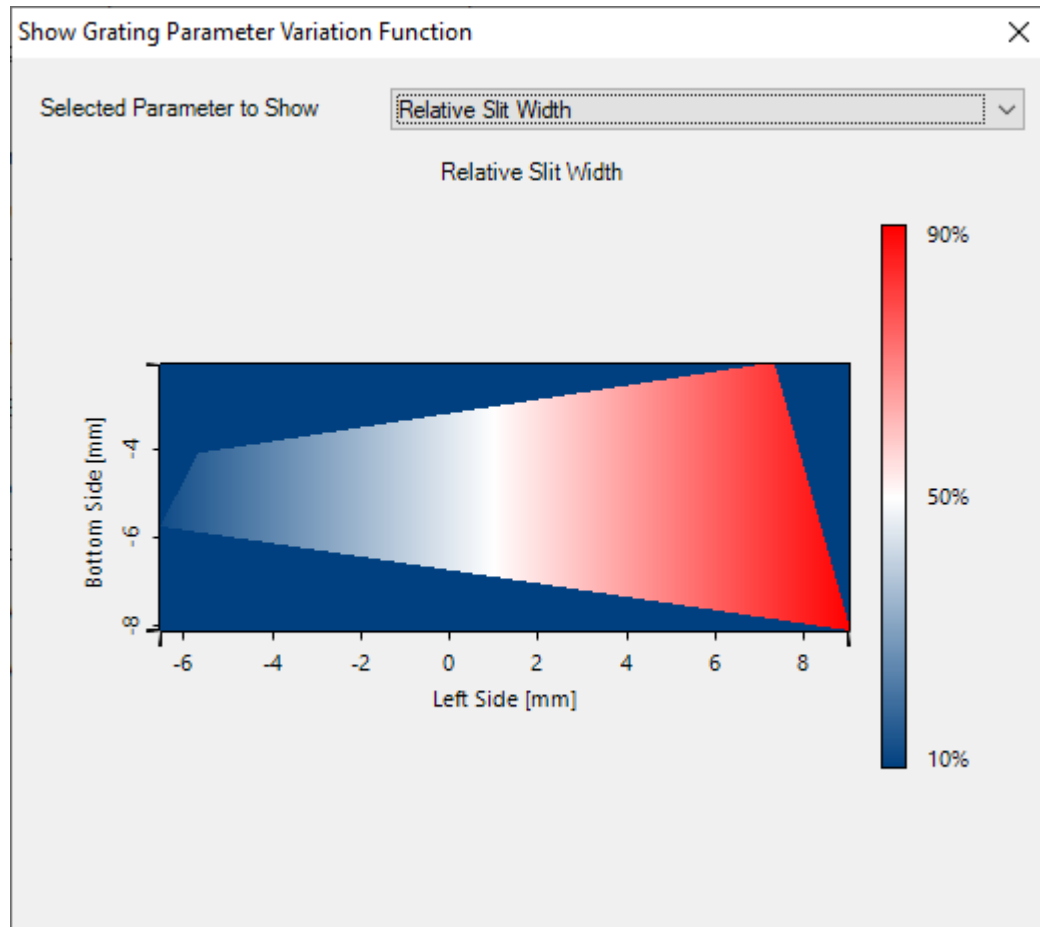


# **Grating Analysis and Smoothly Modulated Grating Parameters on Lightguides**

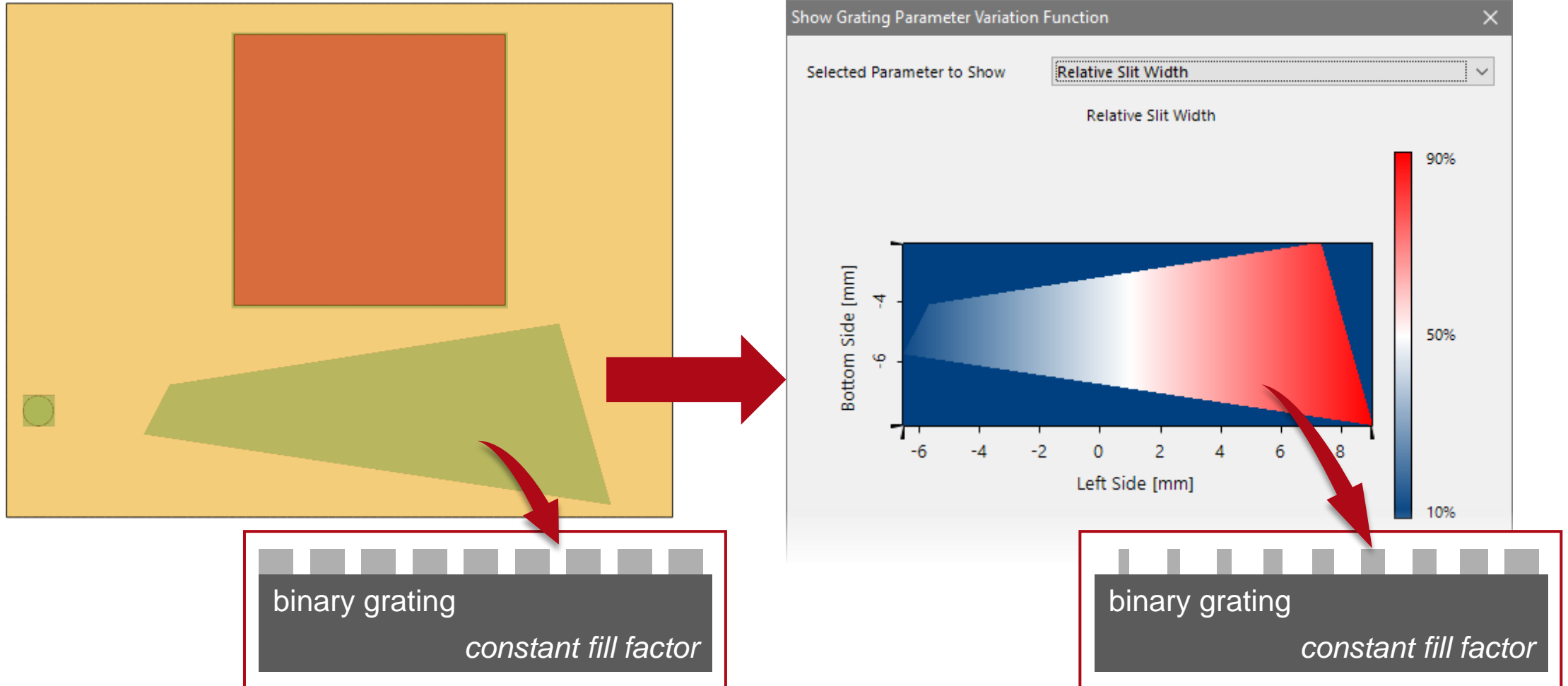
# Abstract



In order to control the uniformity and efficiency in a lightguide device for AR/MR applications, it is necessary to vary grating parameters, such as fill factor and grating height, over certain areas, e.g. in the expansion and outcoupling grating regions. For this purpose, VirtualLab Fusion enables the introduction of smoothly varied grating parameters inside one region, where the desired variation can be configured in very different ways. This also includes a tool to investigate the provided diffraction efficiencies for the specific incident conditions and grating parameters. This example explains, how to apply these tools.

# Illustration of the Modeling Task

introduction of continuously modulated grating parameters on lightguides (e.g., fill factor)



# General Workflow with Additional Guidance

1. Configuration of base optical lightguide setup (not part of this use case)
2. Application of the *Footprint and Grating Analysis* tool including the generation of the optical setup equipped with all requirements for the parameter modulation
3. Definition of desired grating parameter modulation

The starting point is an existing, executable lightguide system, which has the basic geometries (desired distances and positioned grating regions) and grating specifications (orientation, period, orders).

- [Construction of a Light Guide](#) [Use Case]
- [Light Guide Layout Design Tool](#) [Use Case]

The regions for which a modulation of parameters is desired must be configured using real grating structures.

- [How to Set Up a Lightguide with Real Grating Structures](#) [Use Case]
- [Simulation of 1D-1D Pupil Expander with Real Gratings](#) [Use Case]

The *Footprint and Grating Analysis* tool is used to specify the desired range for the variation of the grating parameters, calculate rigorously the according Rayleigh coefficients for the specified conditions of the light-grating interactions and generate an optical setup where the actual parameter variation can be defined.

- [Footprint Analysis of Lightguides for AR/MR Applications](#) [Use Case]

**Note:**

The grating modulation is defined for individual grating regions.

# Open Footprint and Grating Analysis Tool & Set Optical Setup

The screenshot displays the Wyrowski VirtualLab Fusion 2021.1 (Build 1.180) software interface. The main workspace shows a simulation setup with components: Plane Wave (0), Light Guide (After Surface Layout) (1), Camera Detector (600), Scanning Source (500), Ray Tracing System Analyzer (800), and Grating Channel Analyzer (801). A red box labeled '1' highlights the 'Light Guides' menu, and a red box labeled '2' highlights the 'Footprint and Grating Analysis' option. A red arrow points from the 'Set' button in the 'Footprint and Grating Analysis' dialog to the 'Optical Setup' section. A callout box states: 'In the sample file (\*.fga), the optical setup is already set.'

**Footprint and Grating Analysis Dialog:**

Optical Setup:

Field of View: Design

$\alpha$   $\beta$

Efficiency of Zeroth Order: 100 % Efficiency of All Other Orders: 100 %

Validity:

Linkage					
	Simulation Method	On/Off	Color		
0	Plane Wave	-	Air in Homogeneous Med...	1	Light Guide (After
1	Light Guide (After	T	Air in Homogeneous Med...		Field Tracing

Simulation Engine: Field Tracing

# Footprint and Grating Analysis Tool

**1** Specify the field of view (FOV) angles for the analysis.

Optical Setup

Field of View Angles for Design

#	$\alpha$	$\beta$
1	-12.5°	-7.5°
2	0°	-7.5°
3	12.5°	-7.5°
4	-12.5°	0°
5	0°	0°
6	12.5°	0°
7	-12.5°	7.5°
8	0°	7.5°
9	12.5°	7.5°

Efficiency of Zeroth Order  Efficiency of All Other Orders

**2**  Run the analysis

[11/26/2021 14:43:16]: Footprint and grating analysis by light path fin  
[11/26/2021 14:43:16]: Extraction of footprint and grating data started  
[11/26/2021 14:43:16]: New incident direction detected for Incoupling Grating: (0.21467; 0.12748; 0.96833)  
[11/26/2021 14:43:16]: New incident direction detected for Expansion Grating: (0.52174; 0.61122; -0.59515)  
[11/26/2021 14:43:16]: New incident direction detected for Expansion Grating: (-0.46055; 0.61122; -0.64367)  
[11/26/2021 14:43:16]: New incident direction detected for Outcoupling Grating: (0.75785; -0.10653; -0.64367)  
[11/26/2021 14:43:16]: Number of detected different directions at grating regions = 4  
[11/26/2021 14:43:16]: Number of footprints found for Incoupling Grating: 1  
[11/26/2021 14:43:16]: Number of footprints found for Expansion Grating: 17  
[11/26/2021 14:43:16]: Number of footprints found for Outcoupling Grating: 66  
[11/26/2021 14:43:16]: Extraction of footprint data finished.

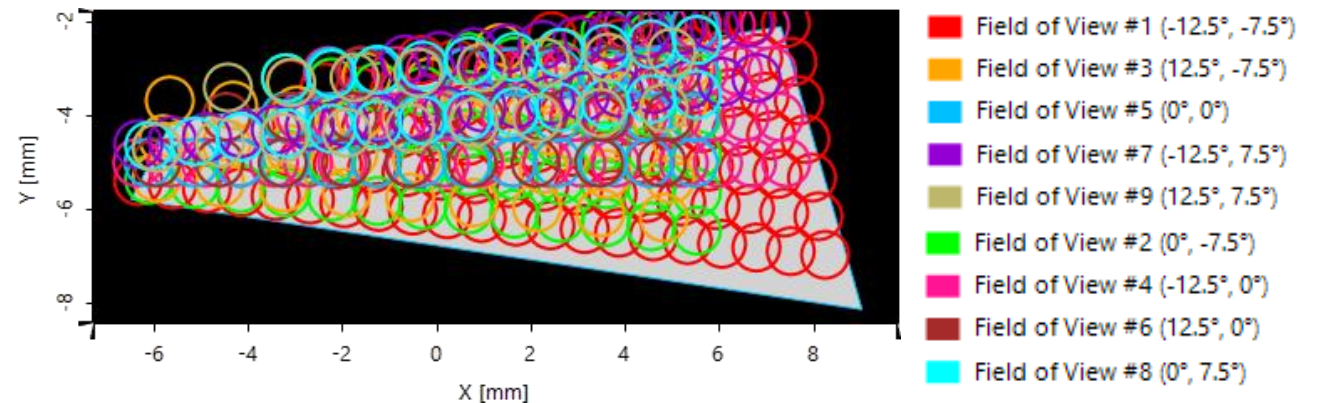
Validity: ☒

**3** Footprints and related results can be displayed.

Path for Storing Lookup Tables: [P:\TempVL\](#)

Detected Grating Regions with Footprint Data

Status	Region	View	Heatmap	Raw Data	Vary
—	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 1: Incoupling Grating	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
—	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 2: Expansion Grating	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="button" value="Configure"/>
—	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 3: Outcoupling Grating	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	



For a general workflow and overview of this tool see the following use case: [Footprint Analysis of Lightguides for AR/MR Applications](#)

# Selection of Grating Parameters and Associated Ranges

The screenshot shows the 'Footprint Tool' interface. The main window displays 'Detected Grating Regions with Footprint Data' with a table of regions. A red box labeled '1' highlights the 'Vary' column, which contains a 'Configure' button for the 'Expansion Grating' region. A red arrow points from this button to a secondary dialog box titled 'Select Grating Parameters to be Varied'. This dialog box contains a table of parameters for the 'Expansion Grating' (Surface #1). A red box labeled '2' highlights the 'Relative Slit Width' parameter, which is checked in the 'Vary' column and has a range of 10% to 90%.

45: C:\Users\...\2021-04-27 Footprint Tool.fga\*

Path for Storing Lookup Tables: [C:\Temp\](#)

Detected Grating Regions with Footprint Data

Status	Region	View	Heatmap	Raw Data	Vary
—	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 1: Incoupling Grating				
	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 2: Expansion Grating				<input checked="" type="checkbox"/> <b>Configure</b>
—	Light Guide (After Surface Layout) (1)   Surface # 1 → Region # 3: Outcoupling Grating				

Select Grating Parameters to be Varied

Filter by... ☐ Show Only Varied Parameters

1 *	Object	Category	Parameter	Vary	From	To	Steps	Step Size
			Outer Definition Area...	<input type="checkbox"/>	1E-10 mm	1E+303 mm	1	1E+303 mm
			Outer Definition Area...	<input type="checkbox"/>	1E-10 mm	1E+303 mm	1	1E+303 mm
			Scaling z-Direction	<input type="checkbox"/>	-1E+300	1E+300	1	2E+300
			Grating Period	<input type="checkbox"/>	1E-10 mm	1E+303 mm	1	1E+303 mm
			Modulation Depth	<input type="checkbox"/>	1E-10 mm	1E+303 mm	1	1E+303 mm
			Lateral Shift	<input type="checkbox"/>	-1E+303 mm	1E+303 mm	1	2E+303 mm
			Rotation Angle	<input type="checkbox"/>	0°	360°	1	360°
			Relative Slit Width	<input checked="" type="checkbox"/>	10 %	90 %	41	2 %

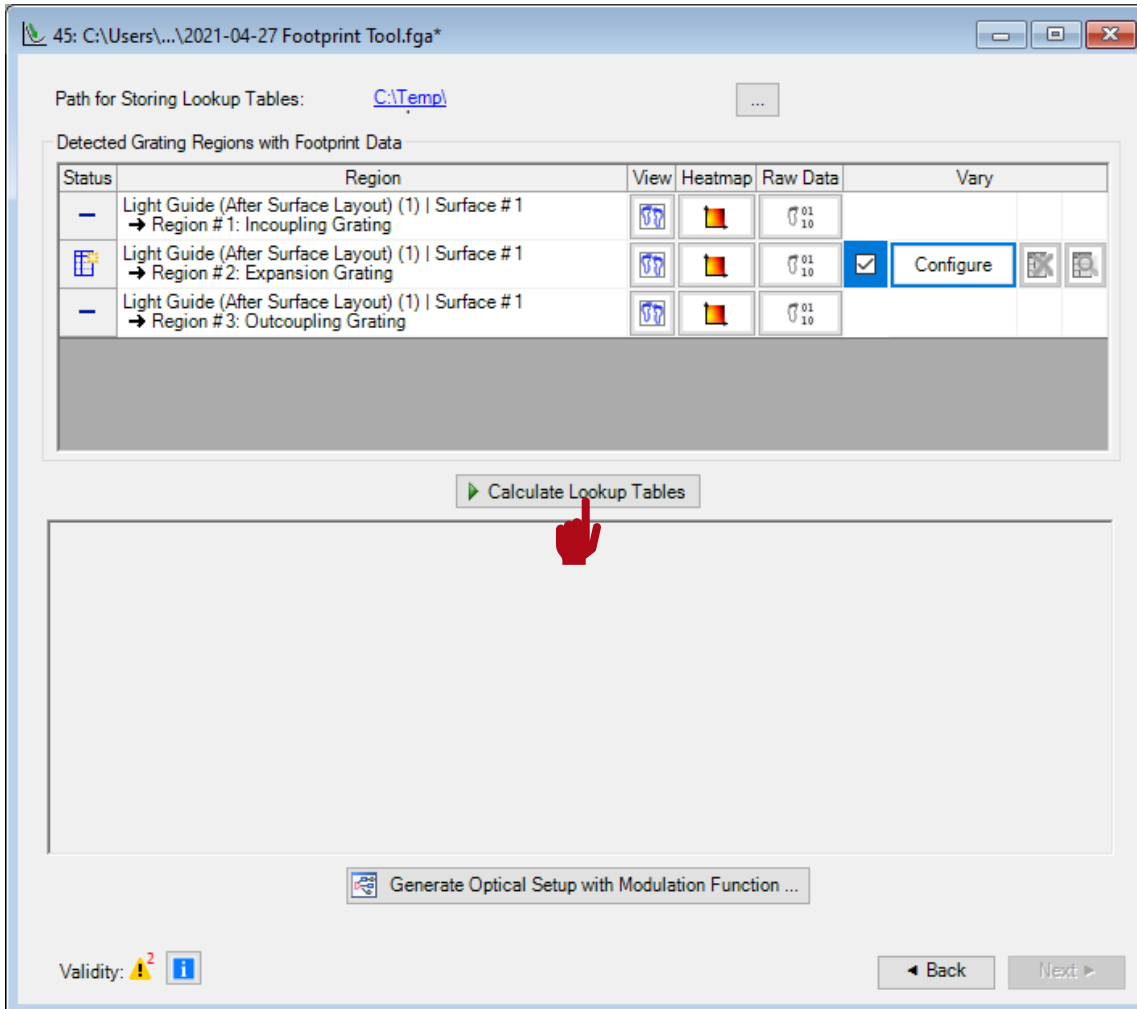
Validity:

Validity:

OK Cancel Help

- It is possible to vary one or two grating parameters at the same time.
- The sampling of the parameter space can be relatively coarse, since afterwards interpolation techniques will be applied in between the calculated points.
- The table lists all available parameters of the grating. For the introduction of modulated grating parameters within a region, it is not allowed to use a parameter that changes the light paths (e.g., such as the period).

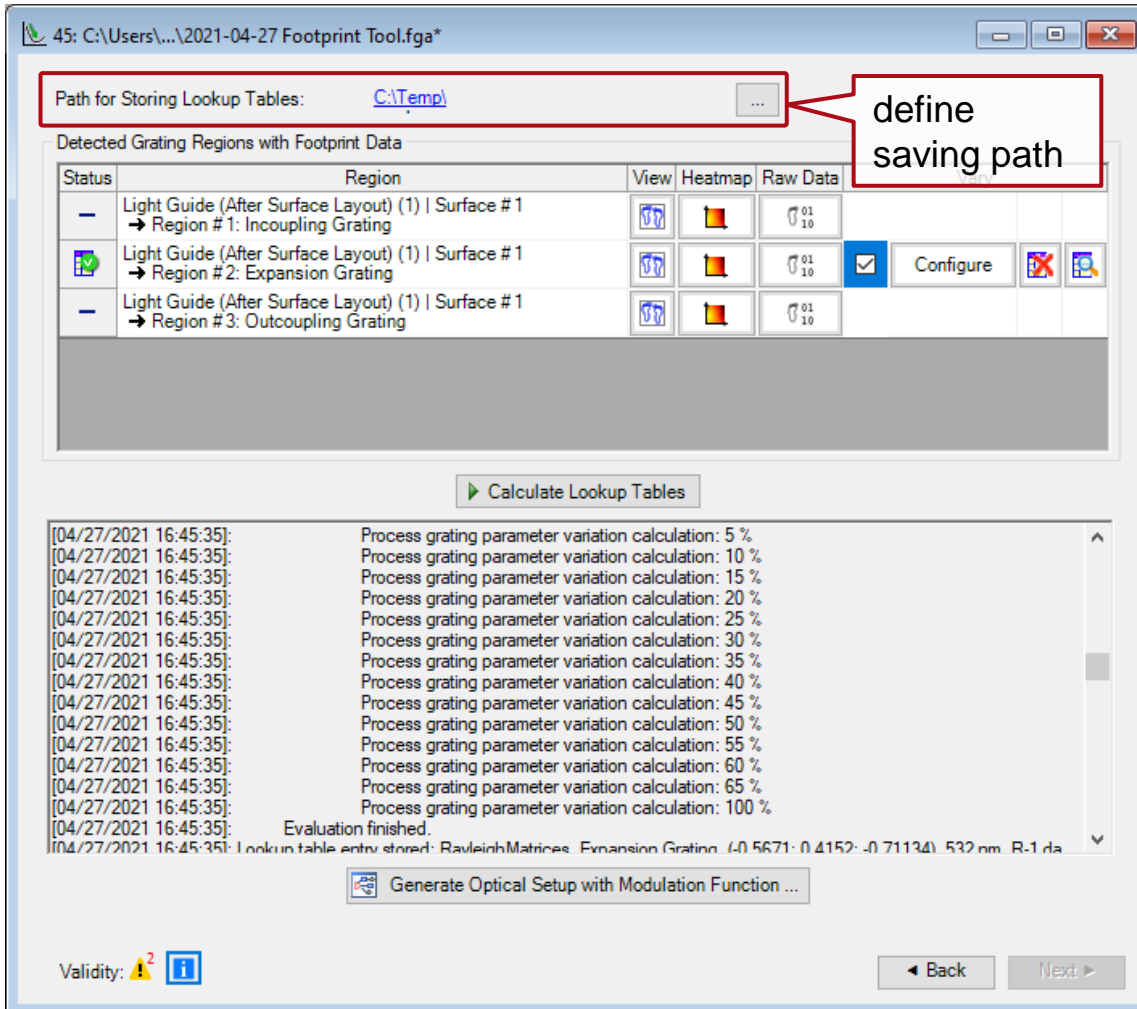
# Calculation of Lookup Tables



After configuring the desired variation of the grating parameters, the resulting grating characteristic can be calculated and stored in lookup tables by clicking on *Calculate Lookup Tables*.



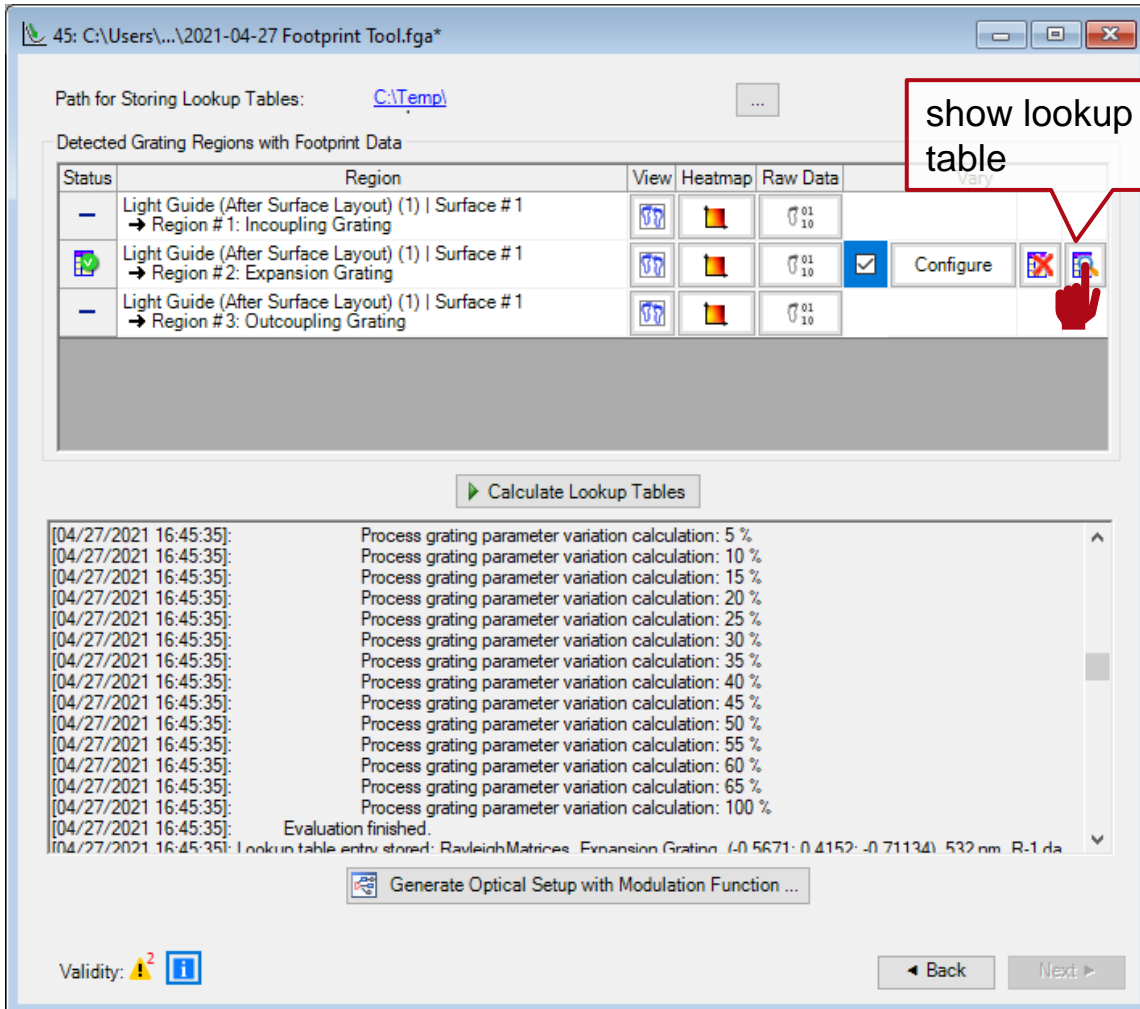
# Calculation of Lookup Tables



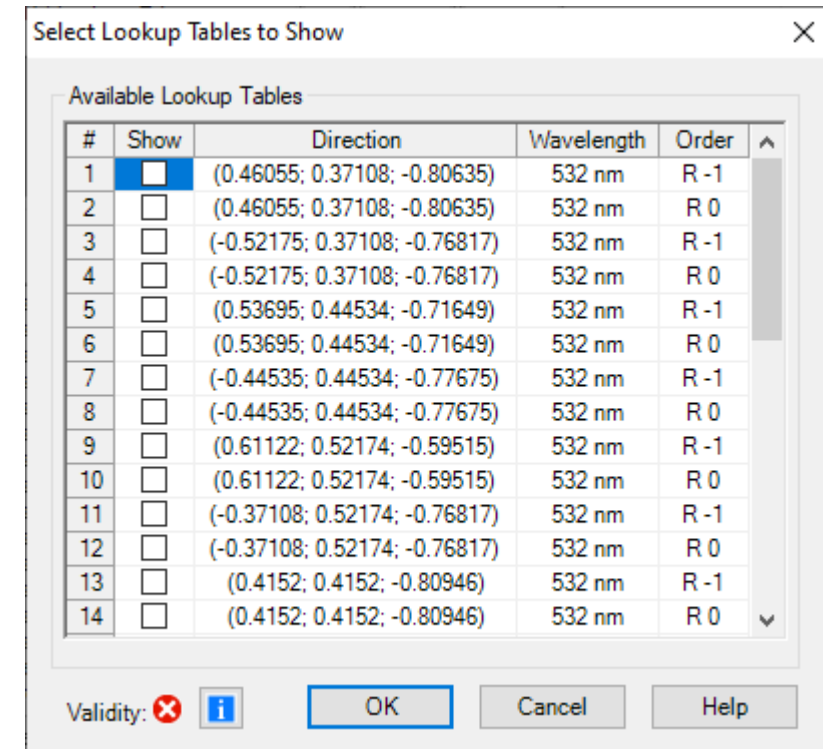
The lookup tables are calculated for the defined variation of the grating parameters and FOV modes determined in the first step of the *Footprint and Grating Analysis* tool. The look up tables are automatically saved to the specified folder:

Name	Date modified	Type	Size
RayleighMatrices_Expansion Grating_(-0.44791; 0.44534; -0.77527)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.46055; 0.37108; -0.80635)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.46055; 0.37108; -0.80635)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.52431; 0.37108; -0.76642)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.52431; 0.37108; -0.76642)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.53695; 0.44534; -0.71649)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.53695; 0.44534; -0.71649)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.61122; 0.52174; -0.59515)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.61122; 0.52174; -0.59515)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.5671; 0.5671; -0.59732)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.5671; 0.5671; -0.59732)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.41776; 0.5671; -0.70984)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.41776; 0.5671; -0.70984)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.49115; 0.49115; -0.71941)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.49115; 0.49115; -0.71941)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.49372; 0.49115; -0.71765)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.49372; 0.49115; -0.71765)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.56967; 0.4152; -0.70929)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.56967; 0.4152; -0.70929)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.37108; 0.46055; -0.80635)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.37108; 0.46055; -0.80635)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.44534; 0.53695; -0.71649)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.44534; 0.53695; -0.71649)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.52174; 0.61122; -0.59515)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.52174; 0.61122; -0.59515)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB

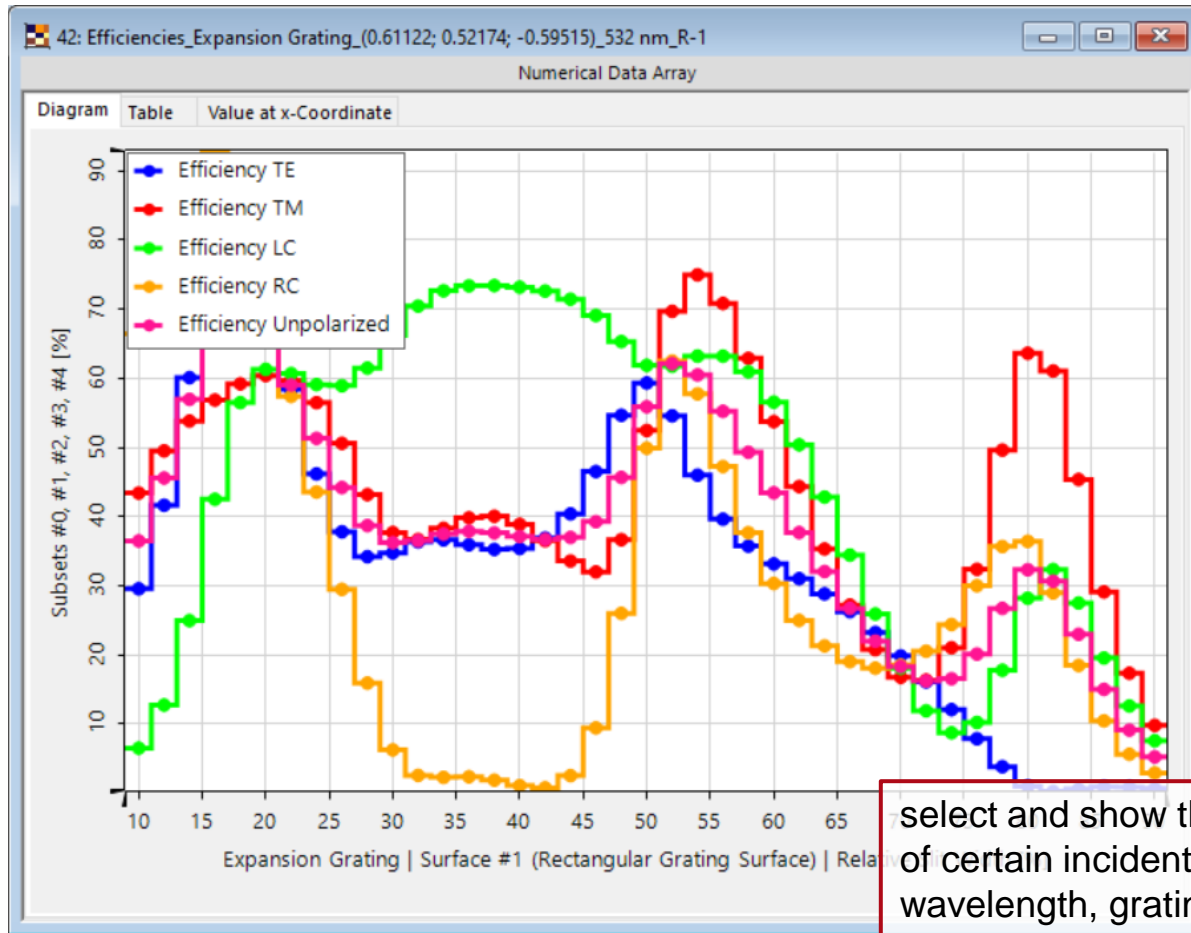
# Calculation of Lookup Tables



By clicking on the button with the magnifying glass, the data for specific orders and directions can be investigated in detail:



# Investigation of Grating Behavior



From the information of the lookup tables (Rayleigh matrix per wavelength, direction, diffraction order and value of grating parameters) the efficiency values for different polarization states are derived and displayed.

Select Lookup Tables to Show

Available Lookup Tables

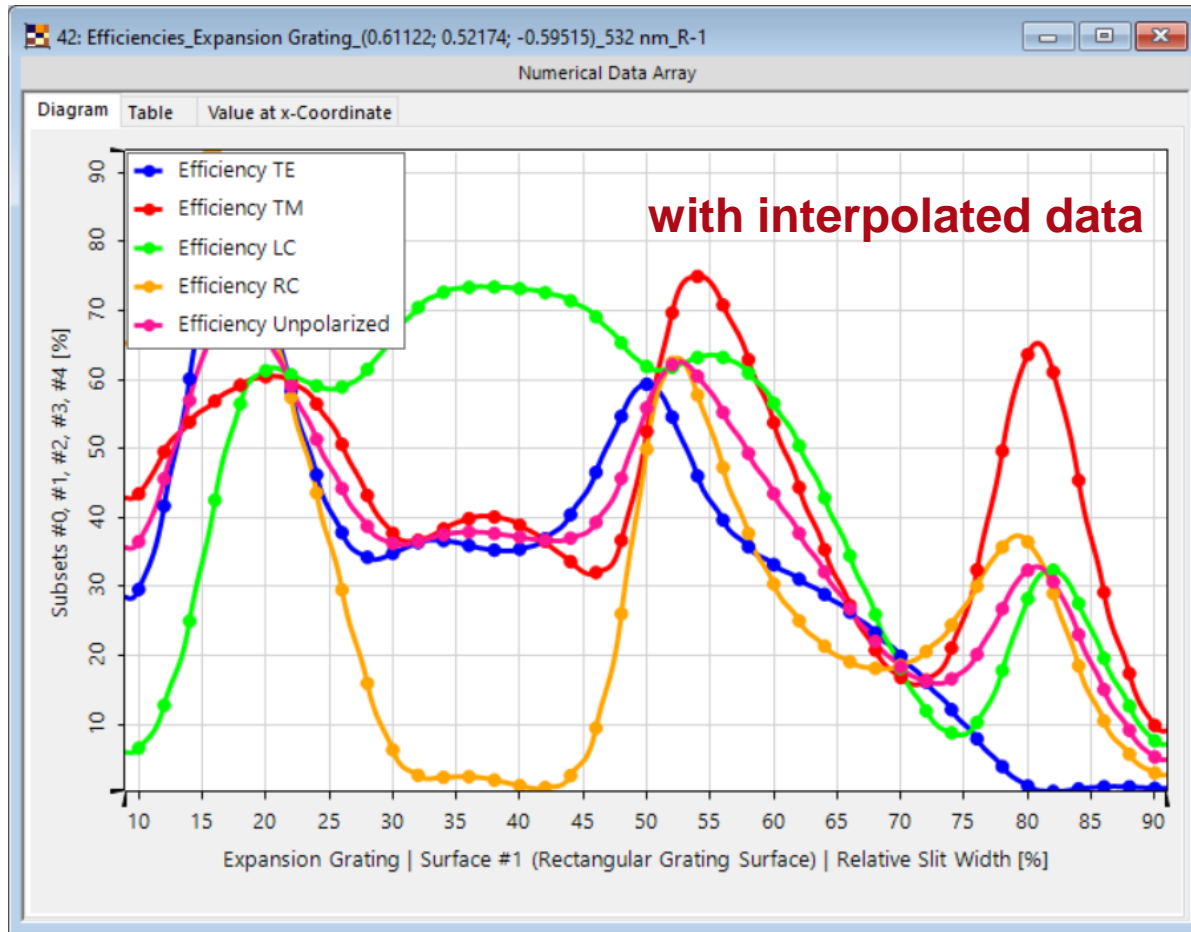
#	Show	Direction	Wavelength	Order
1	<input type="checkbox"/>	(0.46055; 0.37108; -0.80635)	532 nm	R -1
2	<input type="checkbox"/>	(0.46055; 0.37108; -0.80635)	532 nm	R 0
3	<input type="checkbox"/>	(-0.52175; 0.37108; -0.76817)	532 nm	R -1
4	<input type="checkbox"/>	(-0.52175; 0.37108; -0.76817)	532 nm	R 0
5	<input type="checkbox"/>	(0.53695; 0.44534; -0.71649)	532 nm	R -1
6	<input type="checkbox"/>	(0.53695; 0.44534; -0.71649)	532 nm	R 0
7	<input type="checkbox"/>	(-0.44535; 0.44534; -0.77675)	532 nm	R -1
8	<input type="checkbox"/>	(-0.44535; 0.44534; -0.77675)	532 nm	R 0
9	<input checked="" type="checkbox"/>	(0.61122; 0.52174; -0.59515)	532 nm	R -1
10	<input type="checkbox"/>	(0.61122; 0.52174; -0.59515)	532 nm	R 0
11	<input type="checkbox"/>	(-0.37108; 0.52174; -0.76817)	532 nm	R -1
12	<input type="checkbox"/>	(-0.37108; 0.52174; -0.76817)	532 nm	R 0
13	<input type="checkbox"/>	(0.4152; 0.4152; -0.80946)	532 nm	R -1
14	<input type="checkbox"/>	(0.4152; 0.4152; -0.80946)	532 nm	R 0

Validity:

OK Cancel Help

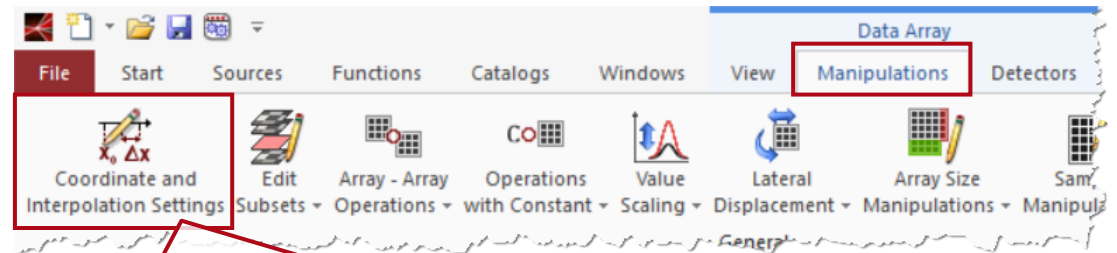
select and show the efficiencies of certain incident direction, wavelength, grating order

# Investigation of Grating Behavior



The efficiency of the grating is shown for different polarization states (TE, TM, left circular, right circular polarization, as well as unpolarized light). In the simulation of the full lightguide, the local occurring polarization states of the incident light will be considered automatically.

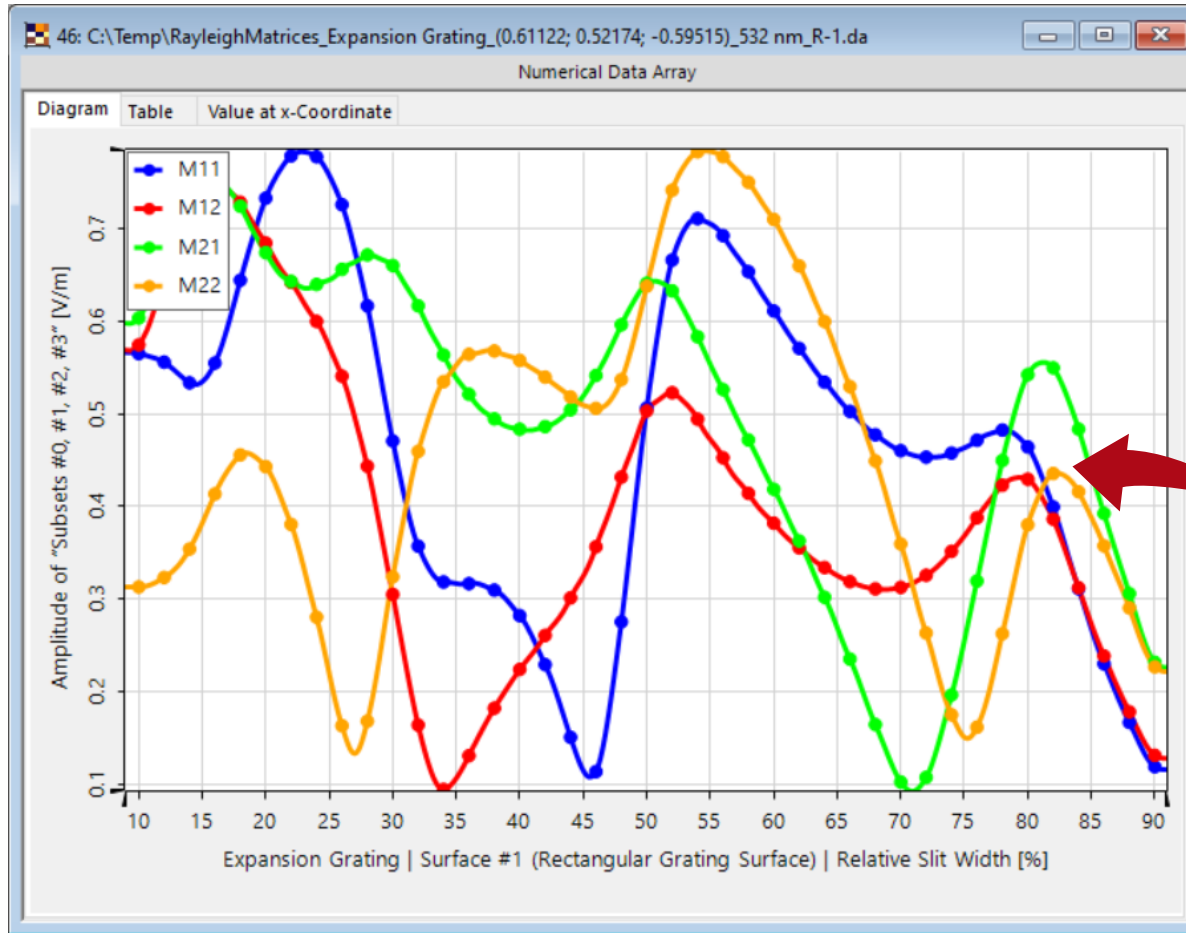
**Note:** In case of two varied grating parameters, the result are 2D color plots.



The interpolation of the data was switched to cubic via *Manipulations > Coordinate and Interpolation Settings*.



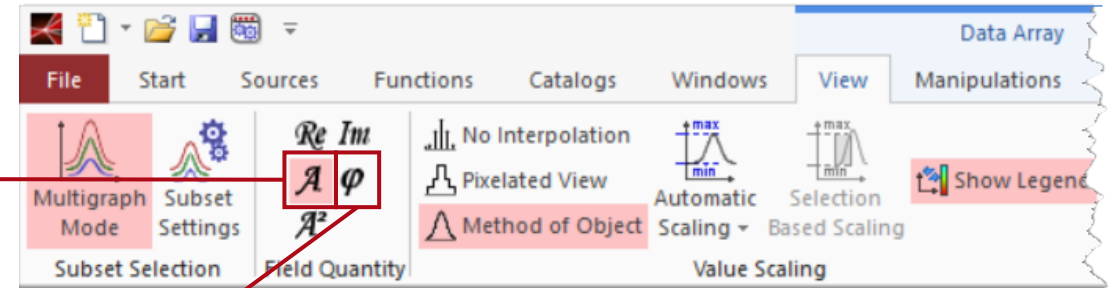
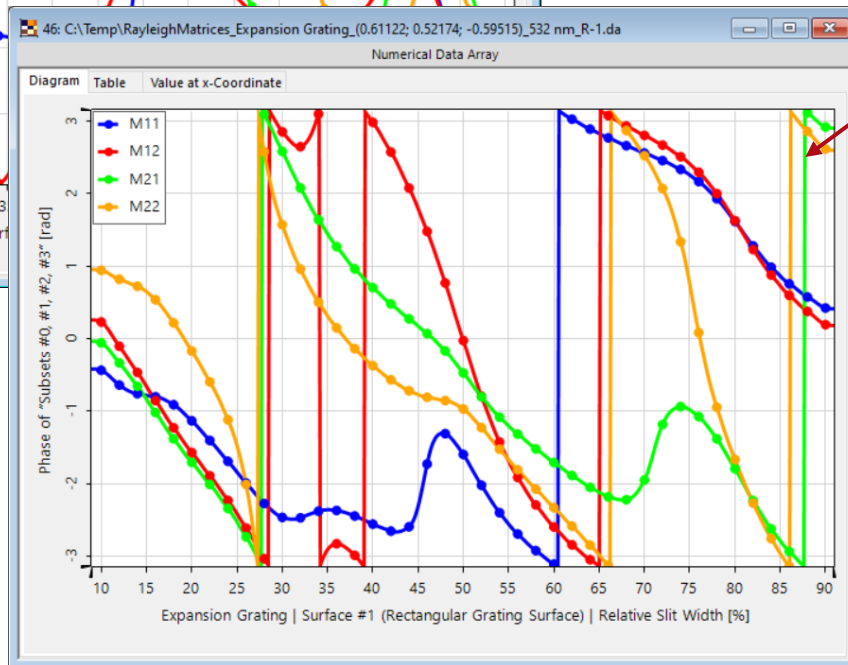
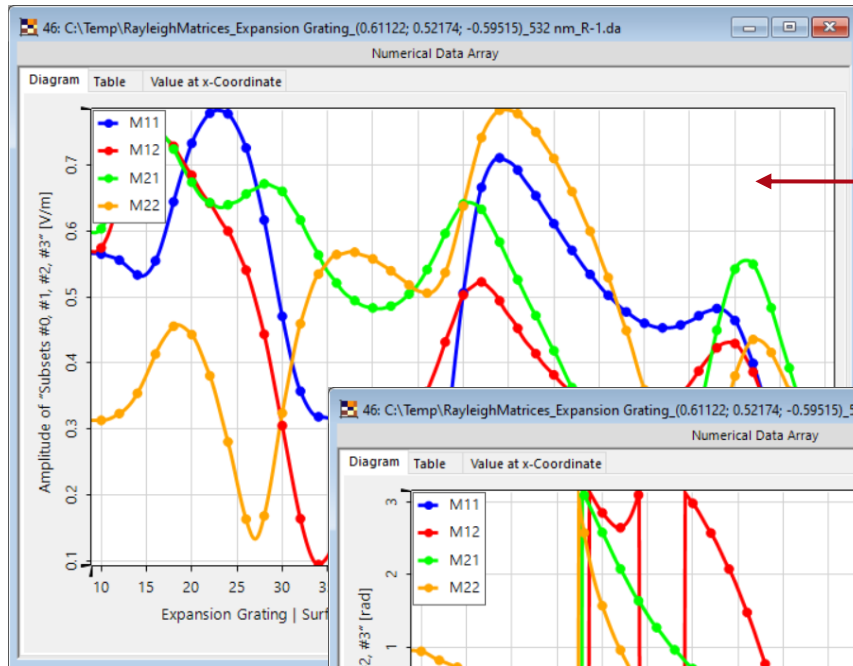
# Load Rayleigh Matrices from Lookup Tables



The Rayleigh matrices saved in the defined folder can be loaded in VirtualLab Fusion and reveal the complex-valued entries of this 2x2 matrices.

Name	Date modified	Type	Size
RayleighMatrices_Expansion Grating_(-0.44791; 0.44534; -0.77527)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.46055; 0.37108; -0.80635)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.46055; 0.37108; -0.80635)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.52431; 0.37108; -0.76642)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.52431; 0.37108; -0.76642)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.53695; 0.44534; -0.71649)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.53695; 0.44534; -0.71649)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.61122; 0.52174; -0.59515)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.61122; 0.52174; -0.59515)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.5671; 0.5671; -0.59732)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.5671; 0.5671; -0.59732)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.41776; 0.5671; -0.70984)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.41776; 0.5671; -0.70984)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.49115; 0.49115; -0.71941)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.49115; 0.49115; -0.71941)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.49372; 0.49115; -0.71765)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.49372; 0.49115; -0.71765)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.56967; 0.4152; -0.70929)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(-0.56967; 0.4152; -0.70929)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.37108; 0.46055; -0.80635)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.37108; 0.46055; -0.80635)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.44534; 0.53695; -0.71649)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.44534; 0.53695; -0.71649)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.52174; 0.61122; -0.59515)_532 nm_R0	22/11/2021 14:06	DA File	7 KB
RayleighMatrices_Expansion Grating_(0.52174; 0.61122; -0.59515)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB

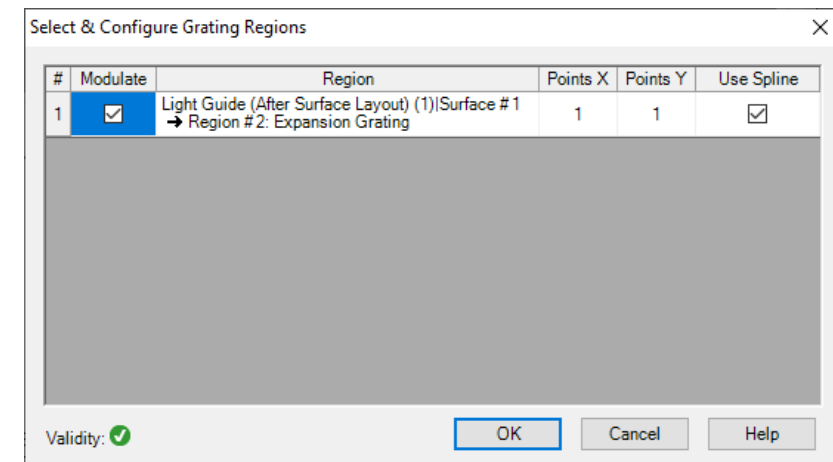
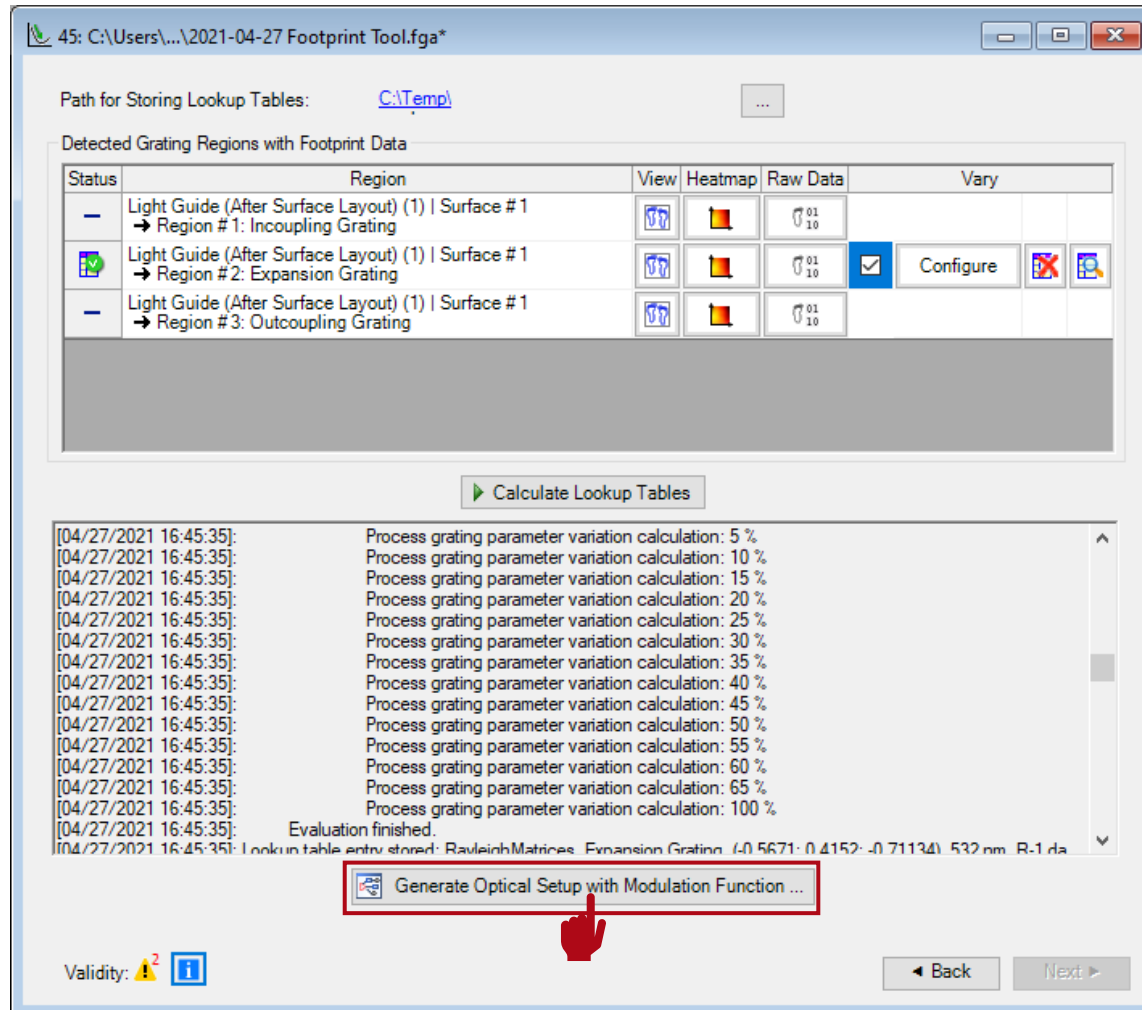
# Load Rayleigh Matrices from Lookup Tables



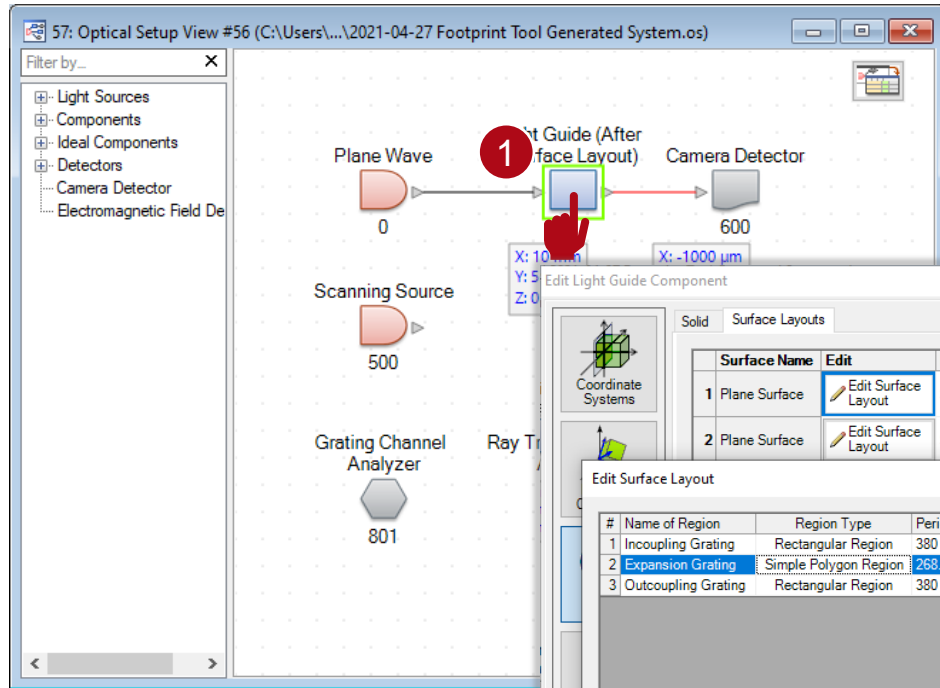
The response of a specific grating (with given period, shape, material, etc.) is defined by a complex-valued  $2 \times 2$  matrix (Rayleigh matrix) per wavelength, incident direction and diffraction order. The Rayleigh matrices provide the fully vectorial response of the grating, which means that all polarization effects are included. This stands in contrast to a treatment purely reliant on calculation of the efficiencies – energy magnitudes that do not contain all the vectorial field information and which can miss relevant physical effects, such as influences cause by changing polarization states.

# Generation of Updated Optical System

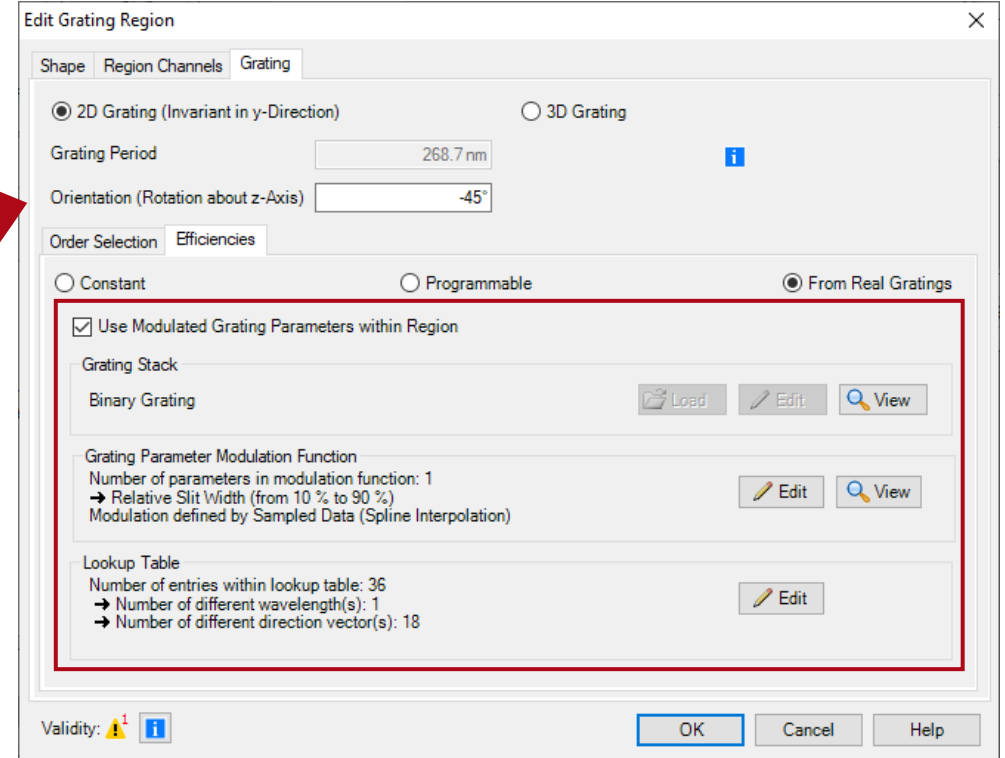
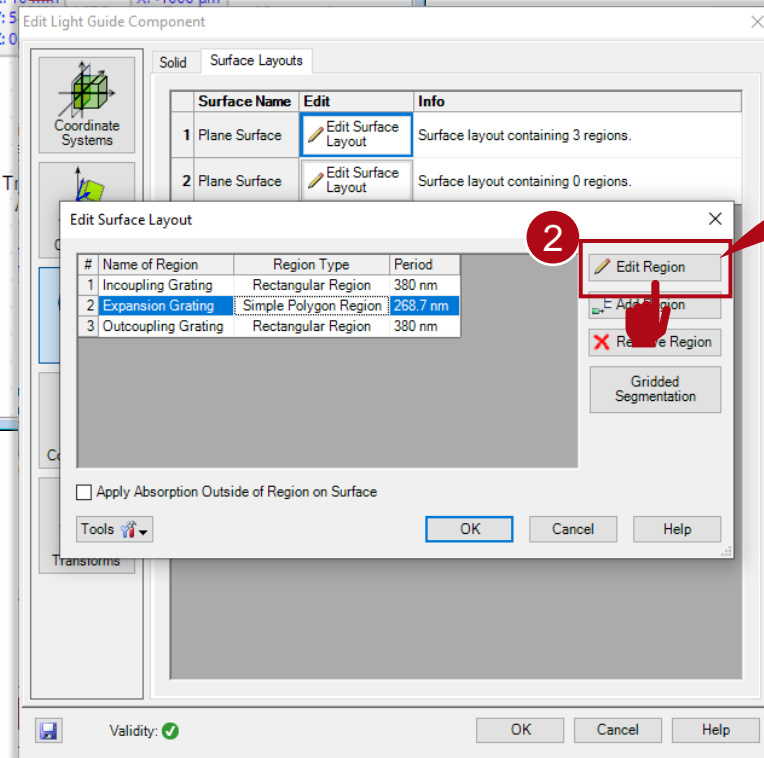
- Finally, an adapted optical system can be generated, where the real grating structures have been replaced by the calculated lookup tables, which enable the configuration of the continuously modulated parameters.
- The *Optical Setup* with modulated grating regions is first generated with an interpolated variation from a finite set of local positions. The user can configure the desired sampling and interpolation before the *Optical Setup* is generated. This can also be modified later, including setting a programmable modulation).



# Generation of Updated Optical System

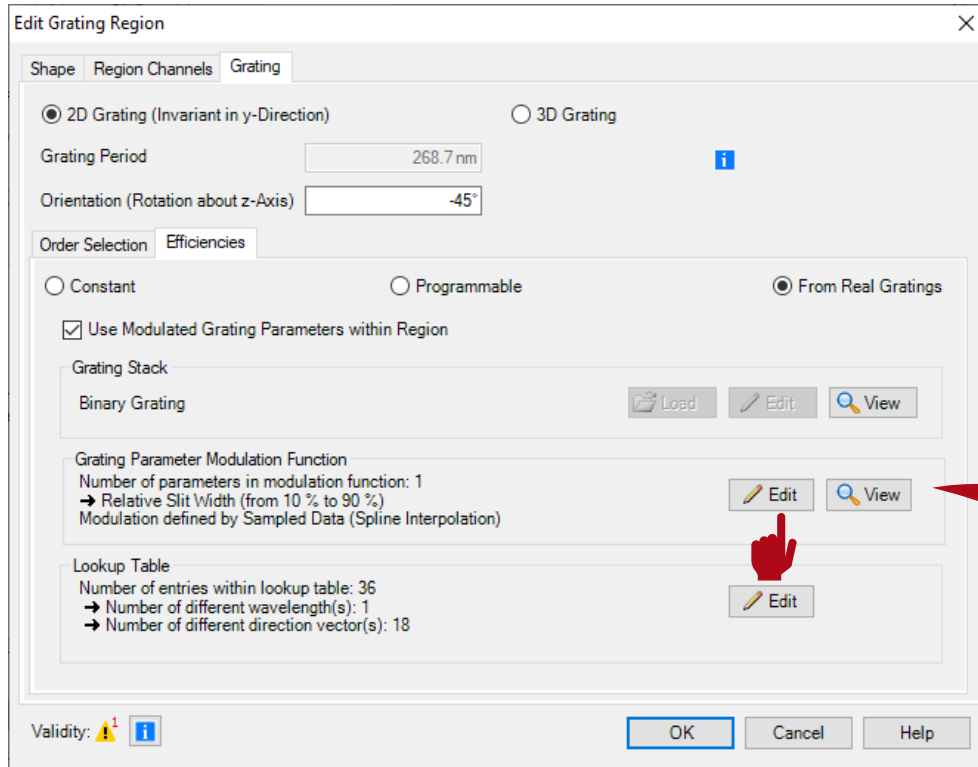


In the resulting optical setup, the option to use the modulated grating parameters has been activated and the corresponding lookup tables have already been loaded into the system.

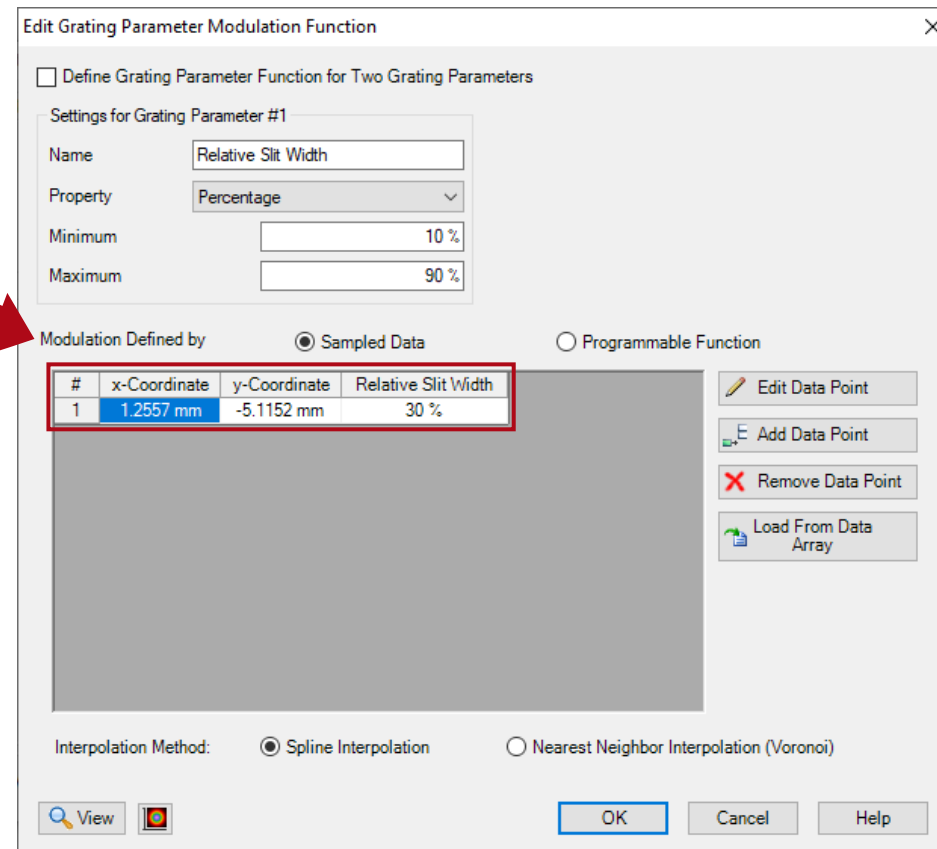




# Configuration of Grating Modulation



The parameter modulation in the region can be configured in detail by clicking on *Edit*. Here you can also find the local positions, that were chosen in the *Generate OS* dialog.



# Modulation Based on Sampled Positions or a Grid

Edit Grating Parameter Modulation Function

☐ Define Grating Parameter Function for Two Grating Parameters

Settings for Grating Parameter #1

Name: Relative Slit Width

Property: Percentage

Minimum: 10 %

Maximum: 90 %

Modulation Defined by: ☒ Sampled Data ☐ Programmable Function

#	x-Coordinate	y-Coordinate	Relative Slit Width
1	1.2557 mm	-5.1152 mm	30 %

Interpolation Method: ☒ Spline Interpolation ☐ Nearest Neighbor Interpolation (Voronoi)

Buttons: View, OK, Cancel, Help

Buttons on the right: Edit Data Point, Add Data Point, Remove Data Point, Load From Data Array

- One possibility to configure the lateral modulation is by using local positions (support points).
- For each position (or support point), a certain value of the grating parameter can be set.
- Points can be added or removed. For an automatic equidistant grid of points, please repeat the steps covered in slide #15.
- In between the support points, an interpolation of the data of the grating parameter(s) is used. There are two options:
  - Spline interpolation
  - Nearest neighbor (hard boundaries)

# Modulation Based on Sampled Positions or a Grid

Edit Grating Parameter Modulation Function

☐ Define Grating Parameter Function for Two Grating Parameters

Settings for Grating Parameter #1

Name: Relative Slit Width

Property: Percentage

Minimum: 10 %

Maximum: 90 %

Modulation Defined by: ☒ Sampled Data ☐ Programmable Function

#	x-Coordinate	y-Coordinate	Relative Slit Width
1	-6.5074 mm	-8.1269 mm	30 %
2	-4.7823 mm	-8.1269 mm	30 %
3	-3.0571 mm	-8.1269 mm	30 %
4	-1.332 mm	-8.1269 mm	30 %
5	393.11 $\mu$ m	-8.1269 mm	30 %
6	2.1182 mm	-8.1269 mm	30 %
7	3.8434 mm	-8.1269 mm	30 %
8	5.5685 mm	-8.1269 mm	30 %
9	7.2936 mm	-8.1269 mm	30 %
10	9.0187 mm	-8.1269 mm	30 %
11	-6.5074 mm	-7.2664 mm	30 %
12	-4.7823 mm	-7.2664 mm	30 %

Interpolation Method: ☒ Spline Interpolation ☐ Nearest Neighbor Interpolation (Voronoi)

Buttons: View, OK, Cancel, Help

Buttons: Edit Data Point, Add Data Point, Remove Data Point, Load From Data Array

Select & Configure Grating Regions

#	Modulate	Region	Points X	Points Y	Use Spline
1	<input checked="" type="checkbox"/>	Light Guide (After Surface Layout) (1) Surface #1 → Region #2: Expansion Grating	10	8	<input checked="" type="checkbox"/>

Validity:

Buttons: OK, Cancel, Help

continuing from slide #15:

Entering a certain number of points during the generation of the new optical setup will result in an equidistant grid of sampled positions (in the rectangular box that fits the regarding arbitrary shaped grating region). For each position, the according grating parameter can be set.

# Modulation Based on Sampled Positions or a Grid

Edit Grating Parameter Modulation Function

☐ Define Grating Parameter Function for Two Grating Parameters

Settings for Grating Parameter #1

Name: Relative Slit Width

Property: Percentage

Minimum: 10 %

Maximum: 90 %

Modulation Defined by: ☒ Sampled Data ☐ Programmable Function

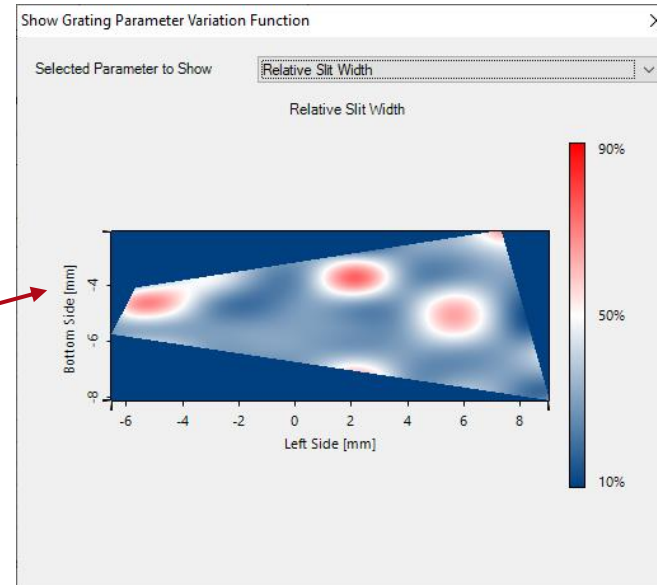
#	x-Coordinate	y-Coordinate	Relative Slit Width
1	-6.5074 mm	-8.1269 mm	10 %
2	-4.7823 mm	-8.1269 mm	30 %
3	-3.0571 mm	-8.1269 mm	20 %
4	-1.332 mm	-8.1269 mm	80 %
5	393.11 $\mu$ m	-8.1269 mm	30 %
6	2.1182 mm	-8.1269 mm	50 %
7	3.8434 mm	-8.1269 mm	30 %
8	5.5685 mm	-8.1269 mm	40 %
9	7.2936 mm	-8.1269 mm	30 %
10	9.0187 mm	-8.1269 mm	30 %
11	-6.5074 mm	-7.2664 mm	50 %
12	-4.7823 mm	-7.2664 mm	30 %

Interpolation Method: ☒ Spline Interpolation ☐ Nearest Neighbor Interpolation (Voronoi)

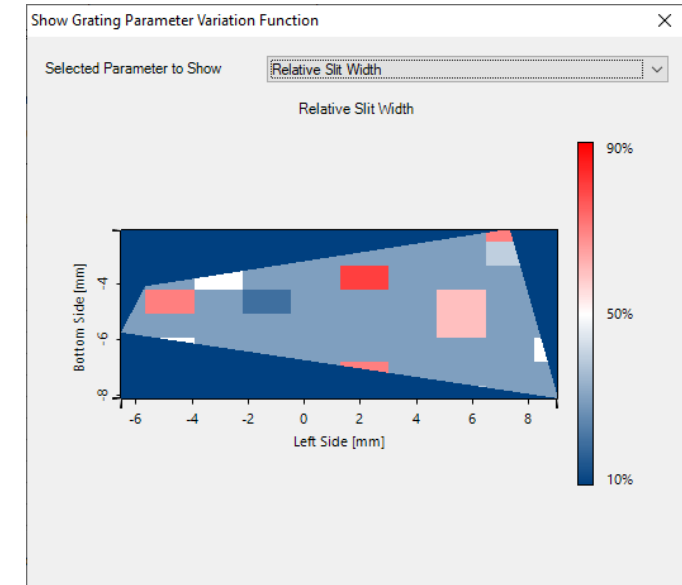
View OK Cancel Help

- Now, the modulation of the grating parameter can be adapted by changing the values at the given positions.
- By clicking on *View*, the resulting variation is shown:

spline interpolated:



nearest neighbor:



# Modulation Based on Analytical Description

Edit Grating Parameter Modulation Function

☐ Define Grating Parameter Function for Two Grating Parameters

Settings for Grating Parameter #1

Name: Relative Slit Width

Property: Percentage

Minimum: 10 %

Maximum: 90 %

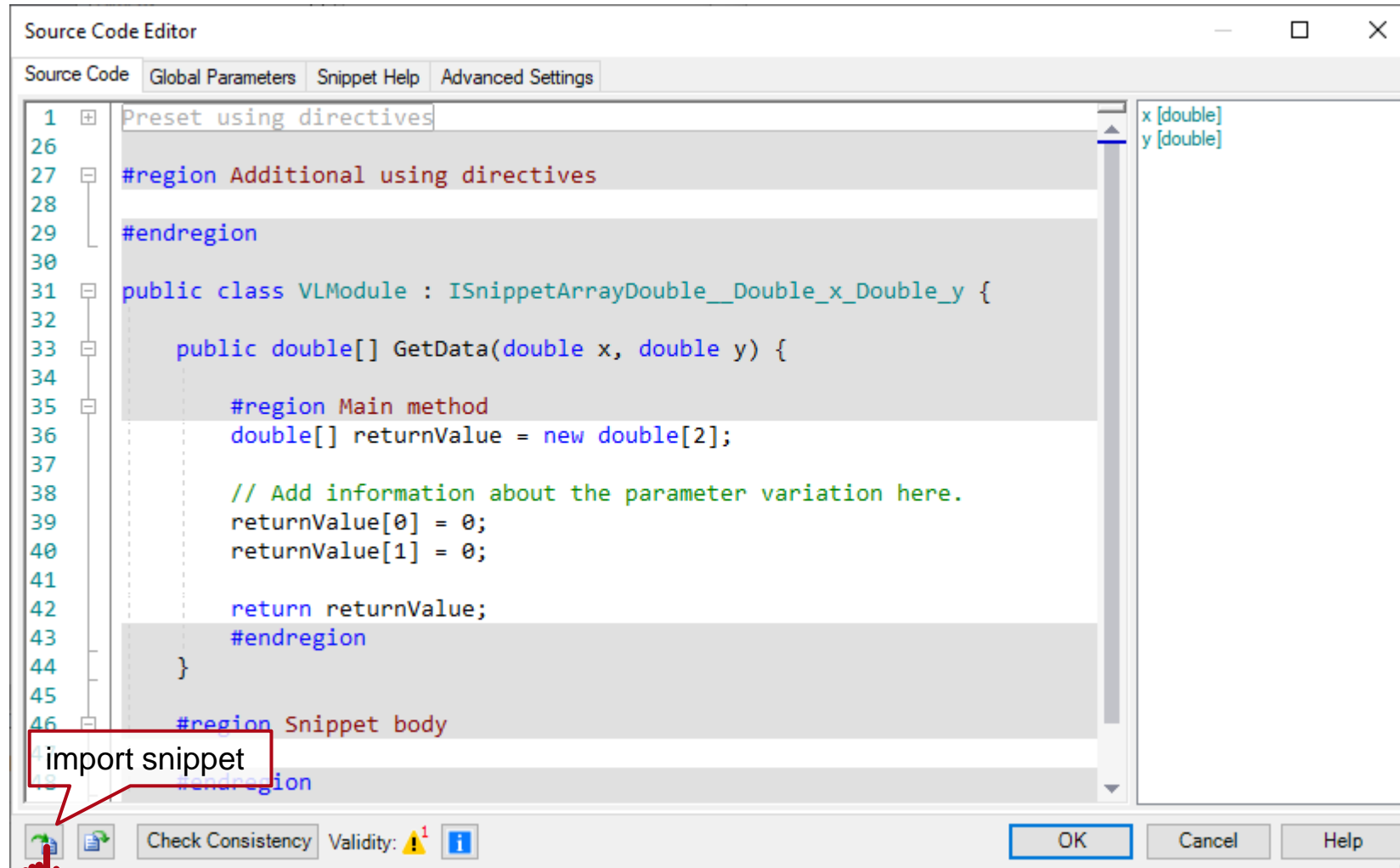
Modulation Defined by: ☐ Sampled Data ☒ Programmable Function

Edit Validity: ✓

View OK Cancel Help

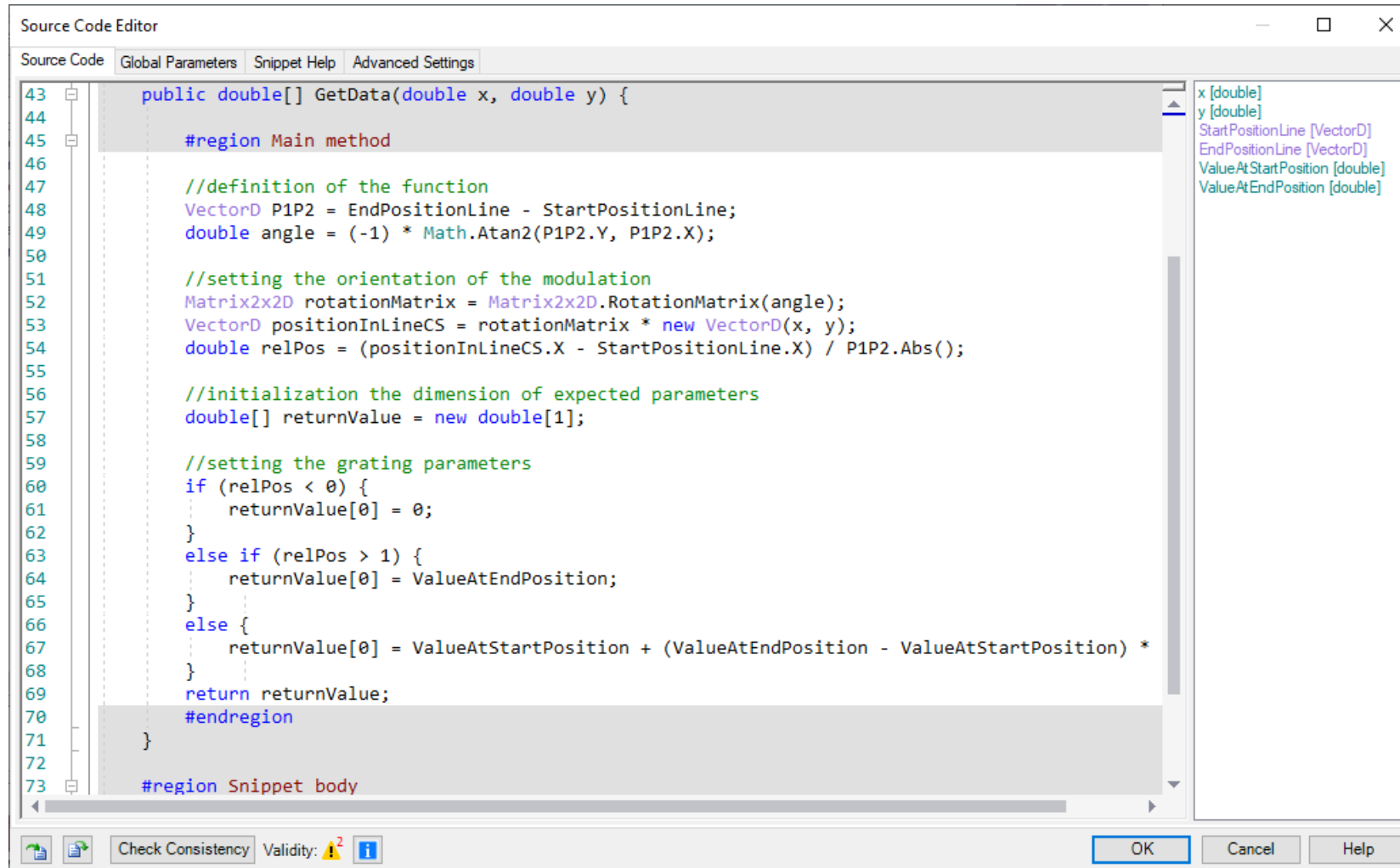
- The second possibility for defining a smooth modulation of the grating parameters is the application of an analytical modulation function.
- In this example, we demonstrate a linear variation in the horizontal direction of the EPE grating region, as this is the expected main direction of light propagation.
- The function and its parameters can be configured by clicking on *Edit*.

# Modulation Based on Mathematical Description



- In this example, a snippet for a linear modulation is provided alongside this document.
- Import the snippet by using the import button.
- In more general, a function has to be defined, that provides the desired grating parameter for the current position (x,y).

# Modulation Based on Mathematical Description



The screenshot shows a 'Source Code Editor' window with a tabbed interface. The 'Source Code' tab is active, displaying a C# function named 'GetData'. The function takes two double parameters, 'x' and 'y', and returns a double array. The code includes comments for different sections: 'Main method', 'definition of the function', 'setting the orientation of the modulation', 'initialization the dimension of expected parameters', and 'setting the grating parameters'. The 'grating parameters' section uses conditional logic to set the return value based on the relative position 'relPos'. A right-hand pane shows a list of variables and their types: 'x [double]', 'y [double]', 'StartPositionLine [VectorD]', 'EndPositionLine [VectorD]', 'ValueAtStartPosition [double]', and 'ValueAtEndPosition [double]'. The bottom status bar indicates 'Check Consistency' and 'Validity: 2' with a warning icon. 'OK', 'Cancel', and 'Help' buttons are at the bottom right.

```
43 public double[] GetData(double x, double y) {
44
45     #region Main method
46
47     //definition of the function
48     VectorD P1P2 = EndPositionLine - StartPositionLine;
49     double angle = (-1) * Math.Atan2(P1P2.Y, P1P2.X);
50
51     //setting the orientation of the modulation
52     Matrix2x2D rotationMatrix = Matrix2x2D.RotationMatrix(angle);
53     VectorD positionInLineCS = rotationMatrix * new VectorD(x, y);
54     double relPos = (positionInLineCS.X - StartPositionLine.X) / P1P2.Abs();
55
56     //initialization the dimension of expected parameters
57     double[] returnValue = new double[1];
58
59     //setting the grating parameters
60     if (relPos < 0) {
61         returnValue[0] = 0;
62     }
63     else if (relPos > 1) {
64         returnValue[0] = ValueAtEndPosition;
65     }
66     else {
67         returnValue[0] = ValueAtStartPosition + (ValueAtEndPosition - ValueAtStartPosition) *
68     }
69     return returnValue;
70     #endregion
71 }
72
73 #region Snippet body
```

Variables and types:

- x [double]
- y [double]
- StartPositionLine [VectorD]
- EndPositionLine [VectorD]
- ValueAtStartPosition [double]
- ValueAtEndPosition [double]

- In this example, the resulting modulation is defined by:
  - starting position
  - end position
  - the grating parameter at the starting position
  - the grating parameter at the end position
- Between the two defined positions the grating parameter is increased or decreased linearly.

# Modulation Based on Mathematical Description

Edit Grating Parameter Modulation Function

☐ Define Grating Parameter Function for Two Grating Parameters

Settings for Grating Parameter #1

Name: Relative Slit Width

Property: Percentage

Minimum: 10 %

Maximum: 90 %

Modulation Defined by: ☐ Sampled Data ☒ Programmable Function

Edit Validity: ✓

StartPositionLine: -7 mm -5 mm

EndPositionLine: 9 mm -5 mm

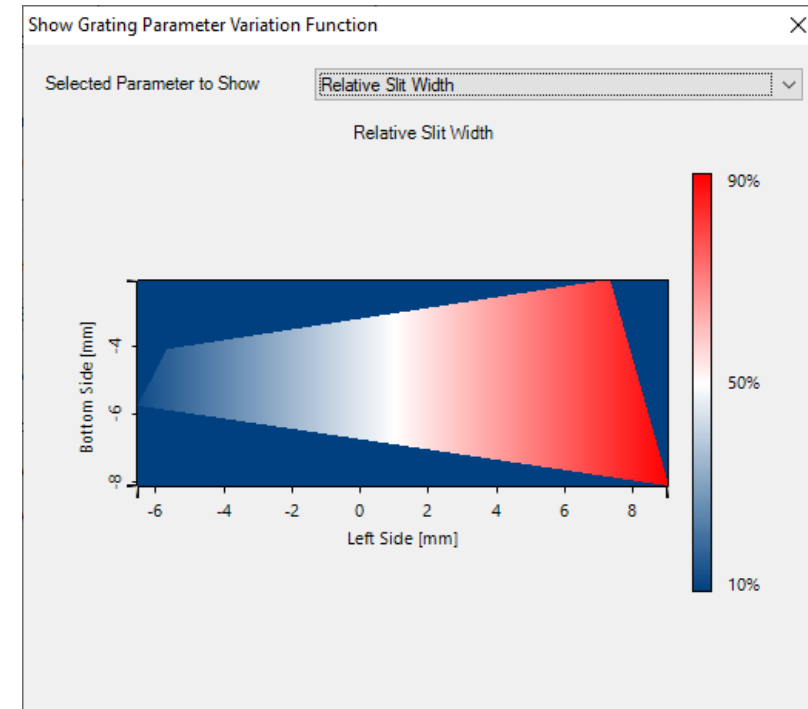
ValueAtStartPosition: 10 %

ValueAtEndPosition: 90 %

View

OK Cancel Help

- The modulation has been configured and can be modified by changing the defined variables of start and end position and the value range of the varied parameter.
- By clicking on *View*, the resulting smooth modulation of the corresponding grating parameter is shown:





# Document Information

title	Grating Analysis and Smoothly Modulated Grating Parameters on Lightguides
document code	LIG.0010
document version	1.0
software edition	<ul style="list-style-type: none"><li>• VirtualLab Fusion Advanced</li><li>• VirtualLab Fusion Light Guide Toolbox Gold</li></ul>
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	<ul style="list-style-type: none"><li>- <a href="#"><u>Footprint Analysis of Lightguides for AR/MR Applications</u></a></li><li>- <a href="#"><u>Construction of a Light Guide</u></a></li><li>- <a href="#"><u>Modeling of a “HoloLens 1”-Type Layout with Light Guide Component</u></a></li><li>- <a href="#"><u>Light Guide Layout Design Tool</u></a></li><li>- <a href="#"><u>k-Domain Layout Visualization</u></a></li><li>- <a href="#"><u>Simulation of Lightguide with 1D-1D Pupil Expander and Real Gratings</u></a></li></ul>