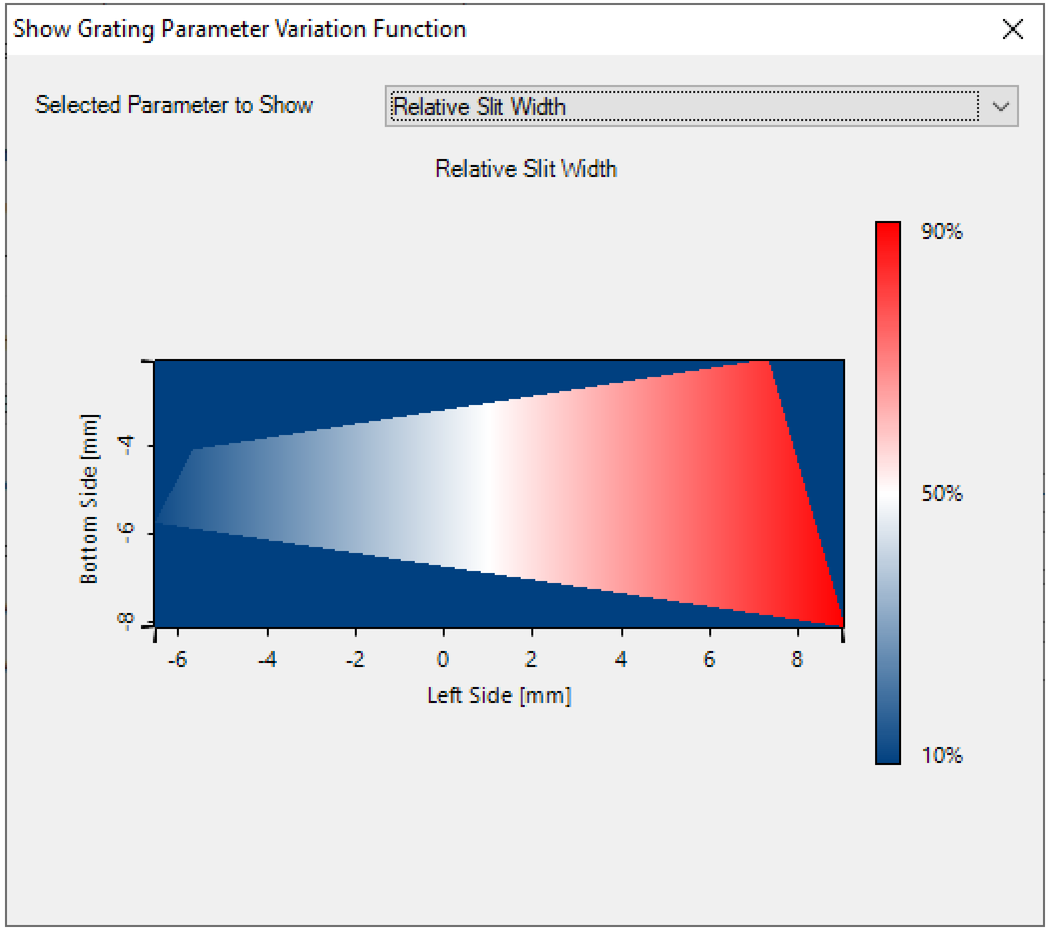
Grating Analysis and Smoothly Modulated Grating Parameters on Lightguides

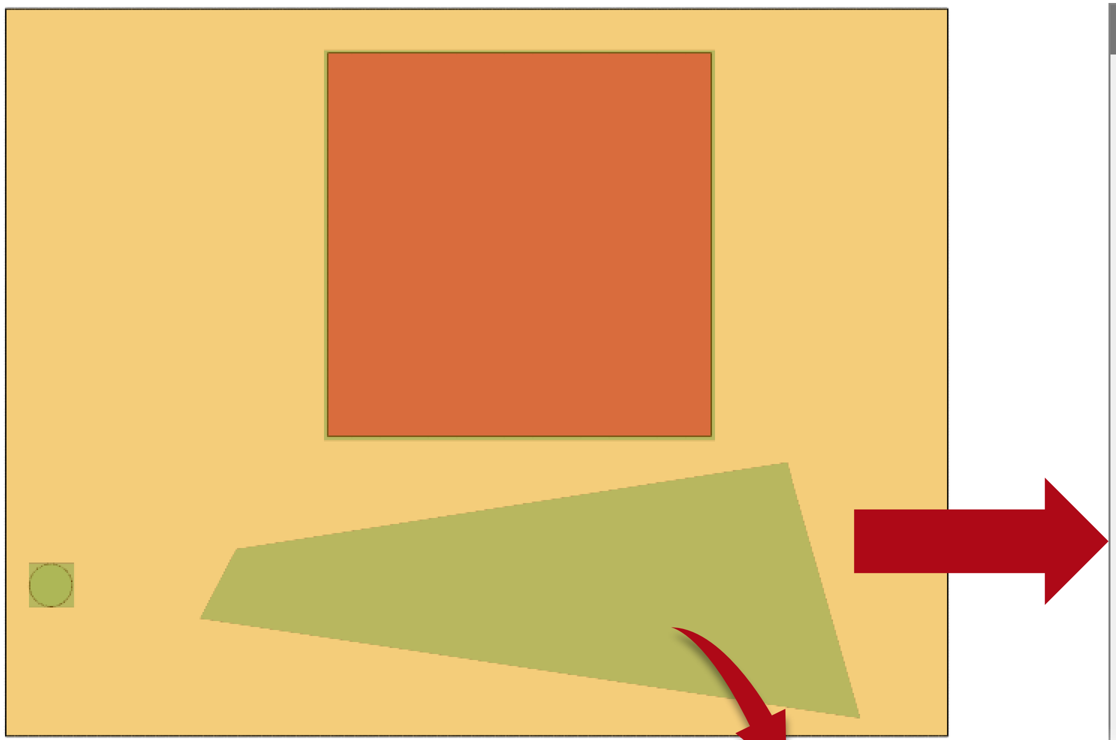
Abstract

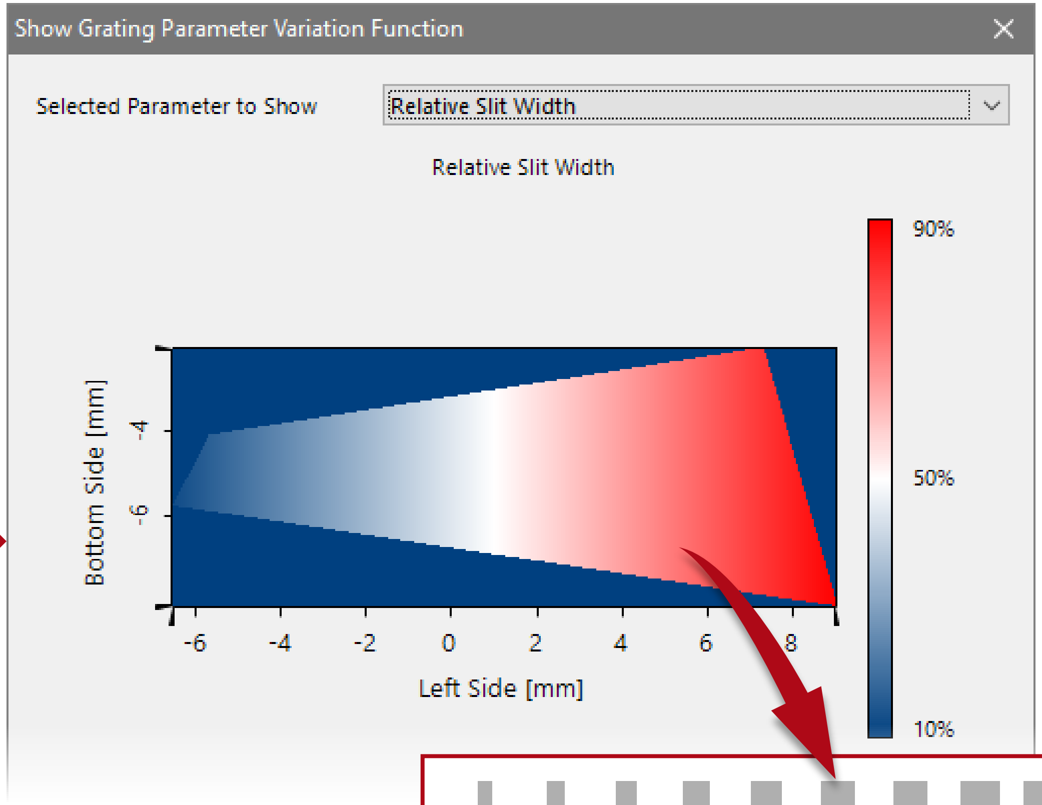


In order to control the uniformity and efficiency in a lightguide device for AR/MR applications, it is necessary to vary grating parameters, such as fill factor and grating height, over certain areas, e.g. in the expansion and outcoupling grating regions. For this purpose, VirtualLab Fusion enables the 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.

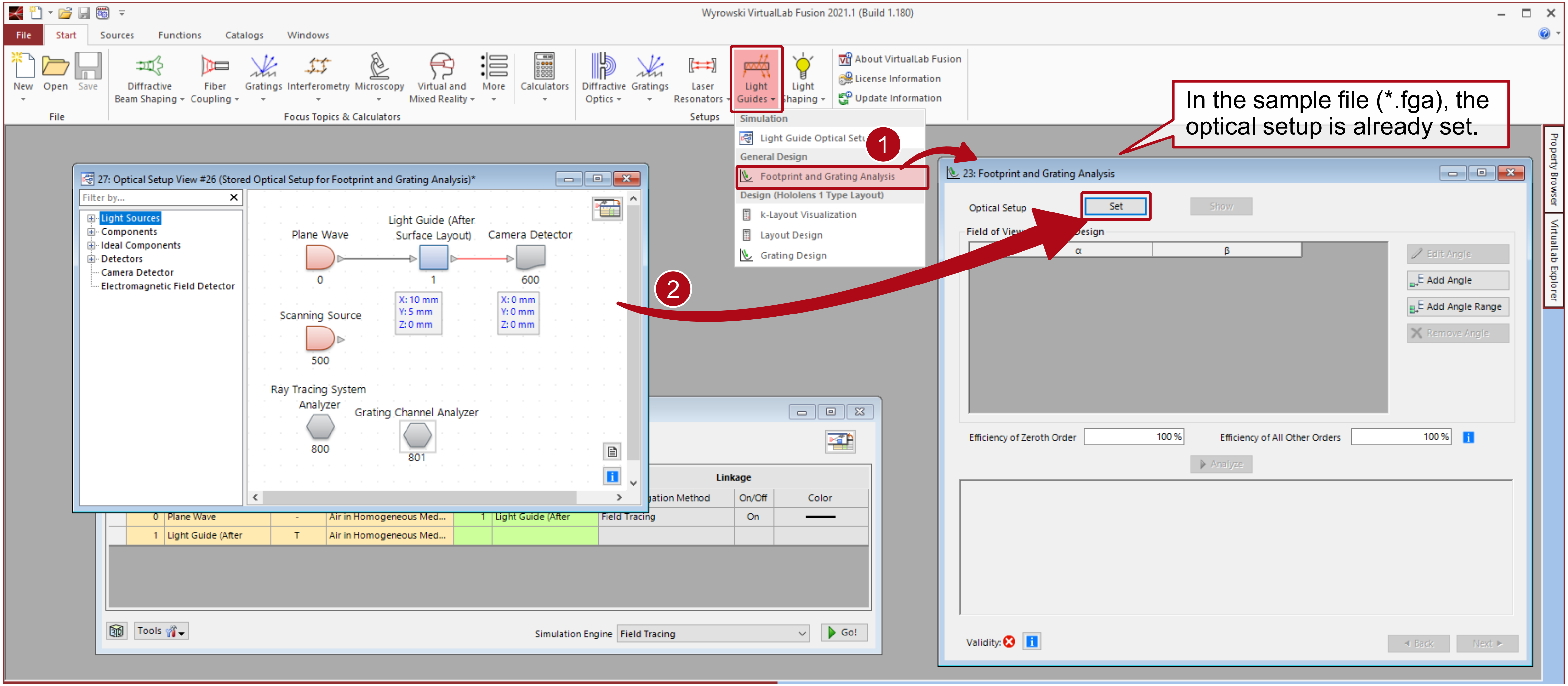
- How to Set Up a Lightguide with Real Grating Structures [Use Case]
- Simulation of 1D-1D Pupil Expander with Real Gratings [Use Case]

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.

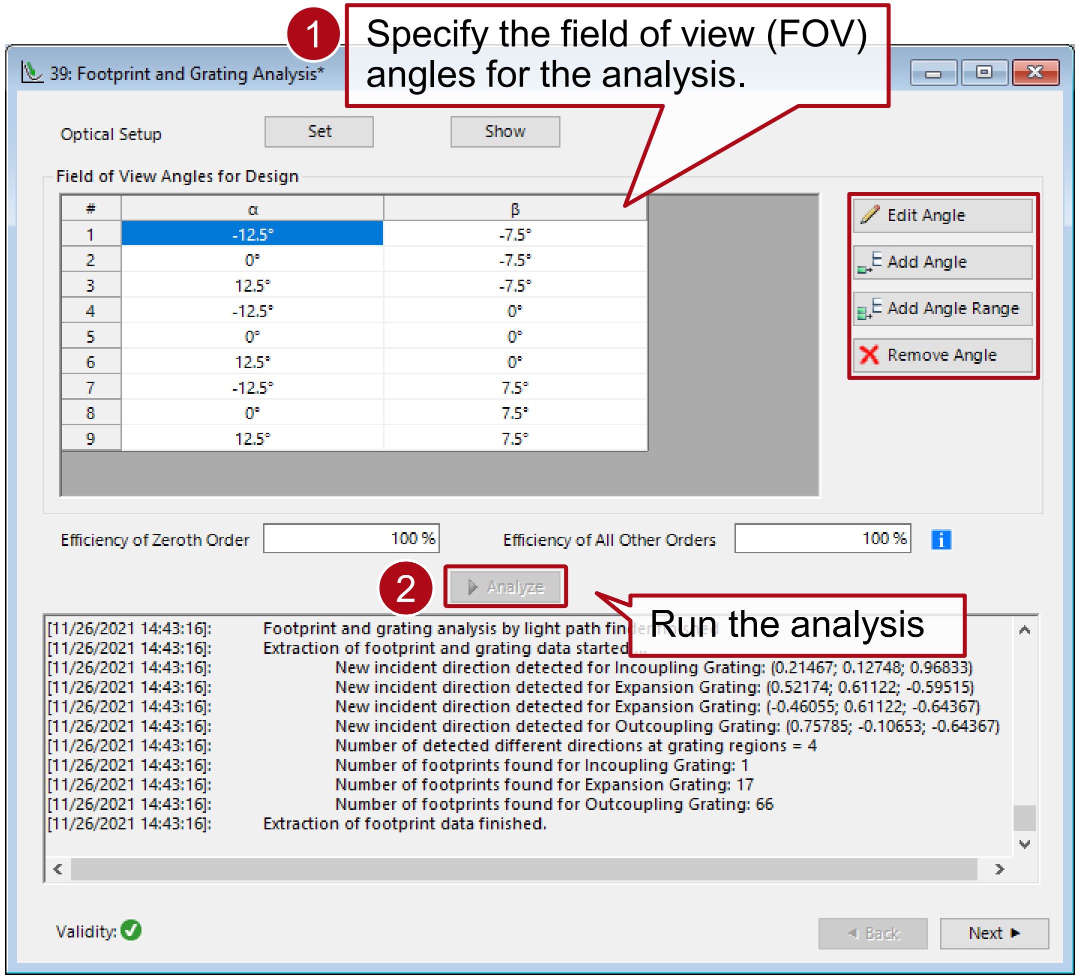
- Footprint Analysis of Lightguides for AR/MR Applications [Use Case]

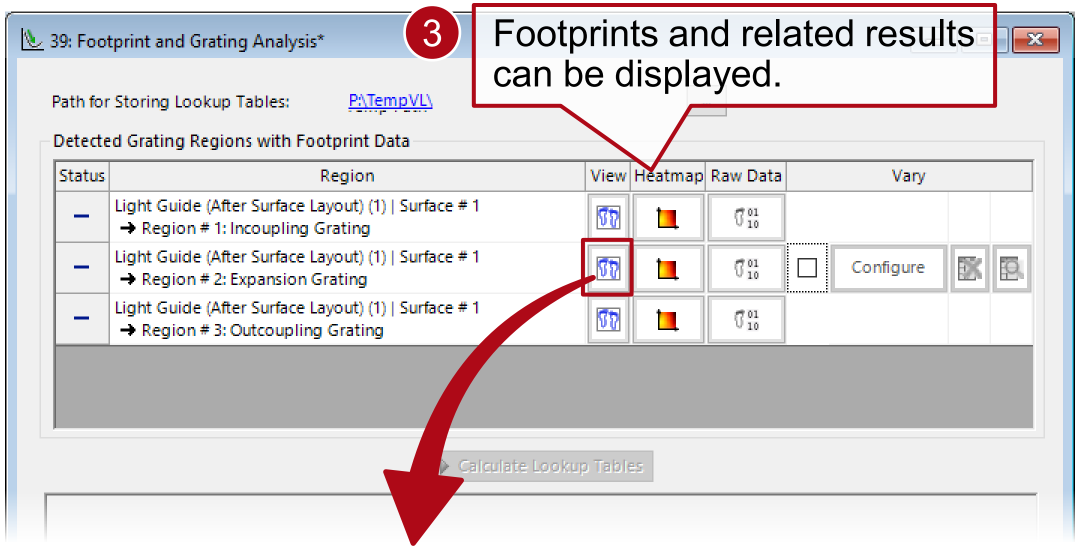
Note:
The grating modulation is defined for individual grating regions.

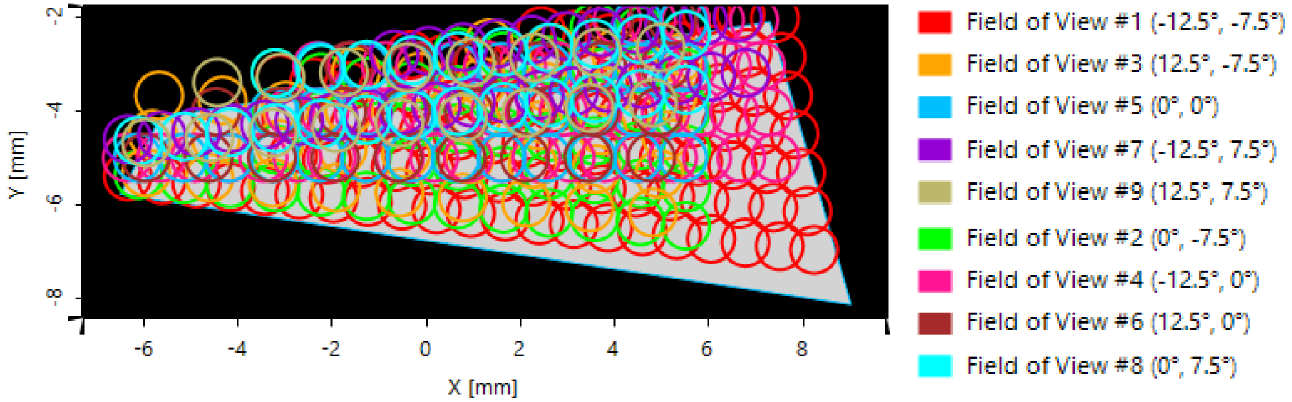
Open Footprint and Grating Analysis Tool & Set Optical Setup



Footprint and Grating Analysis Tool

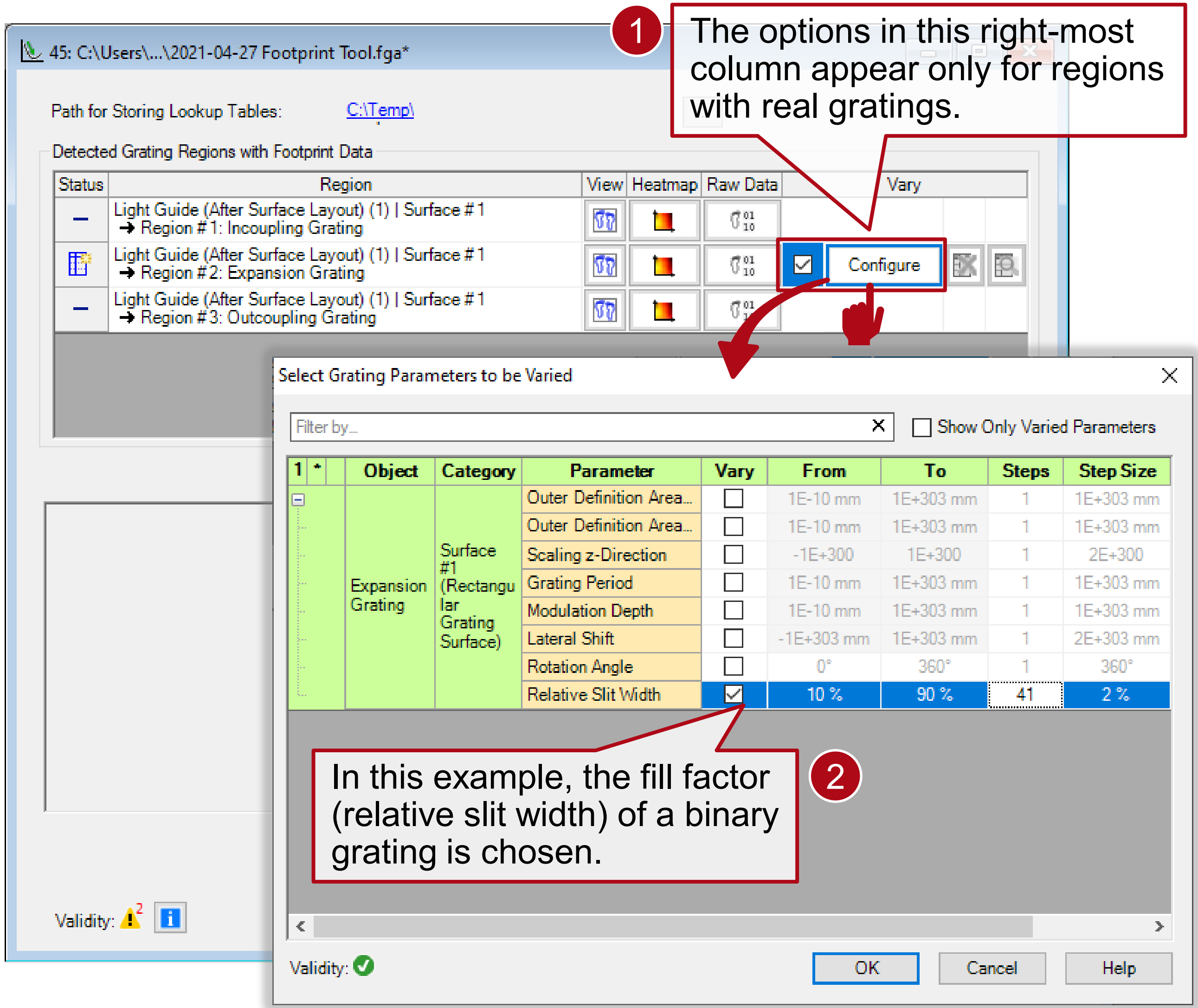






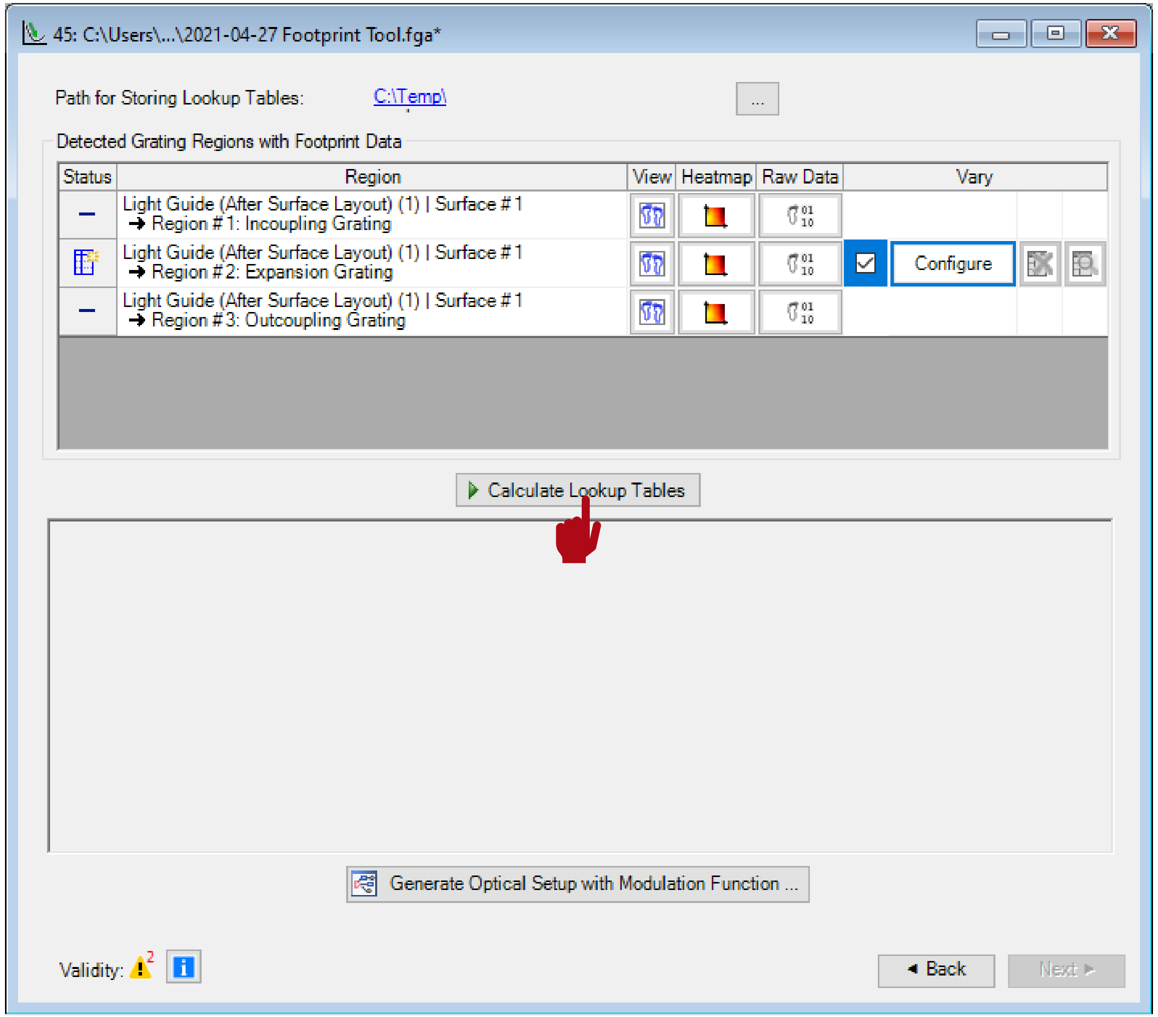
For a general workflow and overview of this tool see the following use case: [Footprint Analysis of Lightguides for AR/MR Applications]

Selection of Grating Parameters and Associated Ranges



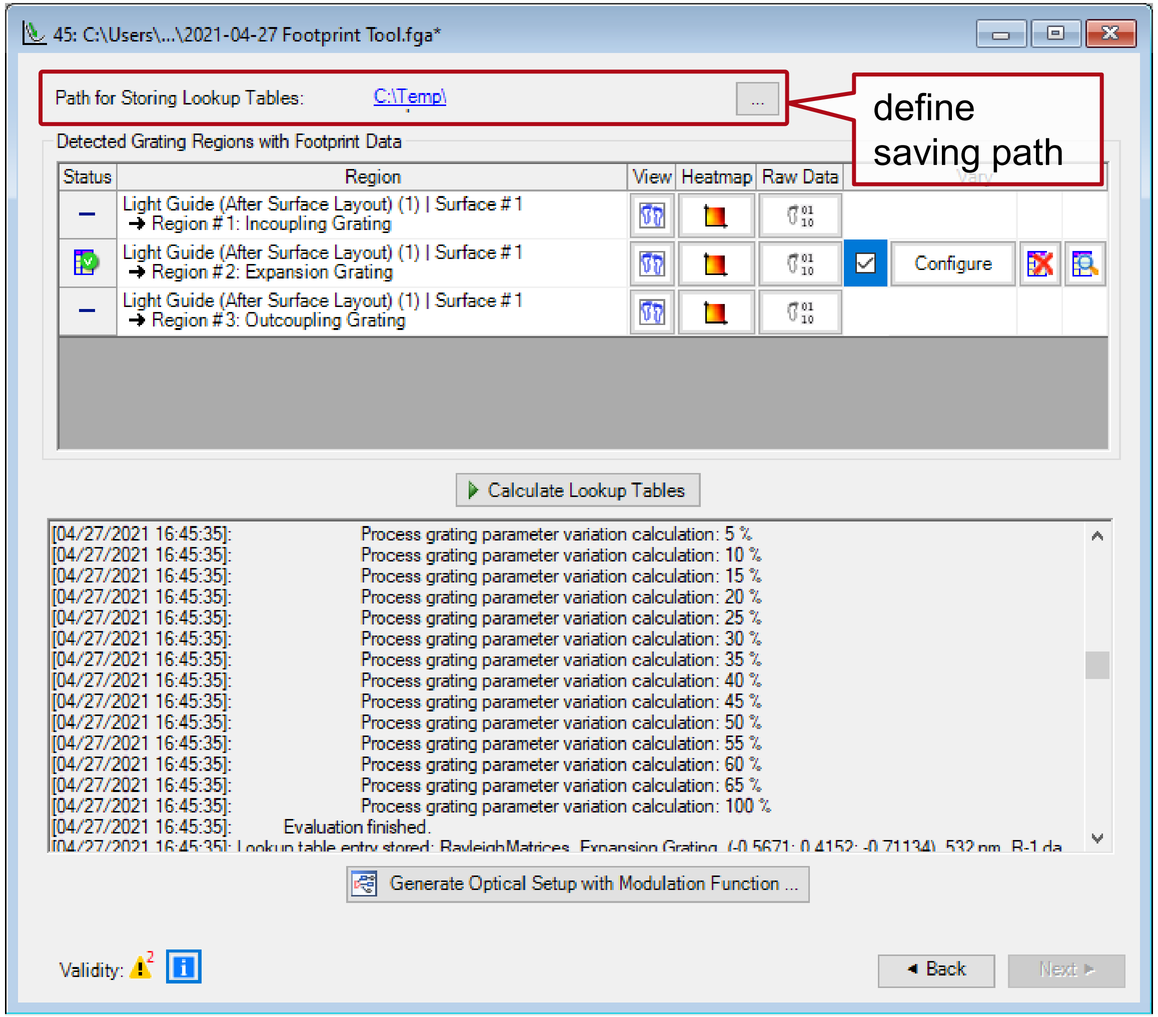
- It is possible to vary one or two grating parameters at the same time.
- The sampling of the parameter space can be relatively coarse, since afterwards interpolation techniques will be applied in between the calculated points.
- The table lists all available parameters of the grating. For the introduction 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

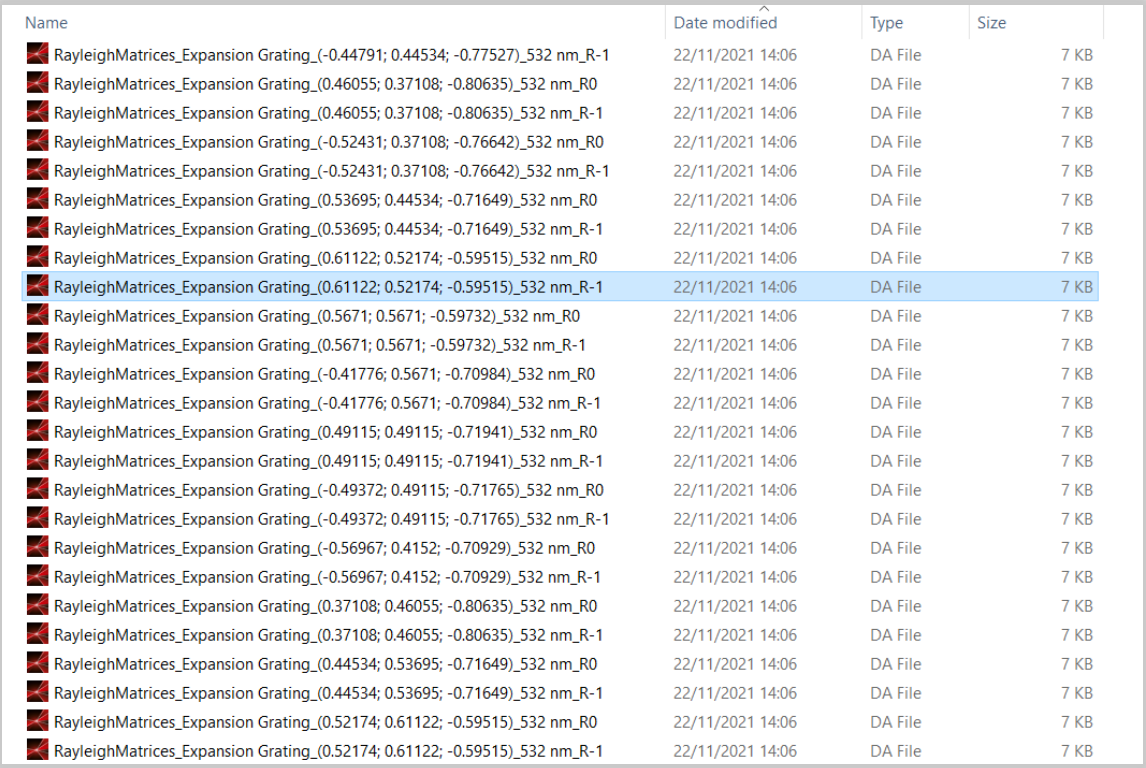


After configuring the desired variation of the grating parameters, the resulting grating characteristic can be calculated and stored in lookup tables by clicking on *Calculate Lookup Tables*.

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:



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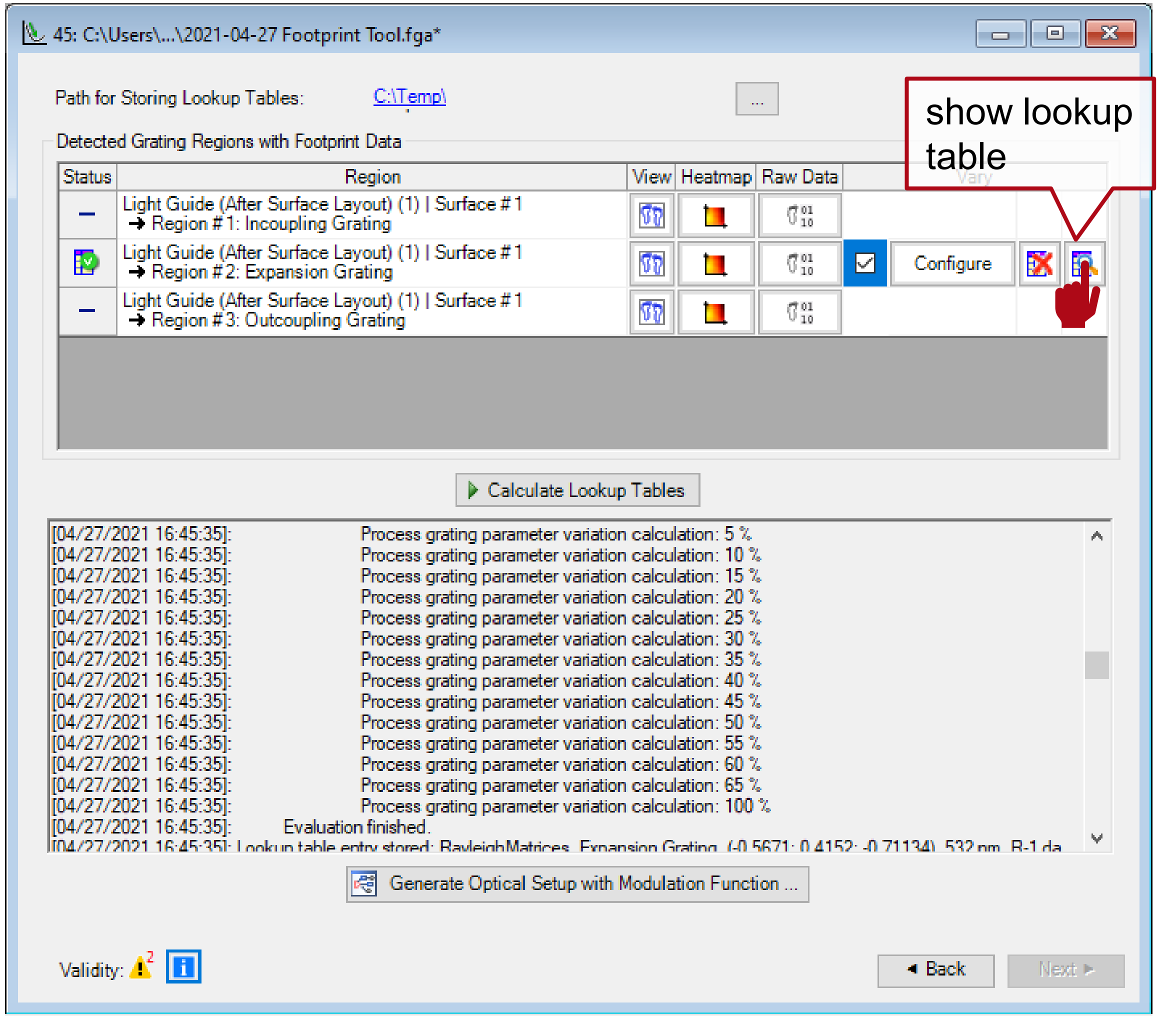
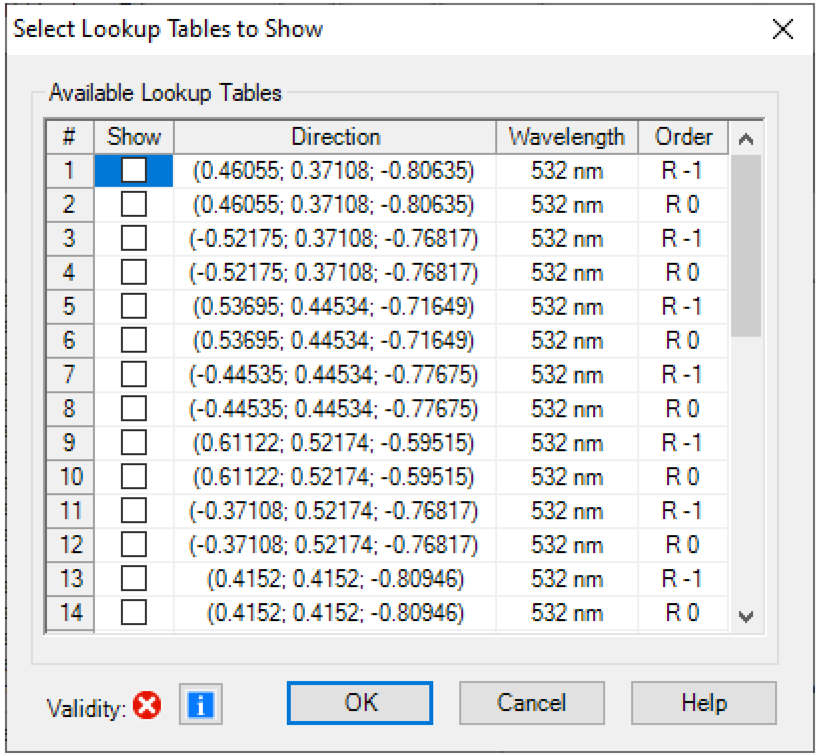
RayleighMatrices_Expansion Grating_(0.52174; 0.61122; -0.59515)_532 nm_R-1	22/11/2021 14:06	DA File	7 KB

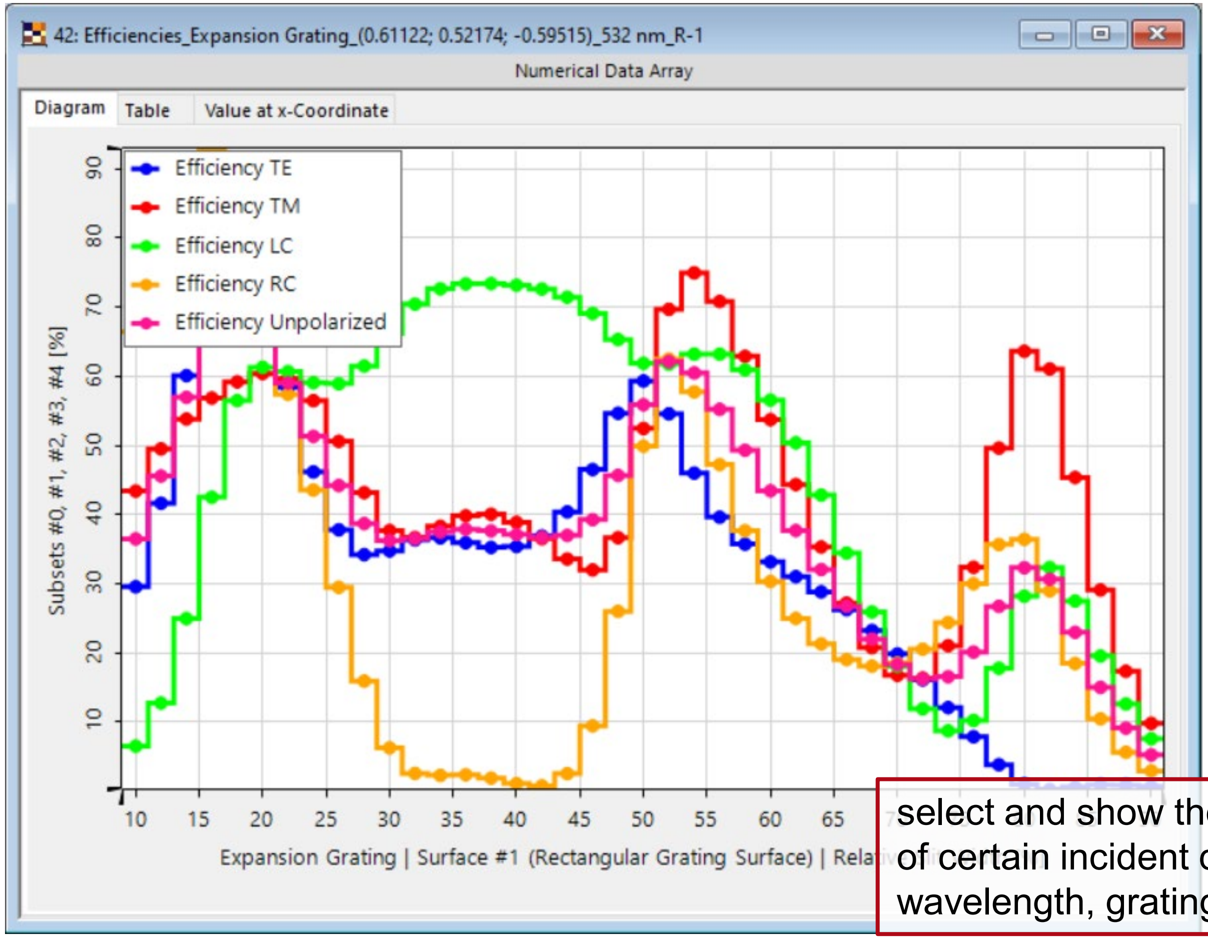
Calculation of Lookup Tables



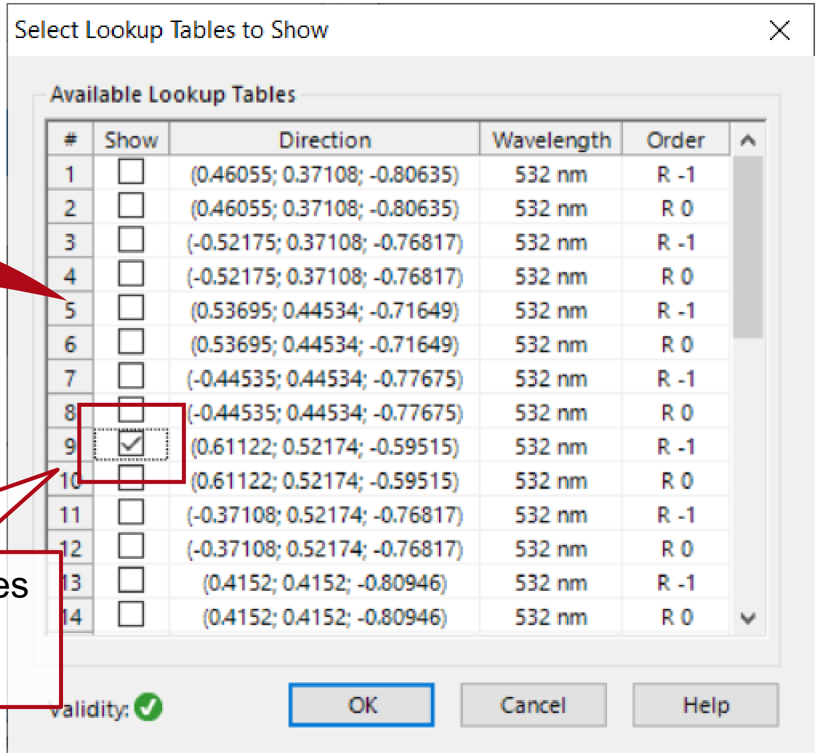
By clicking on the button with the magnifying glass, the data for specific orders and directions can be investigated in detail:



Investigation of Grating Behavior

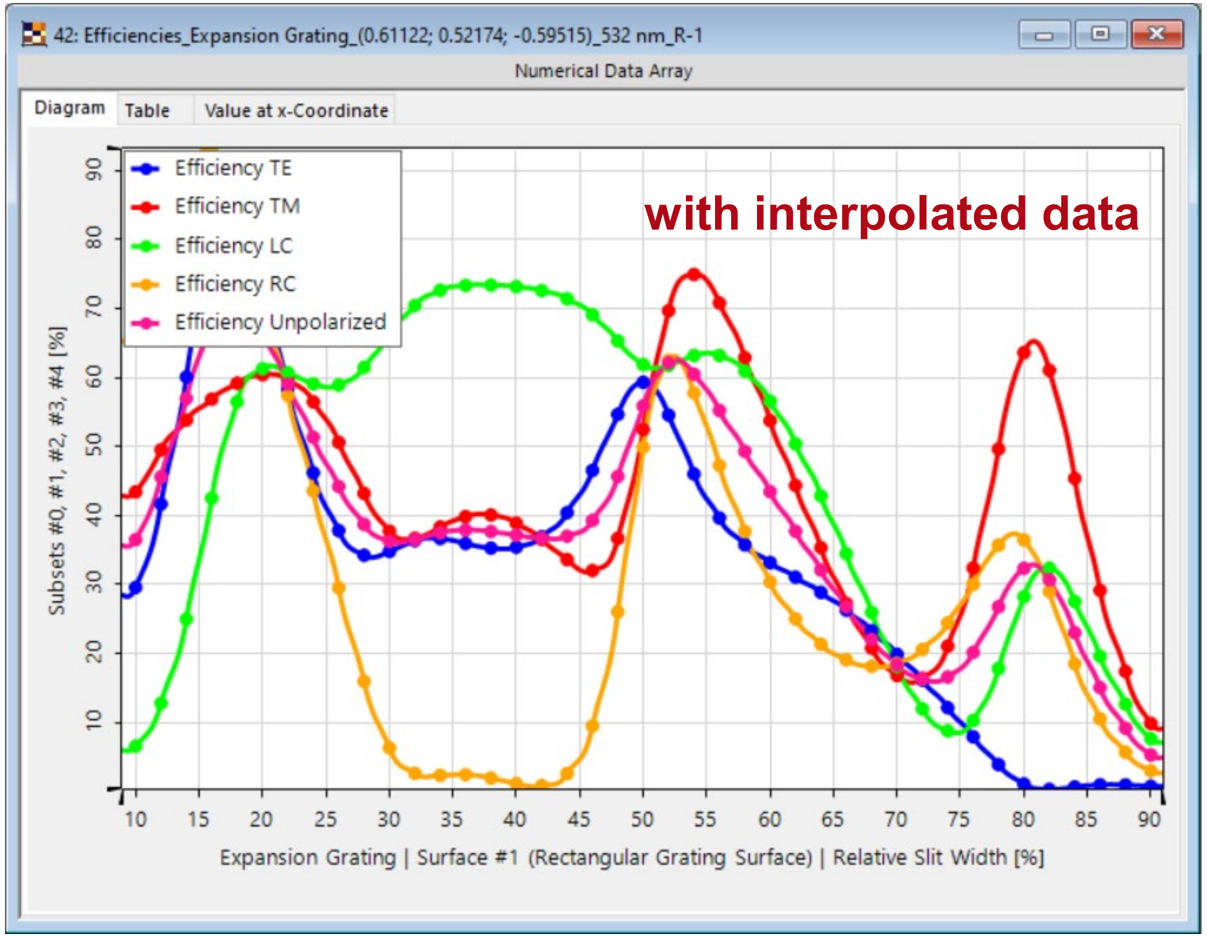


From the information of the lookup tables (Rayleigh matrix per wavelength, direction, diffraction order and value of grating parameters) the efficiency values for different polarization states are derived and displayed.



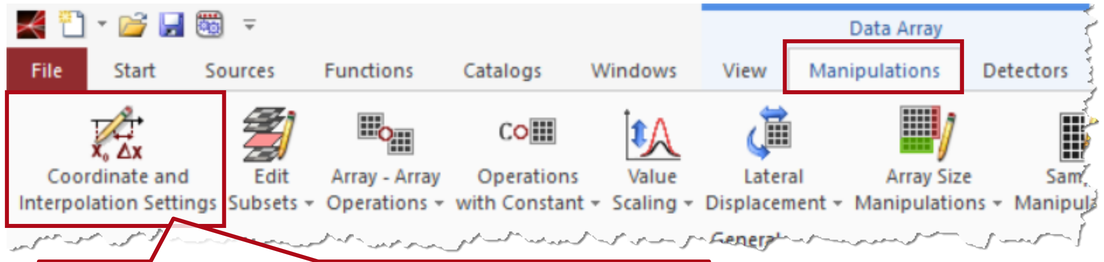
select and show the efficiencies of certain incident direction, wavelength, grating order

Investigation of Grating Behavior



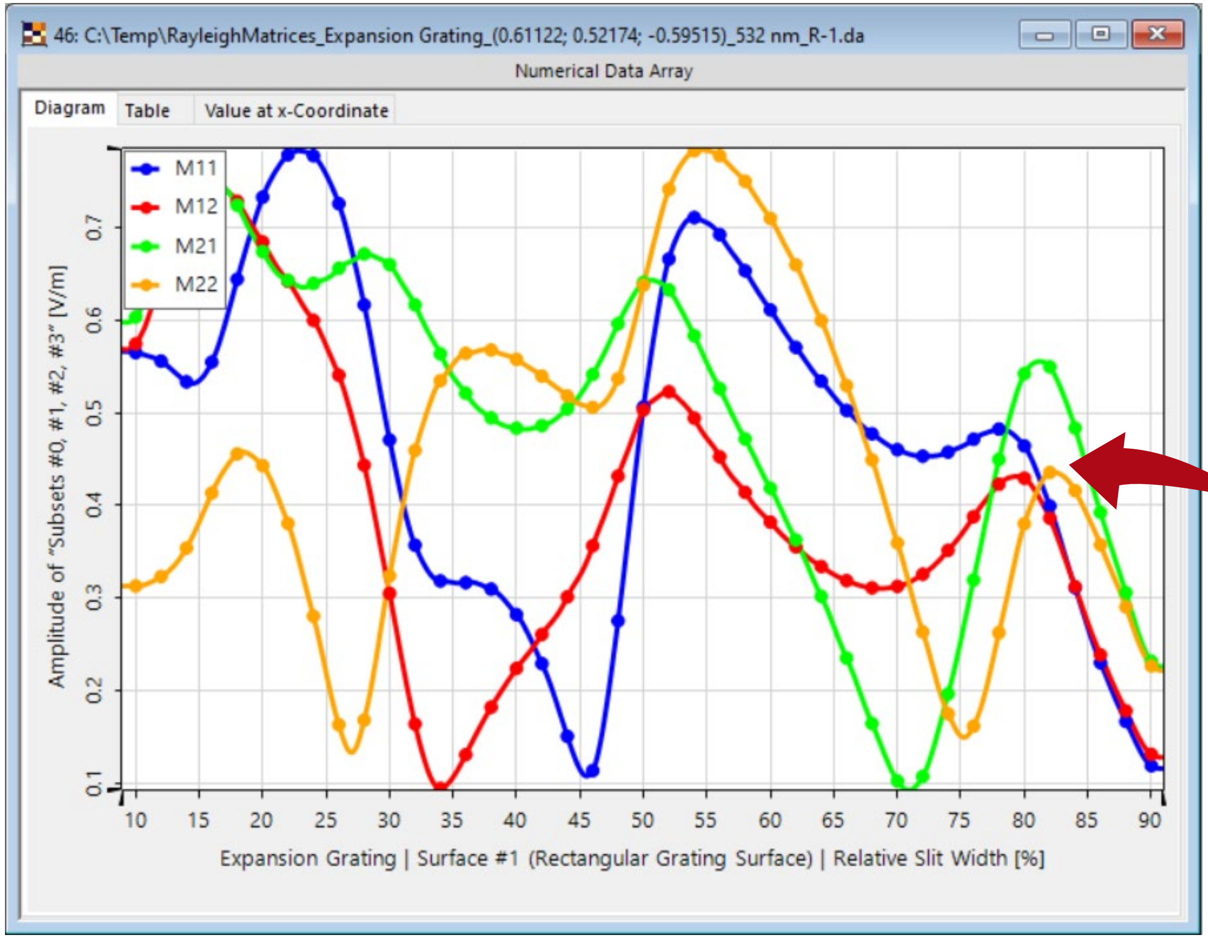
The efficiency of the grating is shown for different polarization states (TE, TM, left circular, right circular polarization, as well as unpolarized light). In the simulation of the full lightguide, the local occurring polarization states of the incident light will be considered automatically.

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

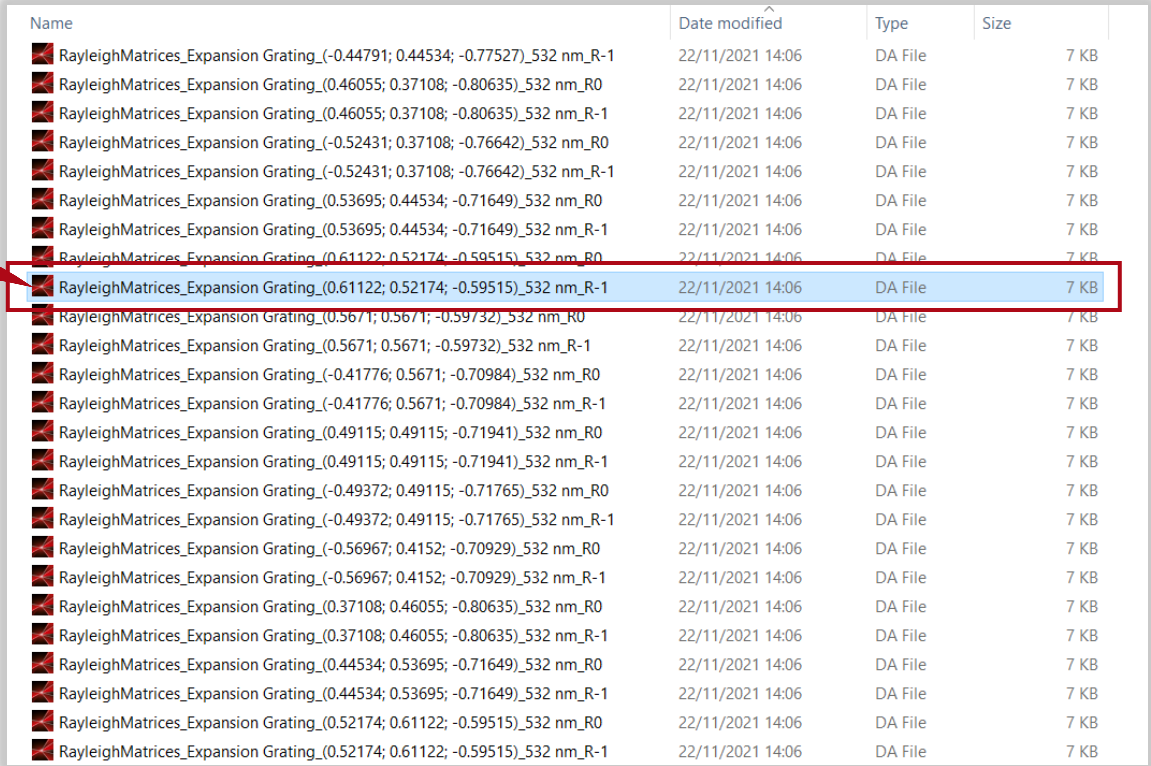


The interpolation of the data was switched to cubic via *Manipulations > Coordinate and Interpolation Settings*.

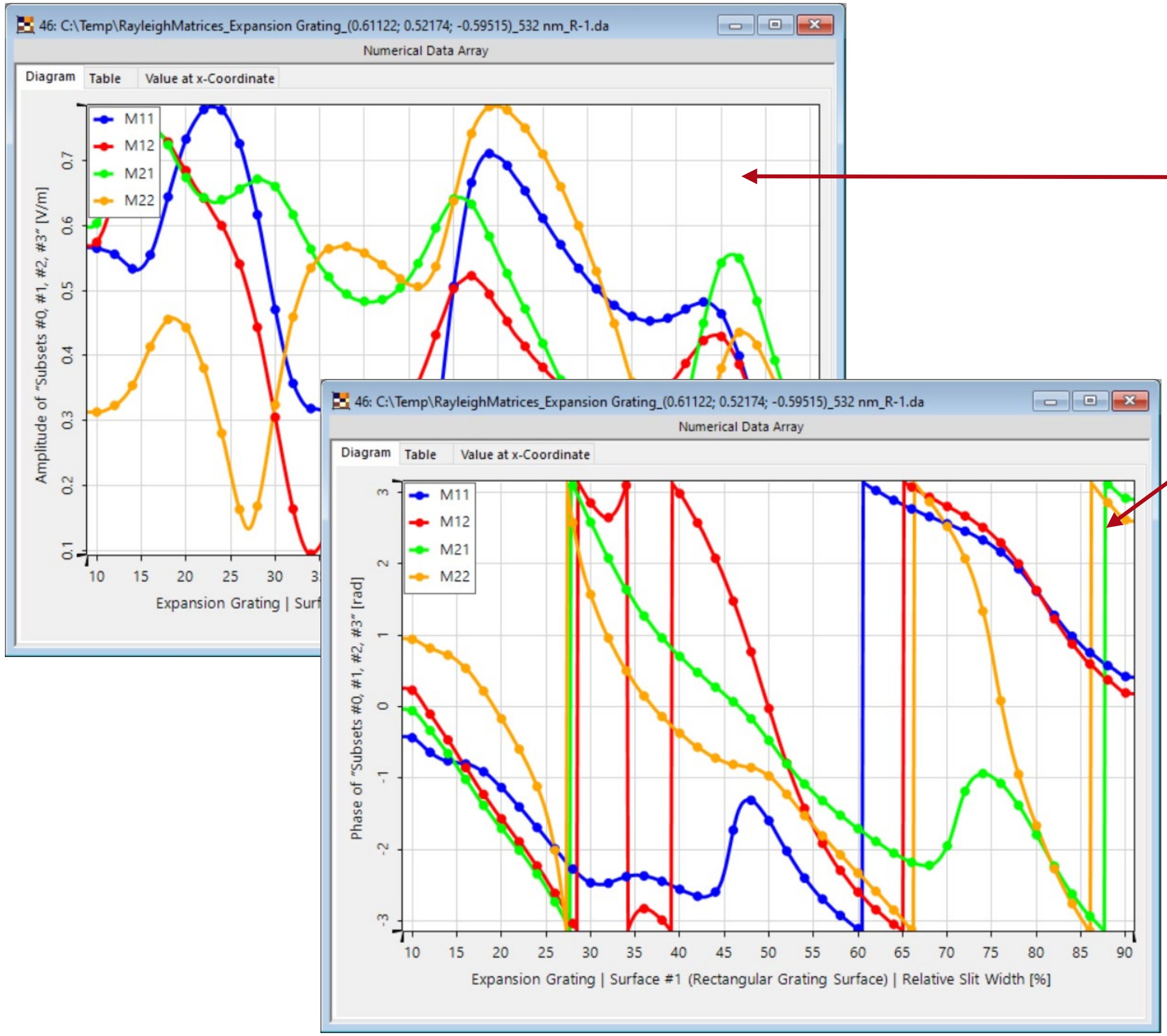
Load Rayleigh Matrices from Lookup Tables

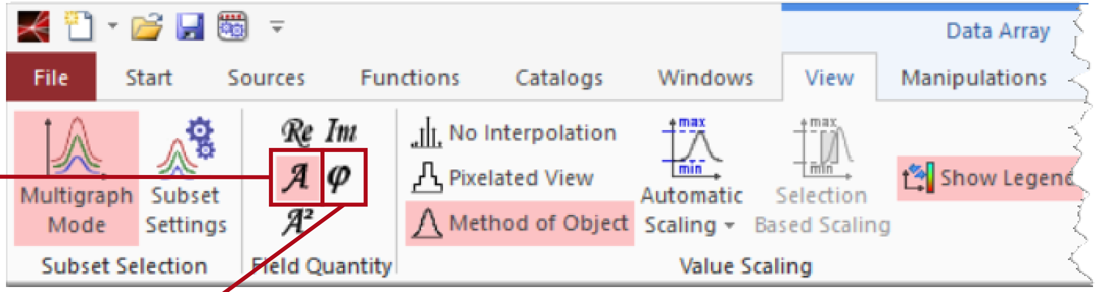


The Rayleigh matrices saved in the defined folder can be loaded in VirtualLab Fusion and reveal the complex-valued entries of this 2×2 matrices.



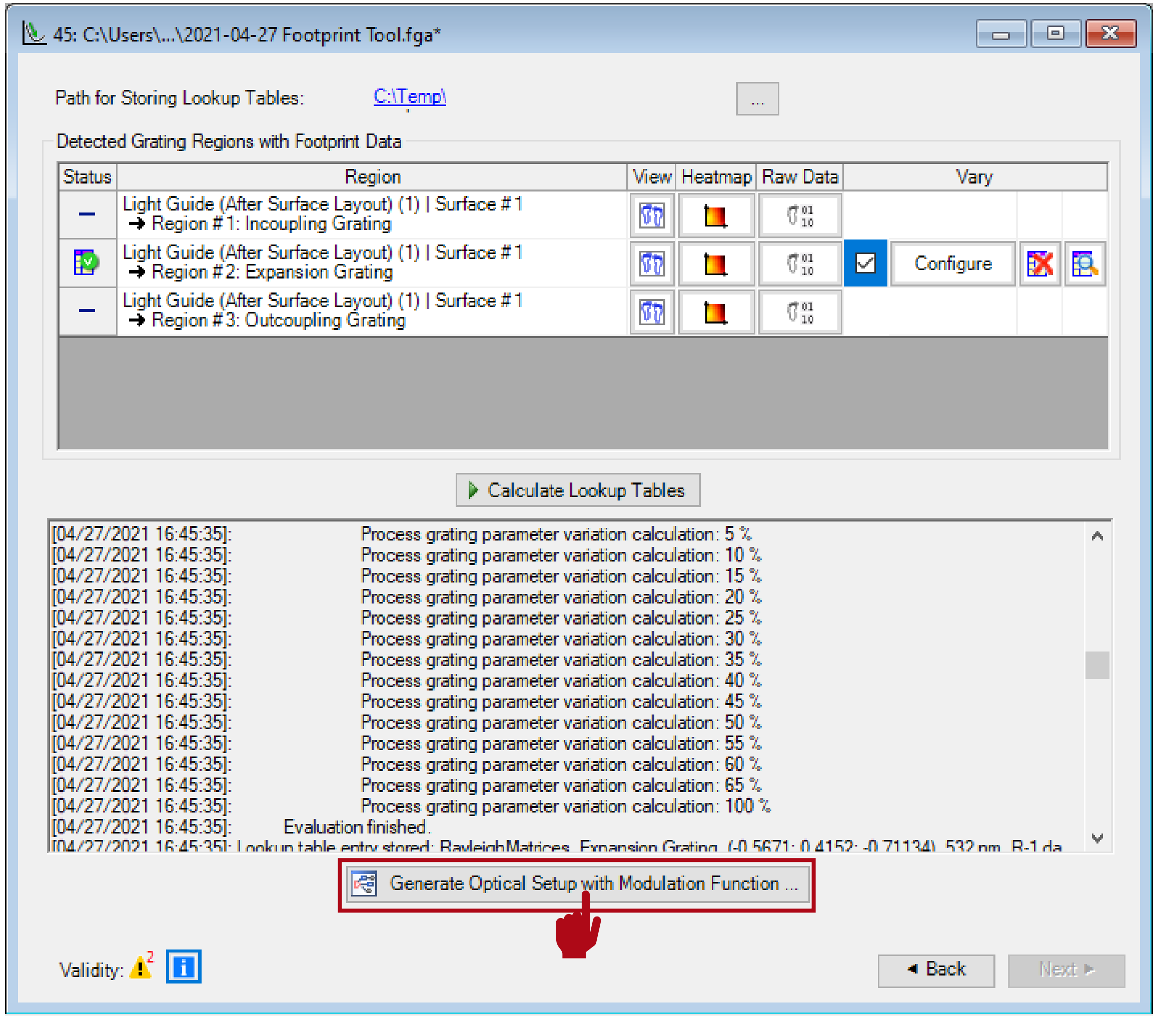
Load Rayleigh Matrices from Lookup Tables



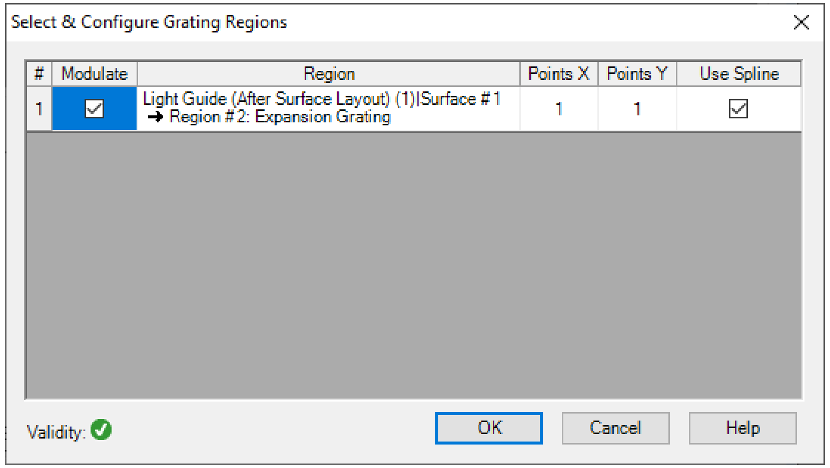


The response of a specific grating (with given period, shape, material, etc.) is defined by a complex-valued 2×2 matrix (Rayleigh matrix) per wavelength, incident direction and diffraction order. The Rayleigh matrices provide the fully vectorial response of the grating, which means that all polarization 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

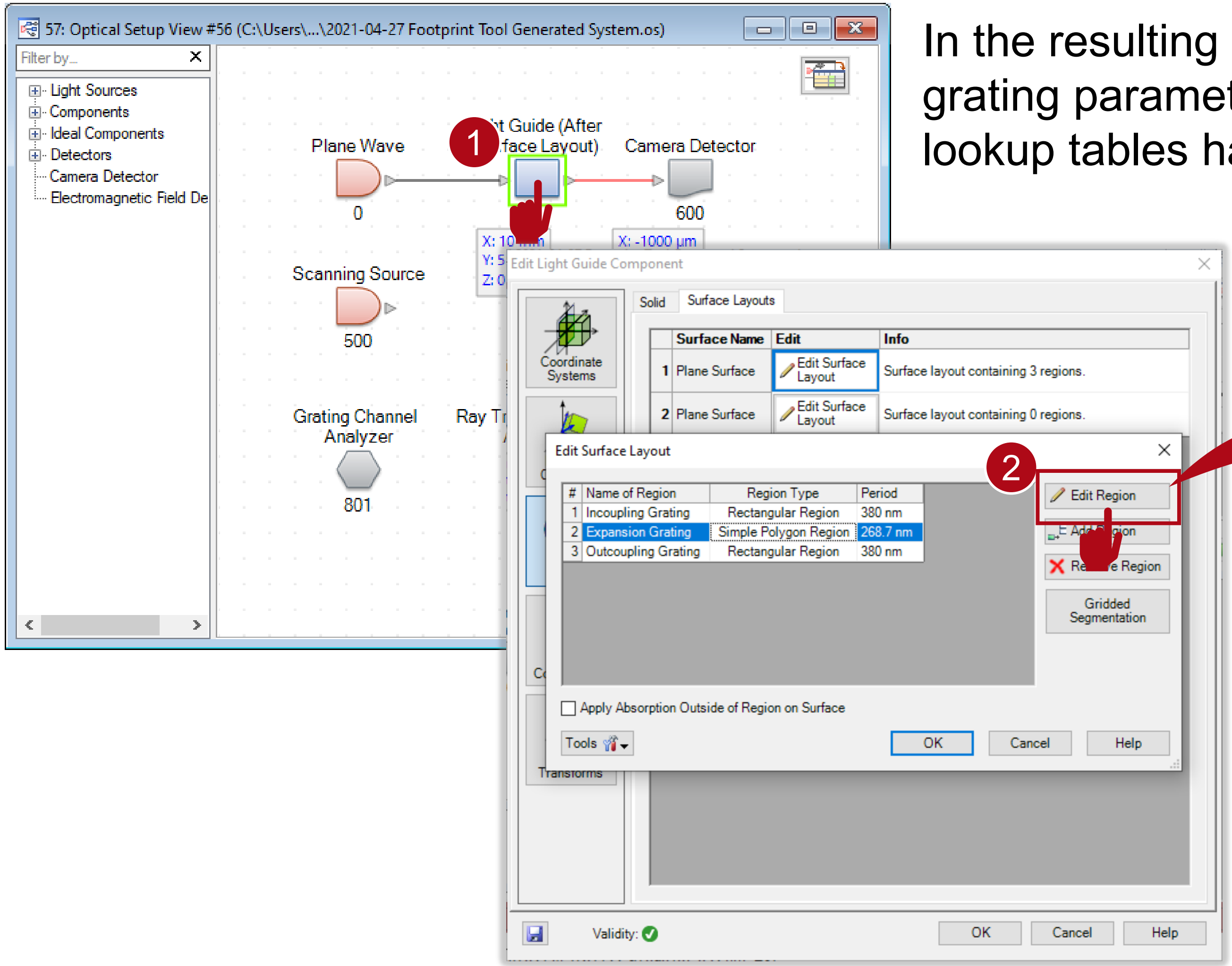


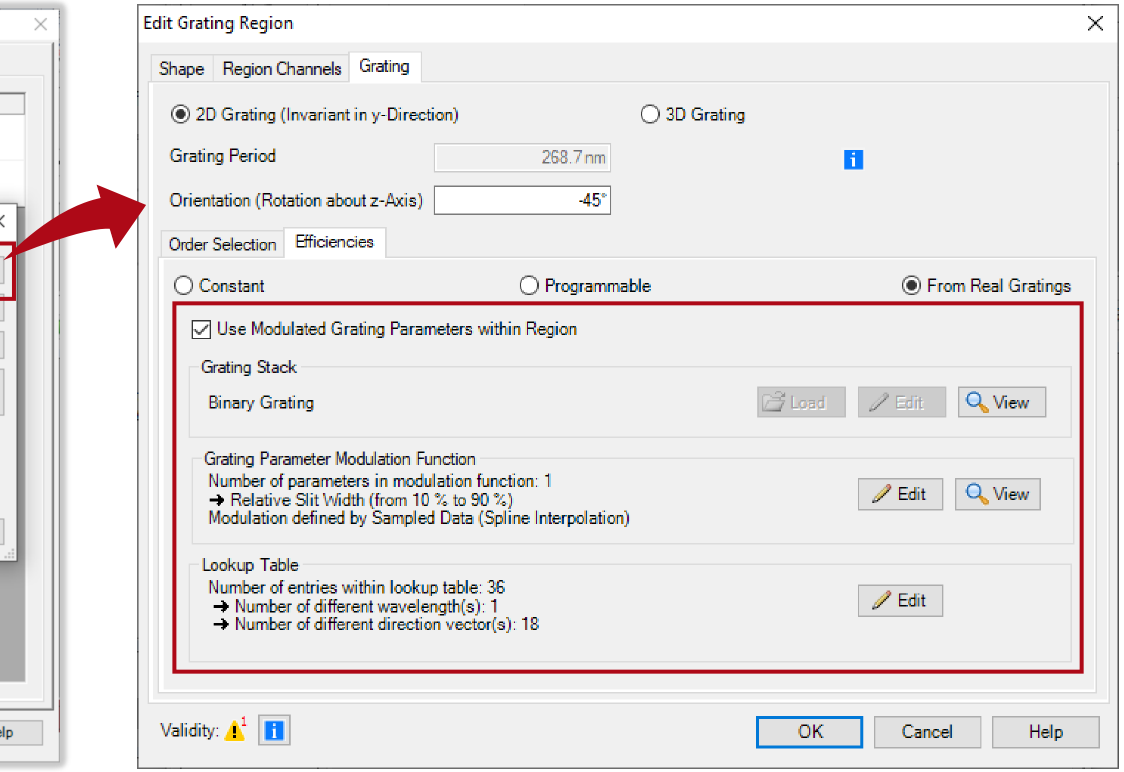
- Finally, an adapted optical system can be generated, where the real grating structures have been replaced by the calculated lookup tables, which enable the configuration of the continuously modulated parameters.
- The *Optical Setup* with modulated grating regions is first generated with an interpolated 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).



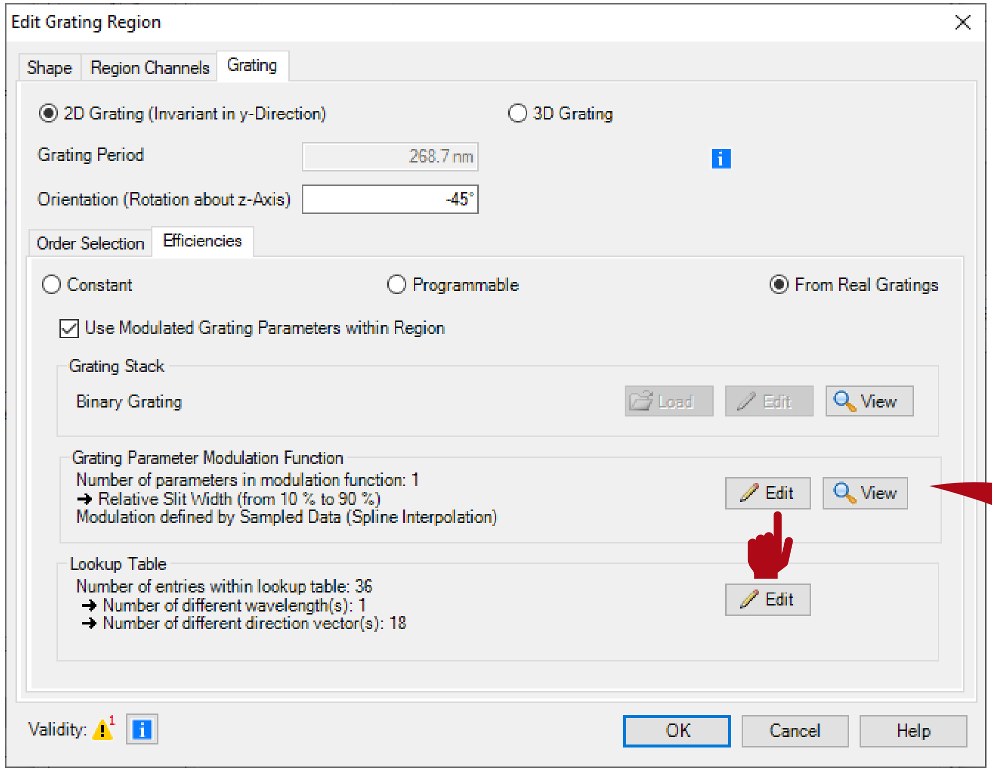
Generation of Updated Optical System

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.

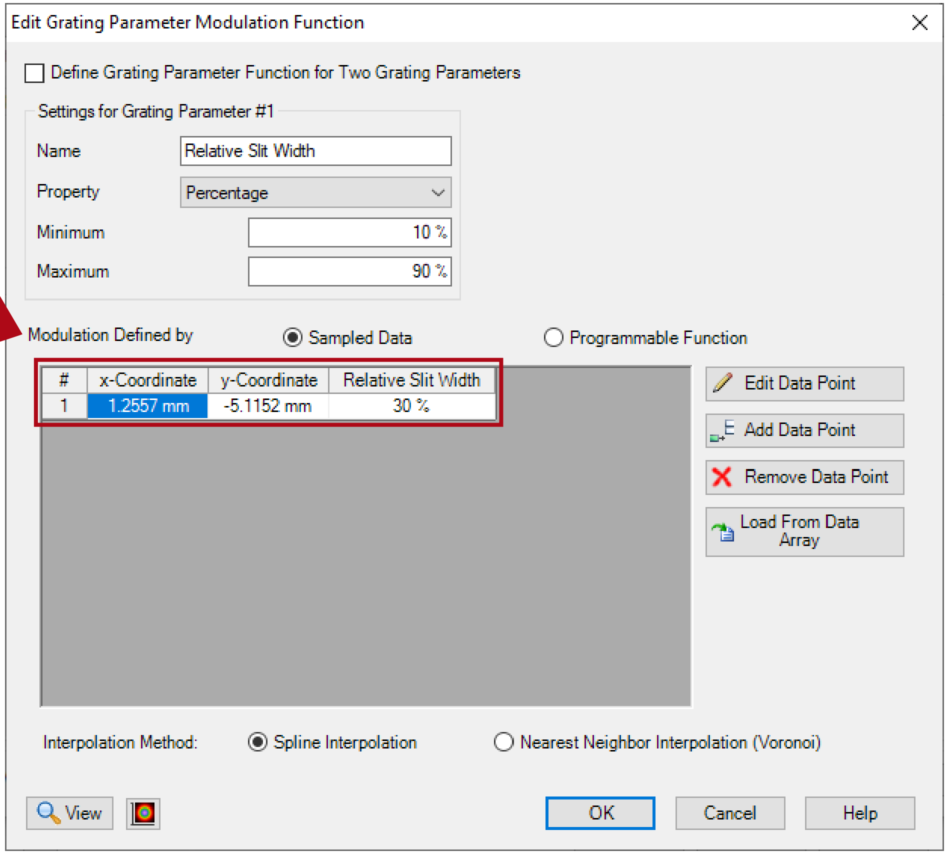




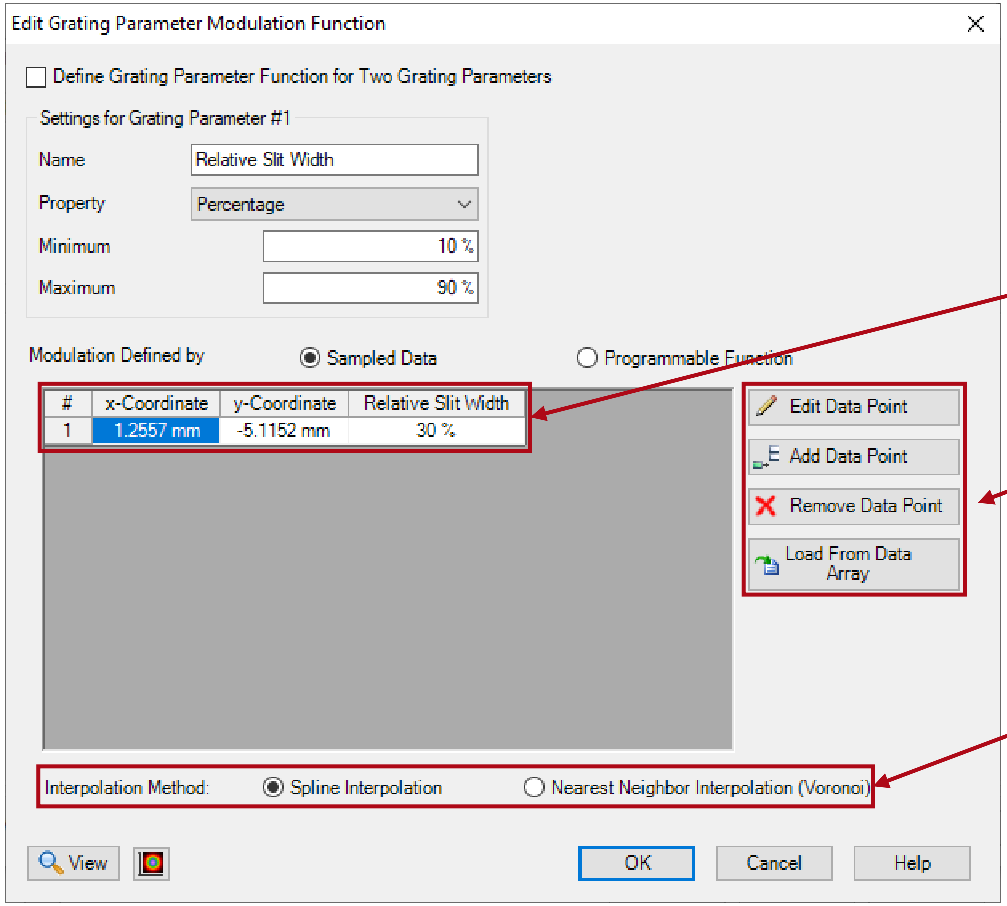
Configuration of Grating Modulation



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.

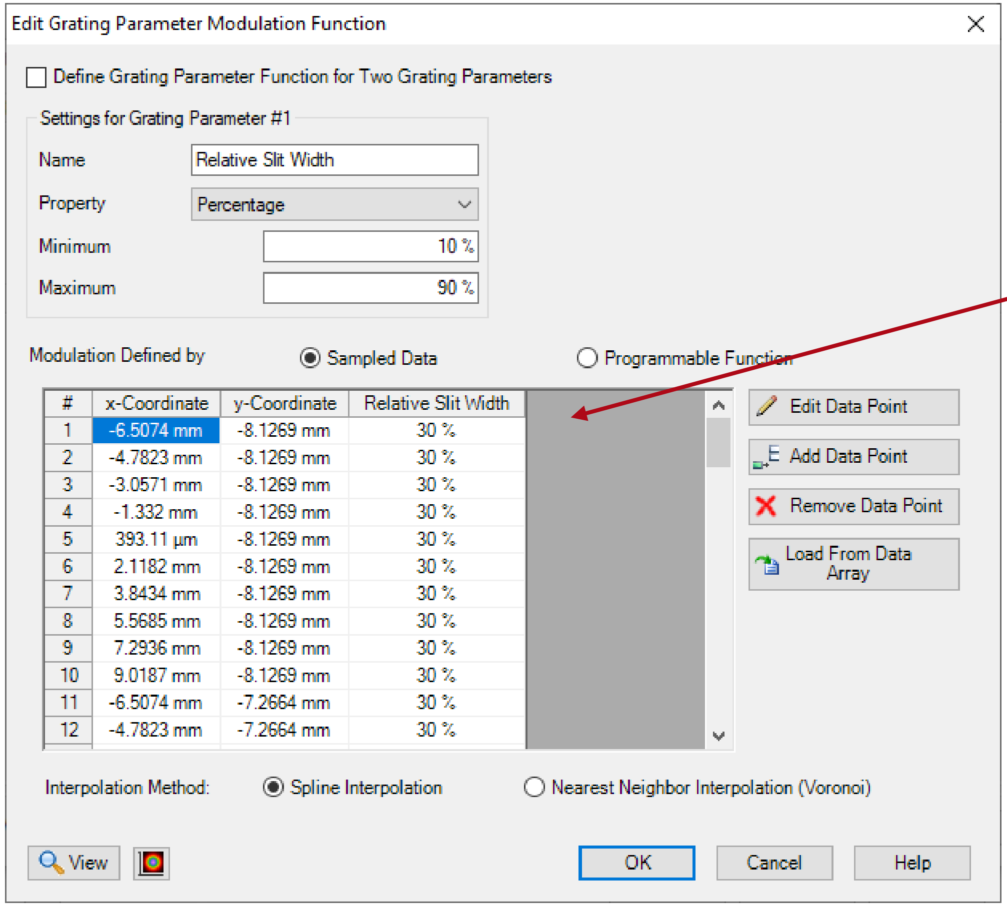


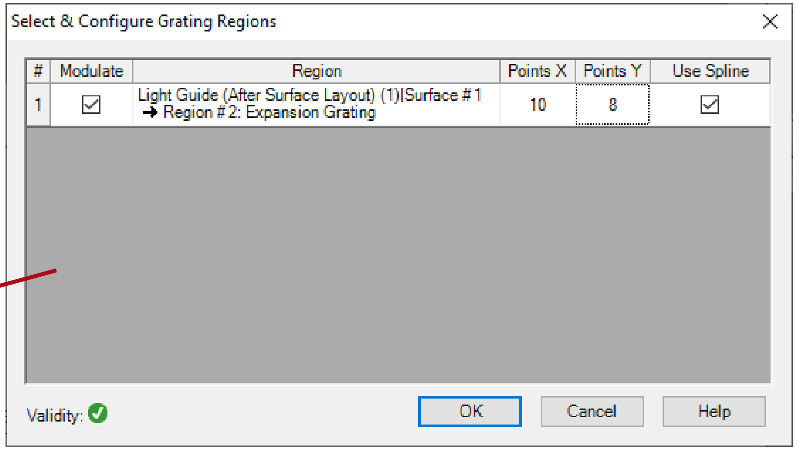
Modulation Based on Sampled Positions or a Grid



- 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)

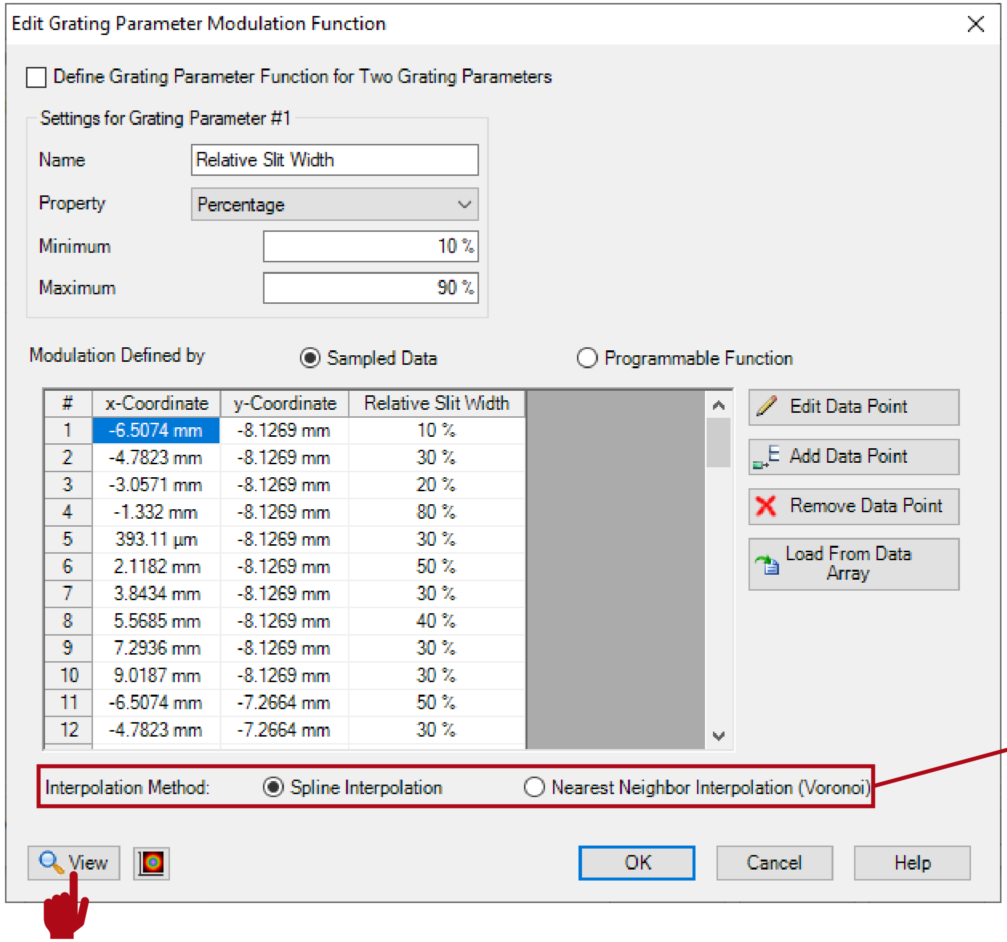
Modulation Based on Sampled Positions or a Grid





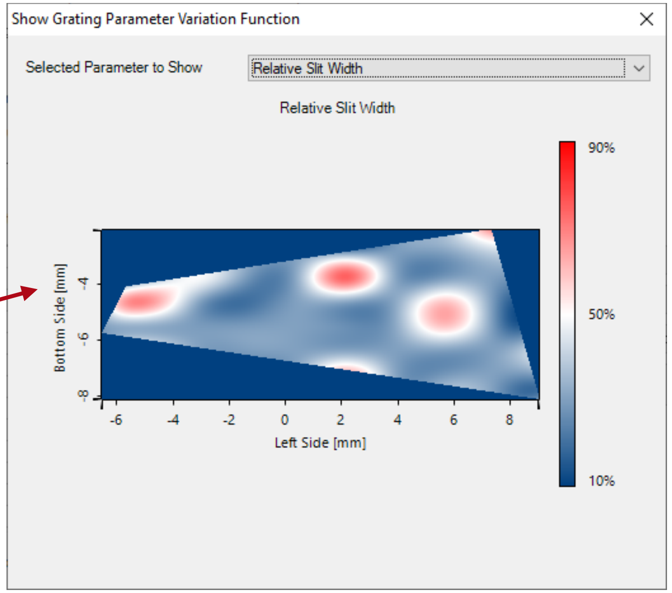
continuing from slide #15:
Entering a certain number of points during the generation of the new optical setup will result in an equidistant grid of sampled positions (in the rectangular box that fits the regarding arbitrary shaped grating region). For each position, the according grating parameter can be set.

Modulation Based on Sampled Positions or a Grid

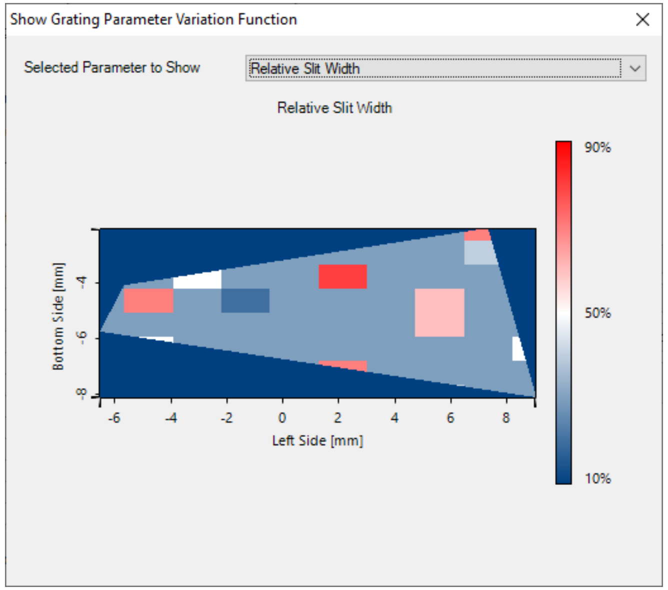


- Now, the modulation of the grating parameter can be adapted by changing the values at the given positions.
- By clicking on *View*, the resulting variation is shown:

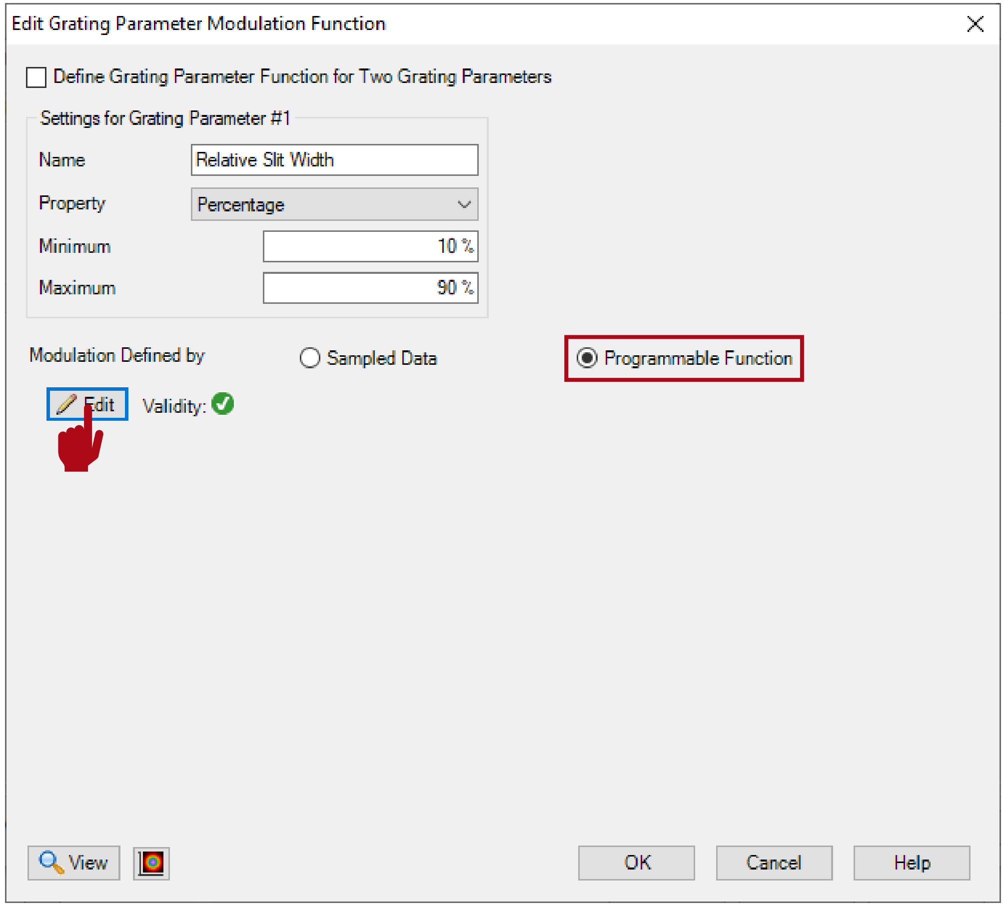
spline interpolated:



nearest neighbor:

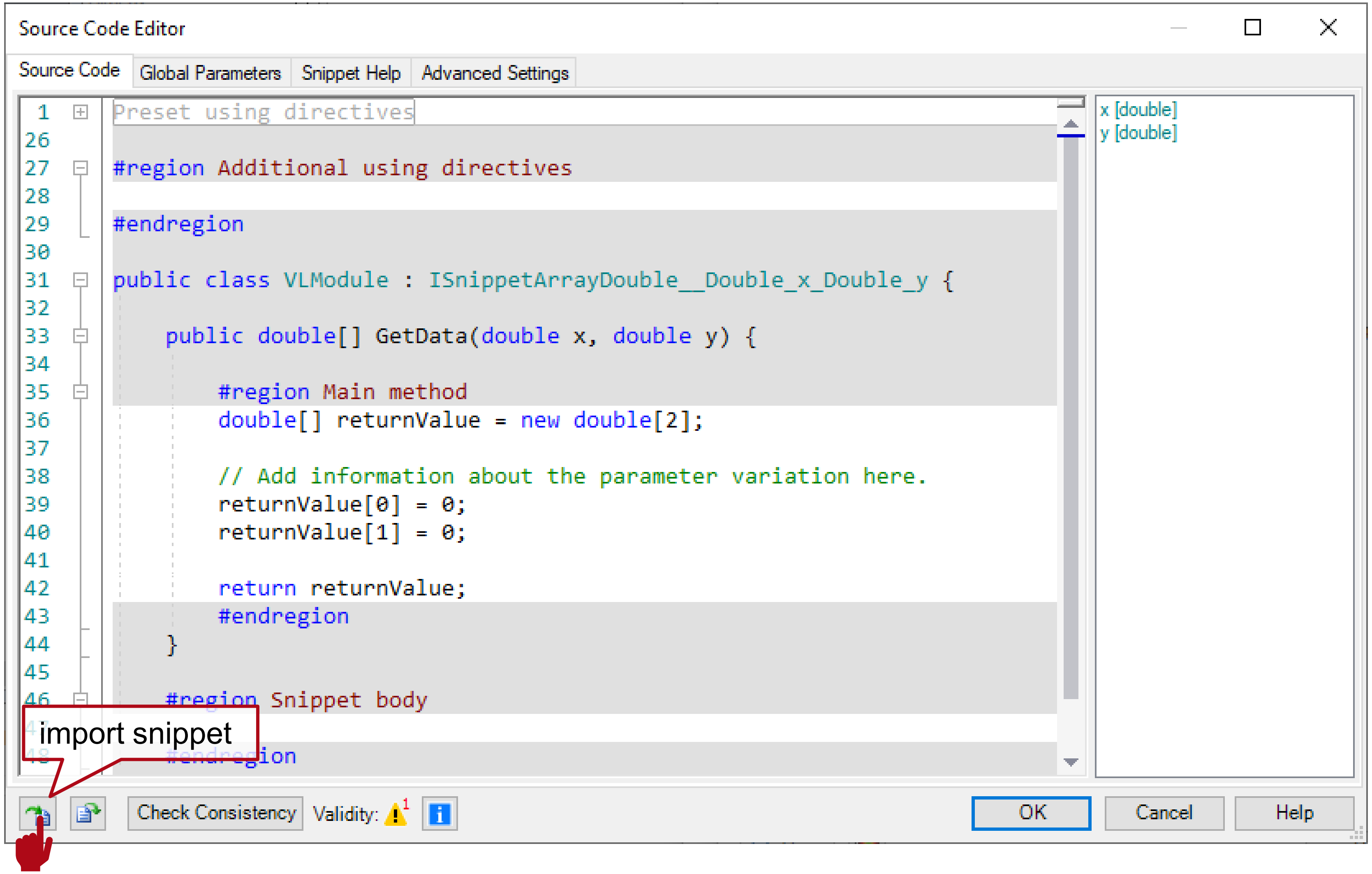


Modulation Based on Analytical Description



- 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



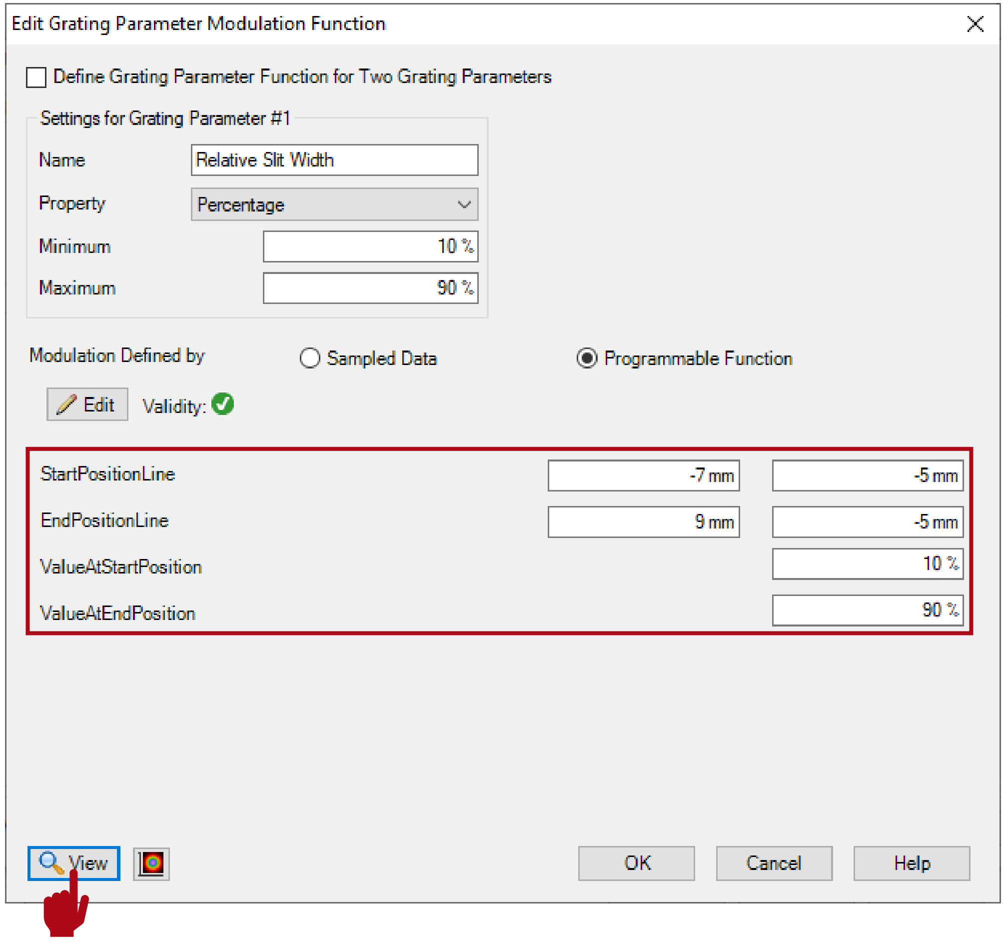
- In this example, a snippet for a linear modulation is provided alongside this document.
- Import the snippet by using the import button.
- In more general, a function has to be defined, that provides the desired grating parameter for the current position (x,y).

Modulation Based on Mathematical Description

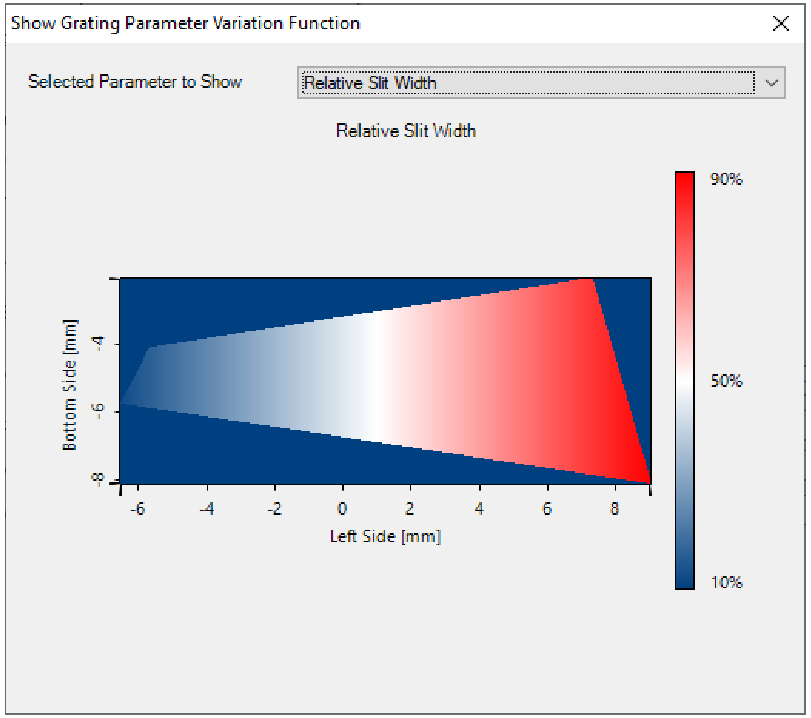
```
    public double[] GetData(double x, double y) {

        #region Main method

        //definition of the function
        VectorD P1P2 = EndPositionLine - StartPositionLine;
        double angle = (-1) * Math.Atan2(P1P2.Y, P1P2.X);

        //setting the orientation of the modulation
        Matrix2x2D rotationMatrix = Matrix2x2D.RotationMatrix(angle);
        VectorD positionInLineCS = rotationMatrix * new VectorD(x, y);
        double relPos = (positionInLineCS.X - StartPositionLine.X) / P1P2.Abs();

        //initialization the dimension of expected parameters
        double[] returnValue = new double[1];

        //setting the grating parameters
        if (relPos < 0) {
            returnValue[0] = 0;
        }
        else if (relPos > 1) {
            returnValue[0] = ValueAtEndPosition;
        }
        else {
            returnValue[0] = ValueAtStartPosition + (ValueAtEndPosition - ValueAtStartPosition) *
        }
        return returnValue;
        #endregion
    }

    #region Snippet body
```

- In this example, the resulting modulation is defined by:
  - starting position
  - end position
  - the grating parameter at the stating 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



- 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	• VirtualLab Fusion Advanced • VirtualLab Fusion Light Guide Toolbox Gold
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	- Footprint Analysis of Lightguides for AR/MR Applications - Construction of a Light Guide - Modeling of a “HoloLens 1”-Type Layout with Light Guide Component - Light Guide Layout Design Tool - k-Domain Layout Visualization - Simulation of Lightguide with 1D-1D Pupil Expander and Real Gratings