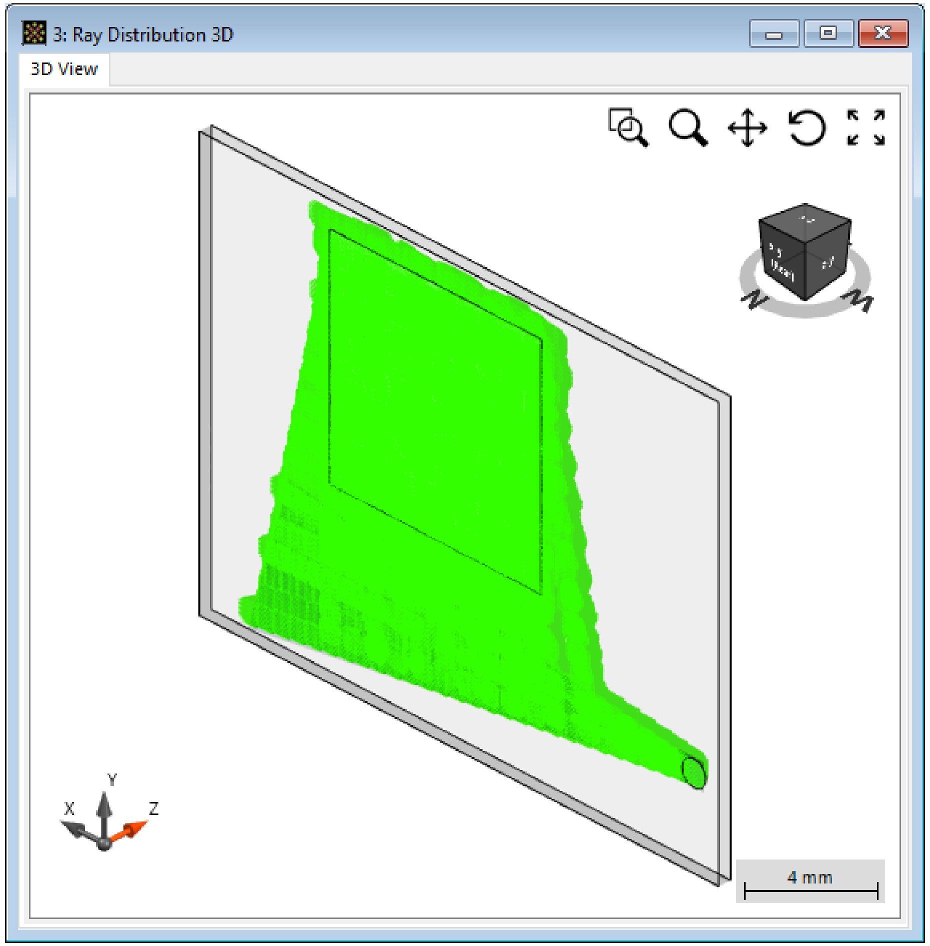
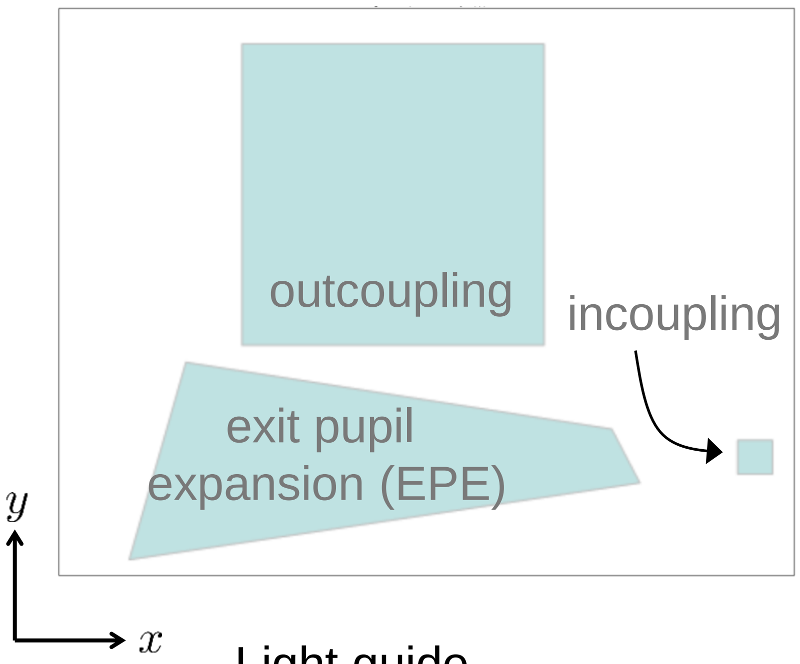
Modeling of a “HoloLens 1”-Type Layout with Light Guide Component

Abstract

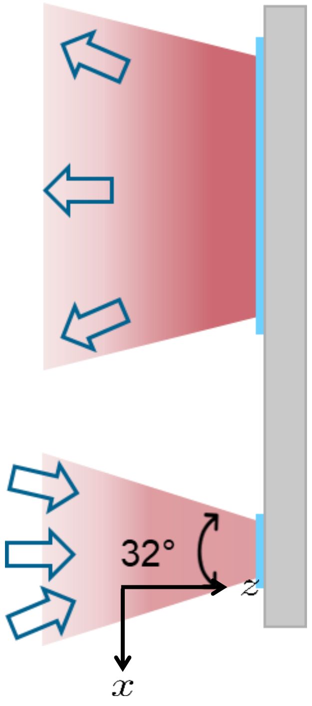


Most innovative augmented and mixed reality devices nowadays are based on light-guide or wave-guide configurations in combination with microstructures to couple light in and out. VirtualLab Fusion is capable of the detailed modeling of such devices by applying our unique physical optics approach, which includes all effects of interest (e.g. coherence, polarization and diffraction). We demonstrate this capability by modeling a device with a “HoloLens 1”-type (1D-1D pupil expander) layout with a Light Guide component capable of guiding light with a 32°×18° field of view.

Modeling Task

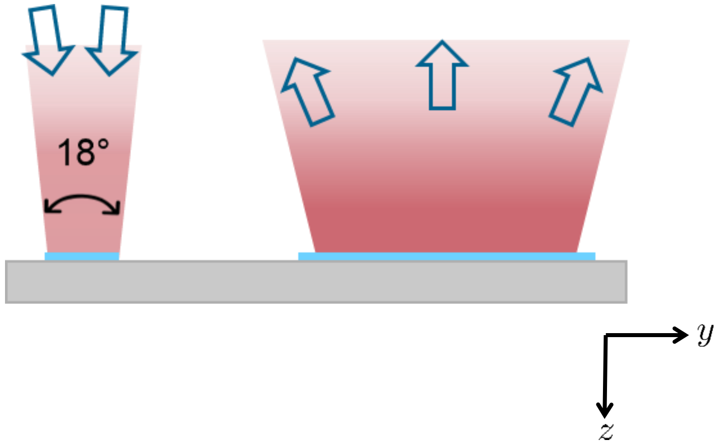


Light guide
consisting of diffractive
- incoupling region
- eye pupil expansion region
- outcoupling region



source: Scanning source
- FoV 32°×18° (cartesian angles)
- wavelength 532 nm

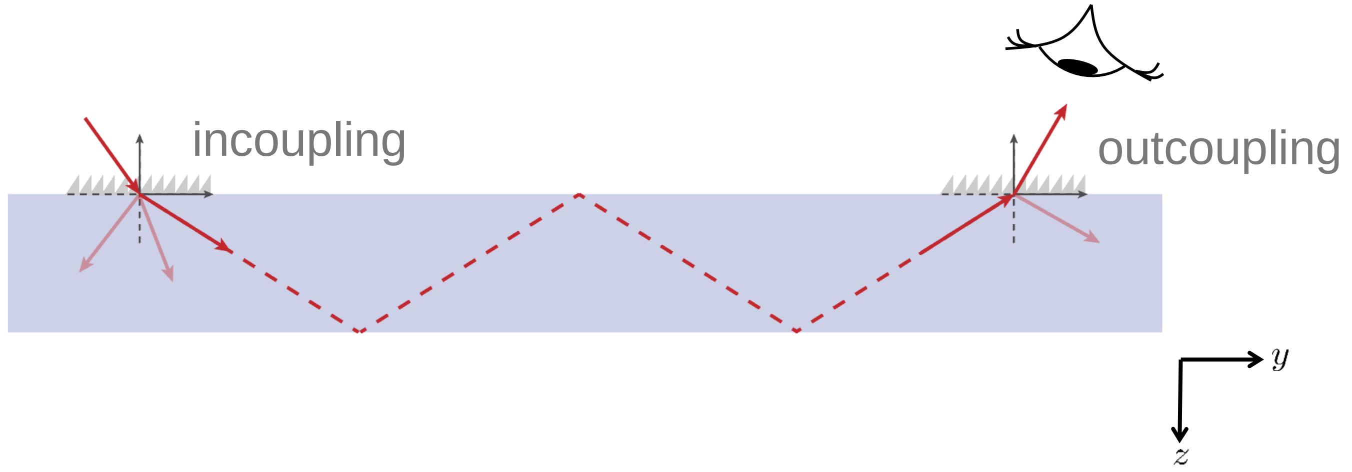
How to model a light guide that can guide a certain field of view (FoV)?

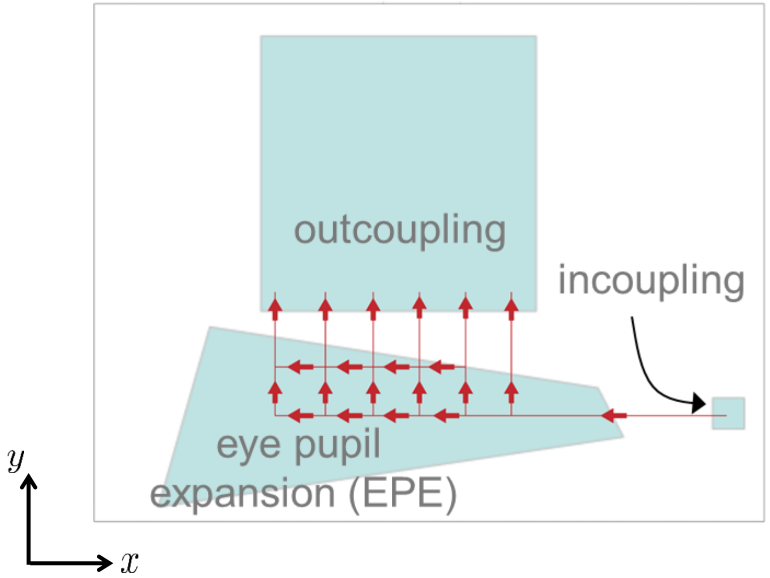


Parameters from default layout by Layout Design Tool, reference patent: WO2011107831A1.

Working Principle of Light Guide

In order to “trap” the light inside the light guide slab, total internal reflection (TIR) is used. For this purpose, gratings are applied to couple the incident light in and out and to ensure that conditions for TIR are fulfilled.



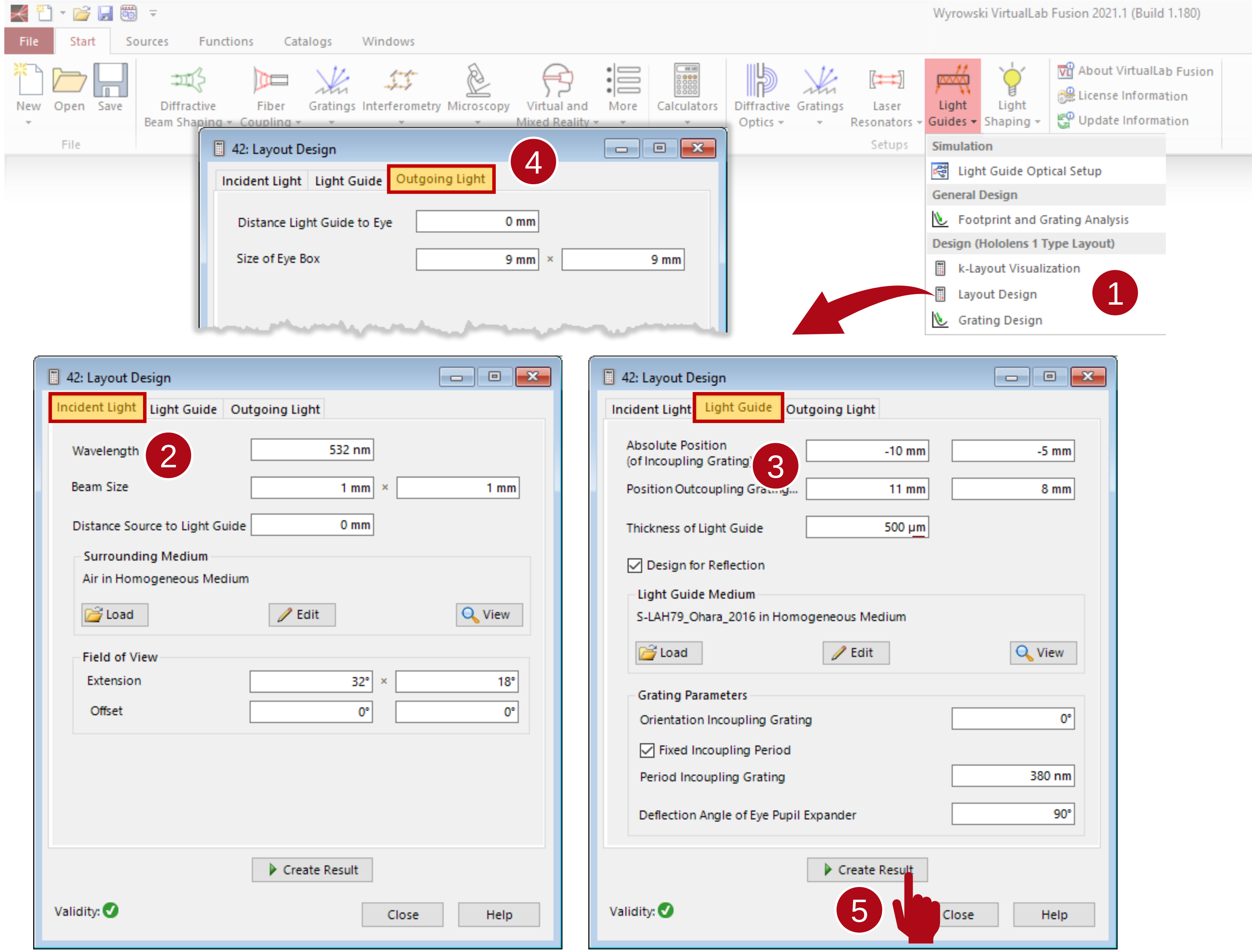


The function of the exit pupil expansion grating is to replicate the incoupled pupil in one direction (here: x direction) in order to expand the exit pupil, or in other words generate the eye box.

In this type of setup, the outcoupling grating is not only responsible for outcoupling the light toward the observer, but also for the pupil expansion in the second direction (here: y-direction).

This separated pupil expansion is characteristic of a “HoloLens 1”-type layout.

Layout Design Tool



- In order to set up the lateral layout of such a light guide the *Layout Design* tool of VirtualLab can be used (only available with the *Light Guide Toolbox Gold*).
- The parameters of this example correspond to the default configuration.
- This tool provides an optical setup with a light guide according to the given specifications of incident light and eye box. In particular, the lateral position and extension of the grating regions as well as the grating periods are determined automatically.
- After defining the parameters, click the button *Create Result*, and the optical setup and the corresponding k-layout diagram will be generated.

k-layout Visualization

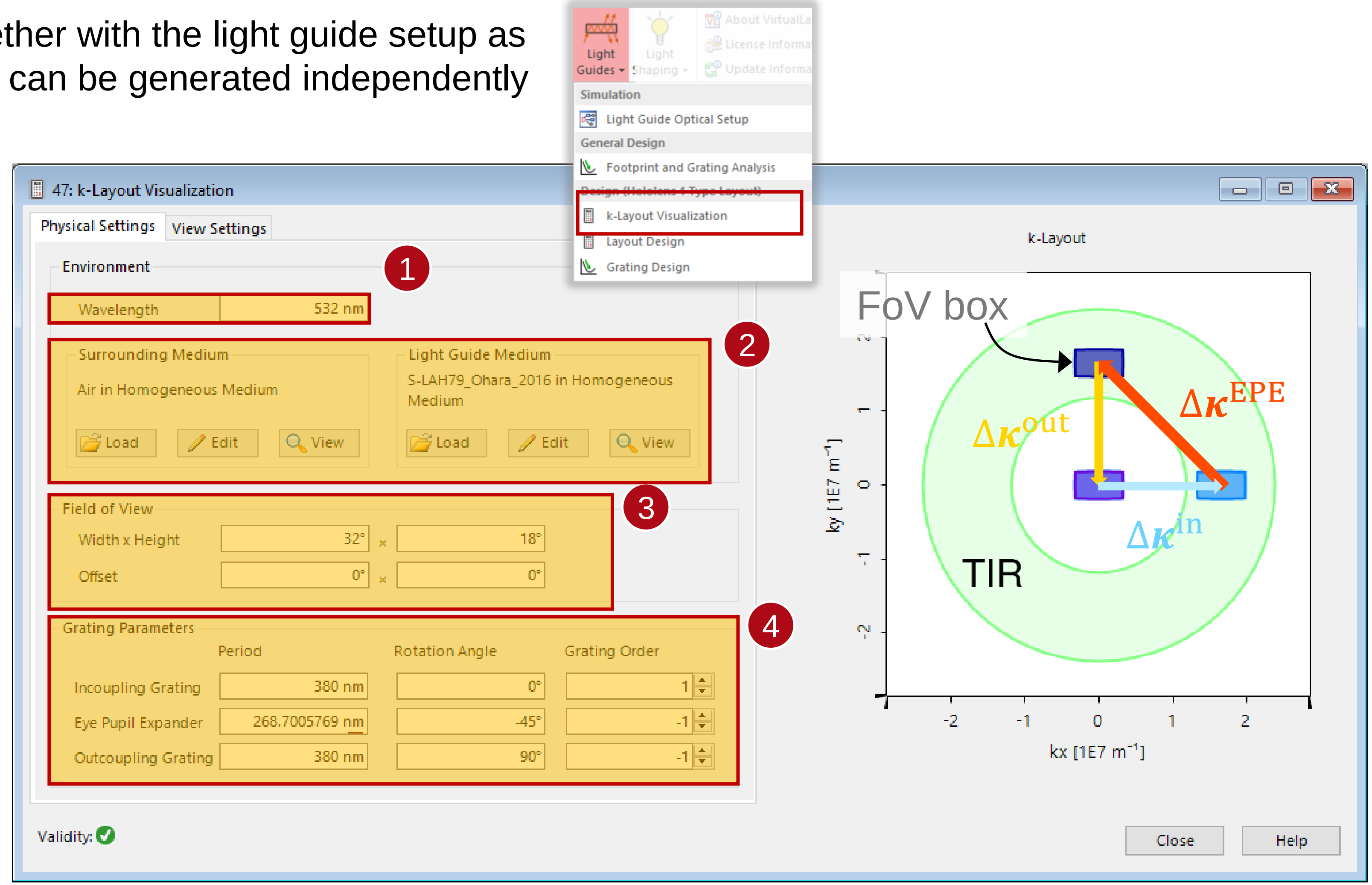
The k-layout diagram is either created together with the light guide setup as a by-product of the *Layout Design* tool or it can be generated independently by the corresponding entry in the menu.

The following parameters can be configured:

- wavelength
- surrounding and slab material
- angular range of FoV
- grating periods & orientations

The resulting diagram contains the following information (in k domain):

- Circles that depict the propagation condition (available directions and k values) inside the materials.
- Extension, shape and position of FoV for impinging and diffracted light after certain grating regions.
- Illustration of shifts of the FoV introduced by the gratings.

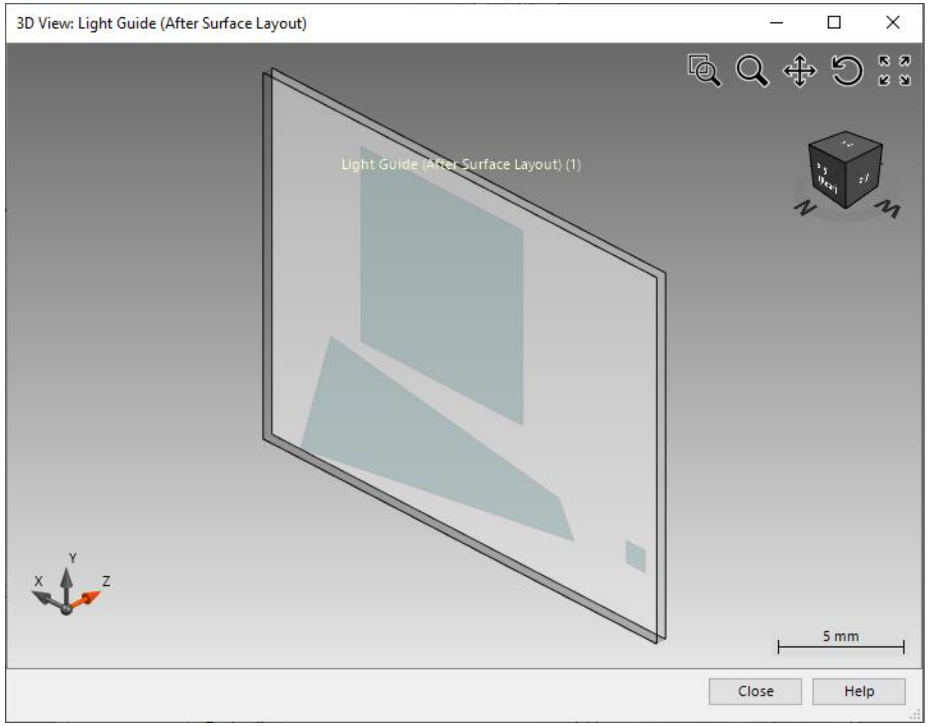


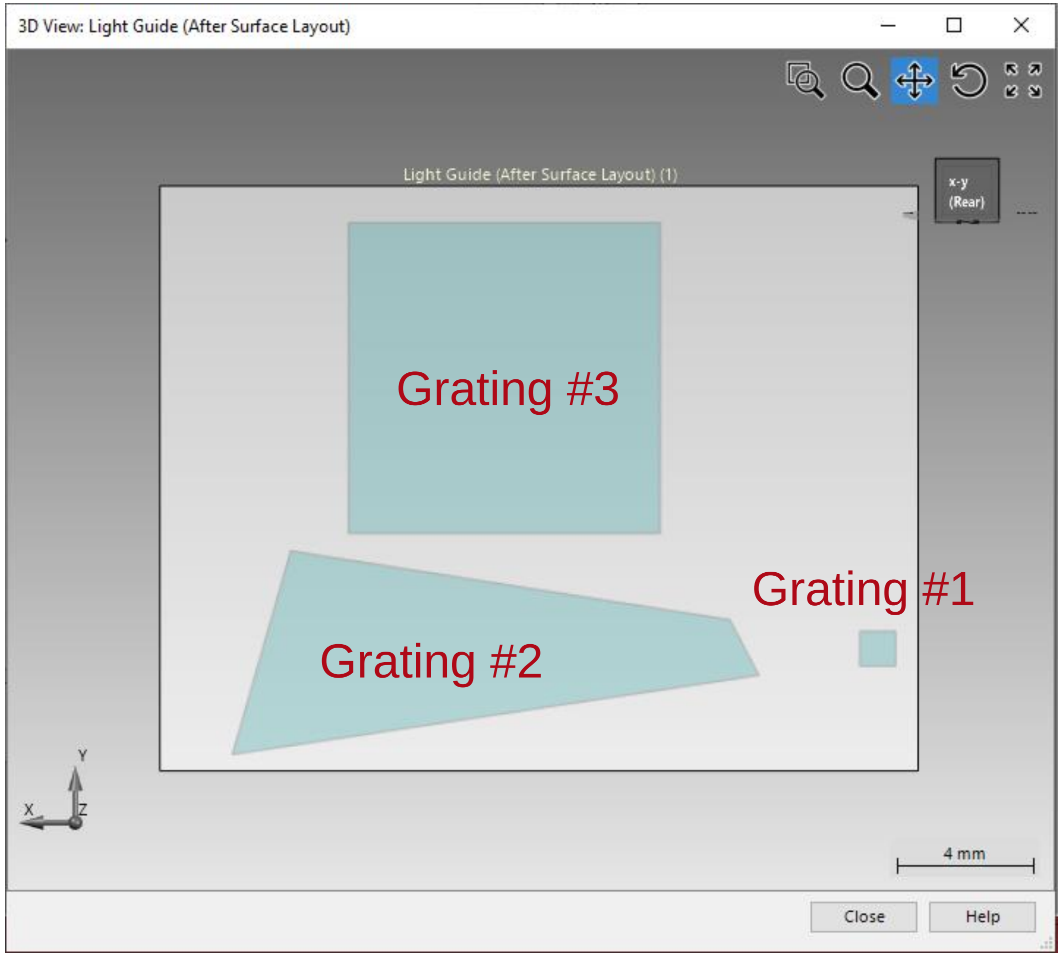
The adjustment of any parameter will change the figure accordingly.

Light Guide Surface Layout

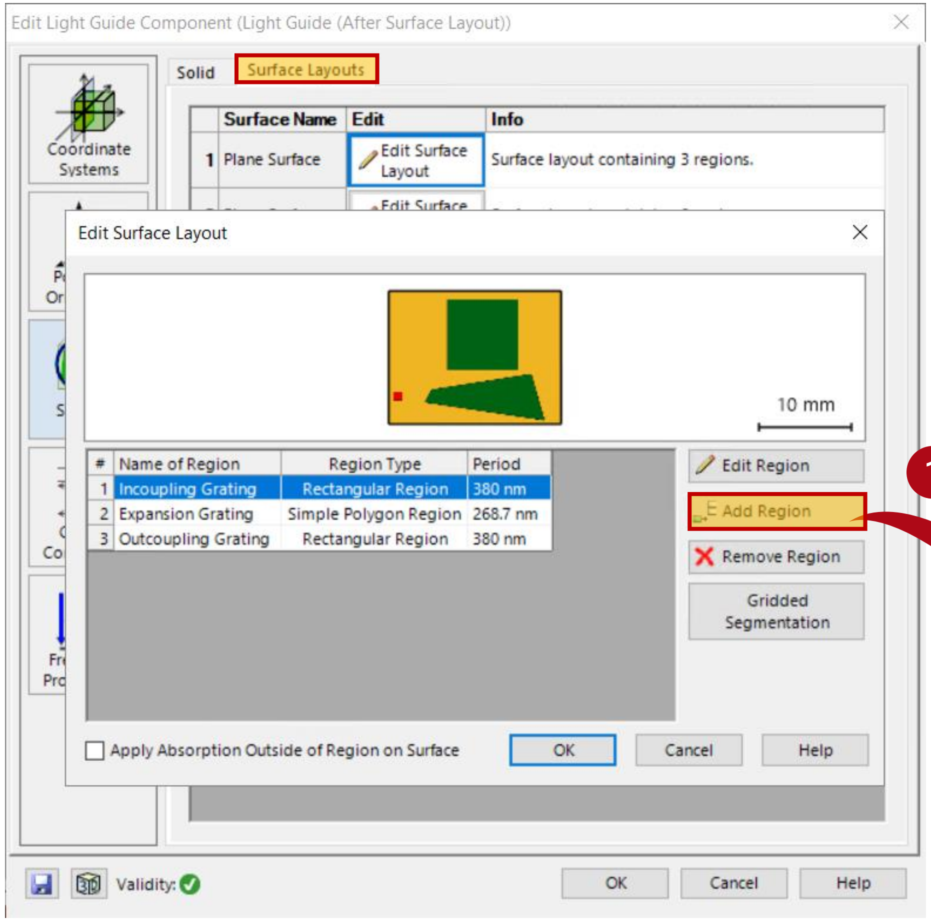
Geometric layout exhibits 3 gratings on the first plane surface:

- Grating #1: incoupling grating
- Grating #2: expansion grating
- Grating #3: outcoupling grating



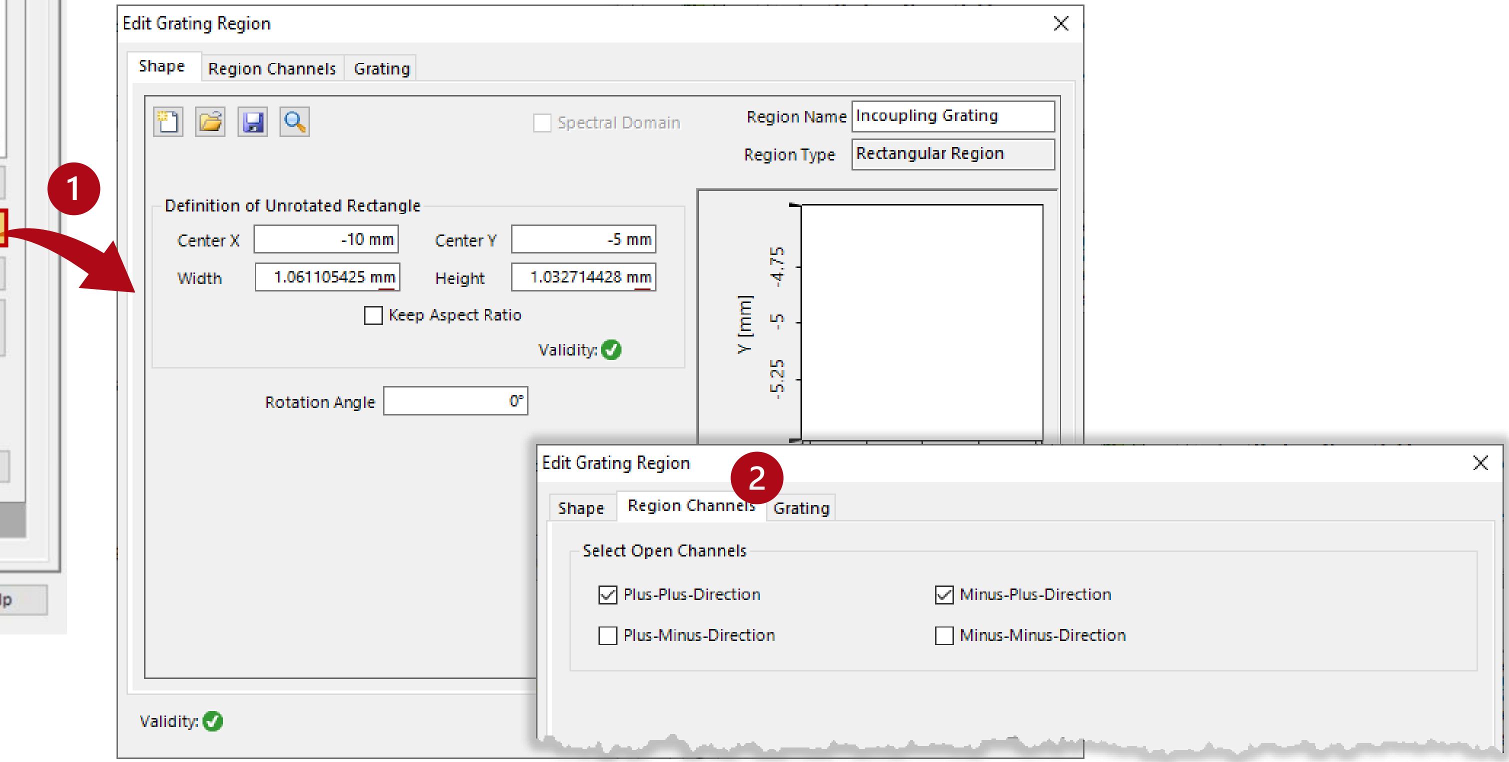


Grating #1: Incoupling Grating

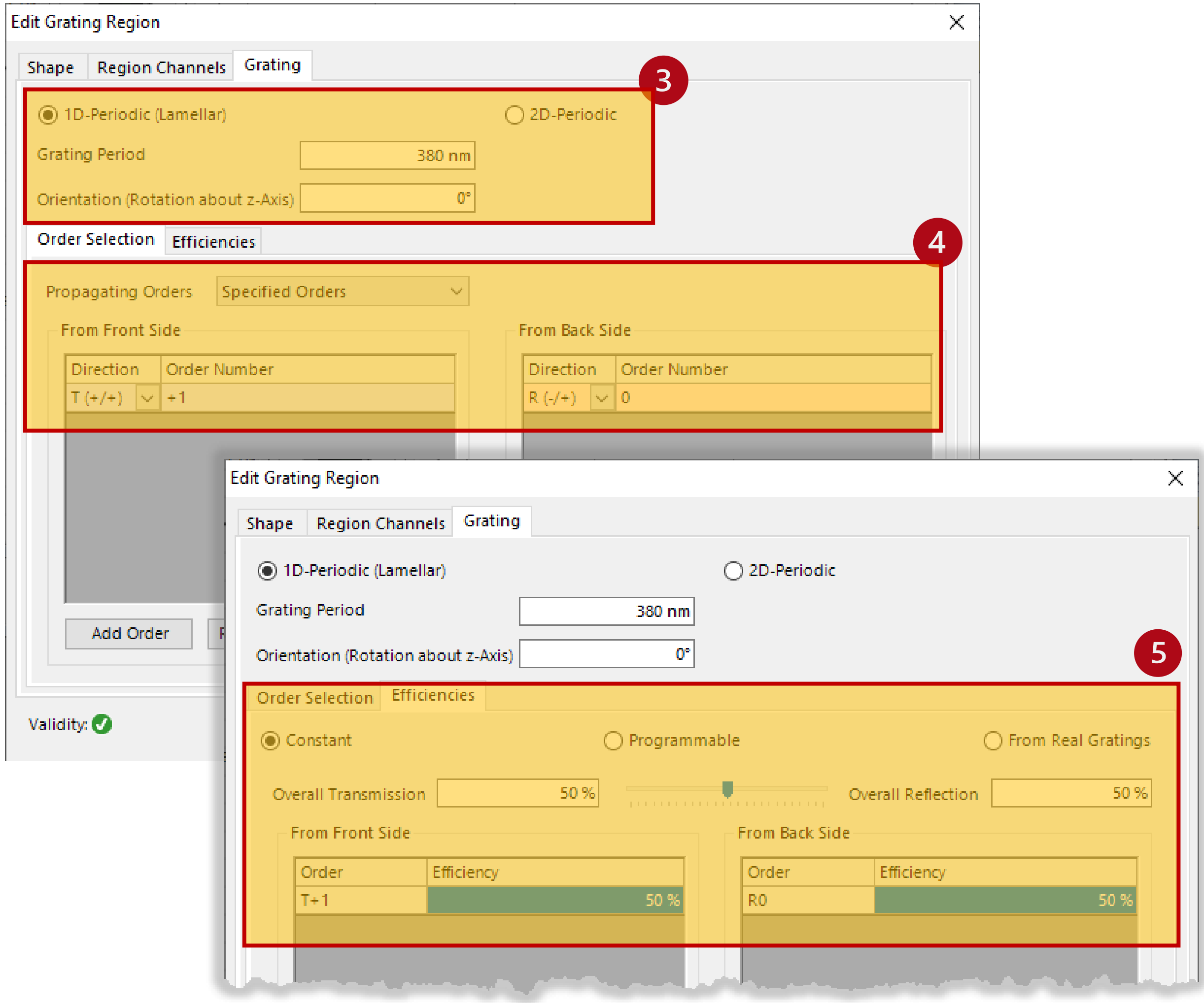


The incoupling grating is defined in a rectangular region. The general workflow to define grating regions is:

1. determine the shape and size of the region
2. select region channels

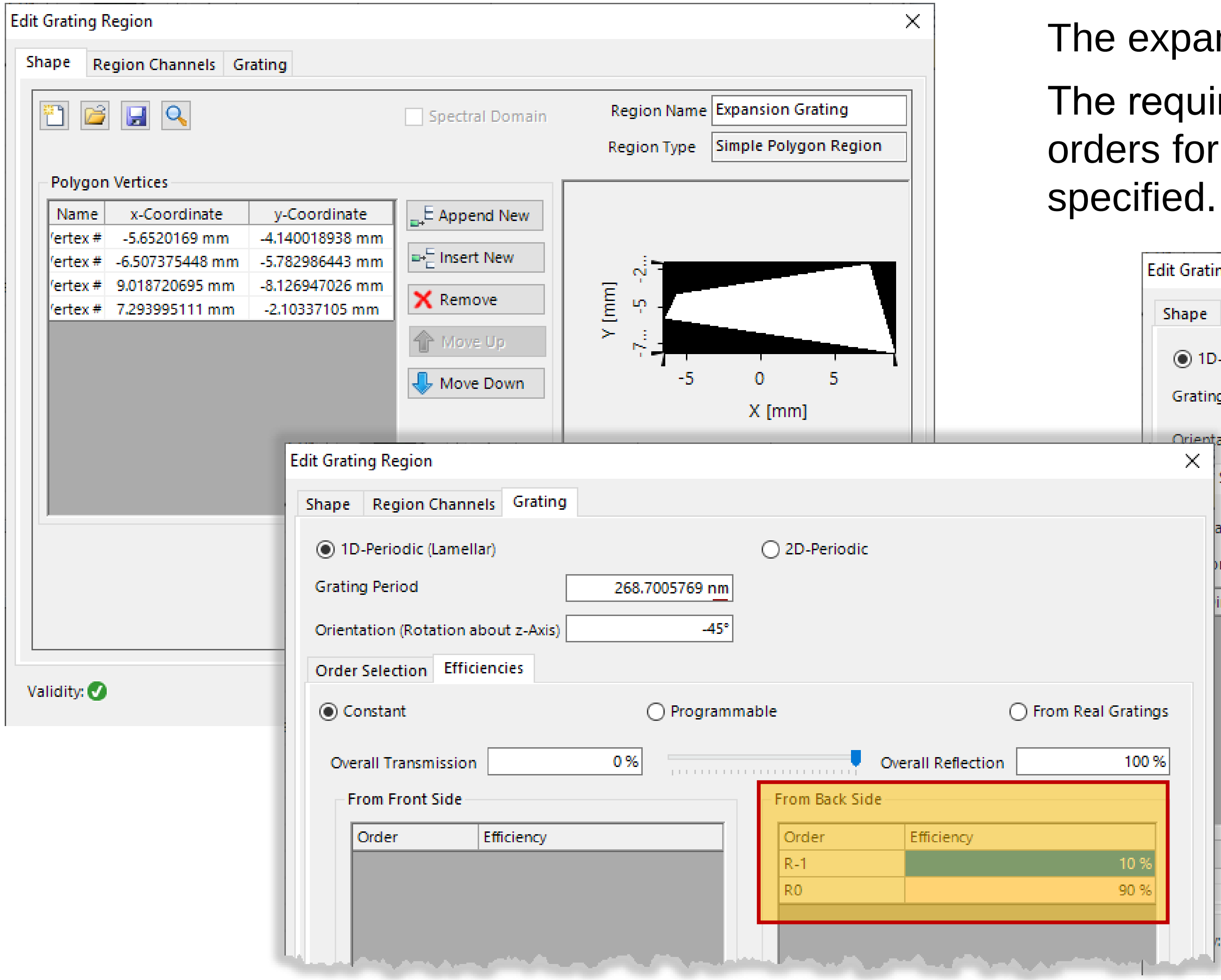


Grating #1: Incoupling Grating



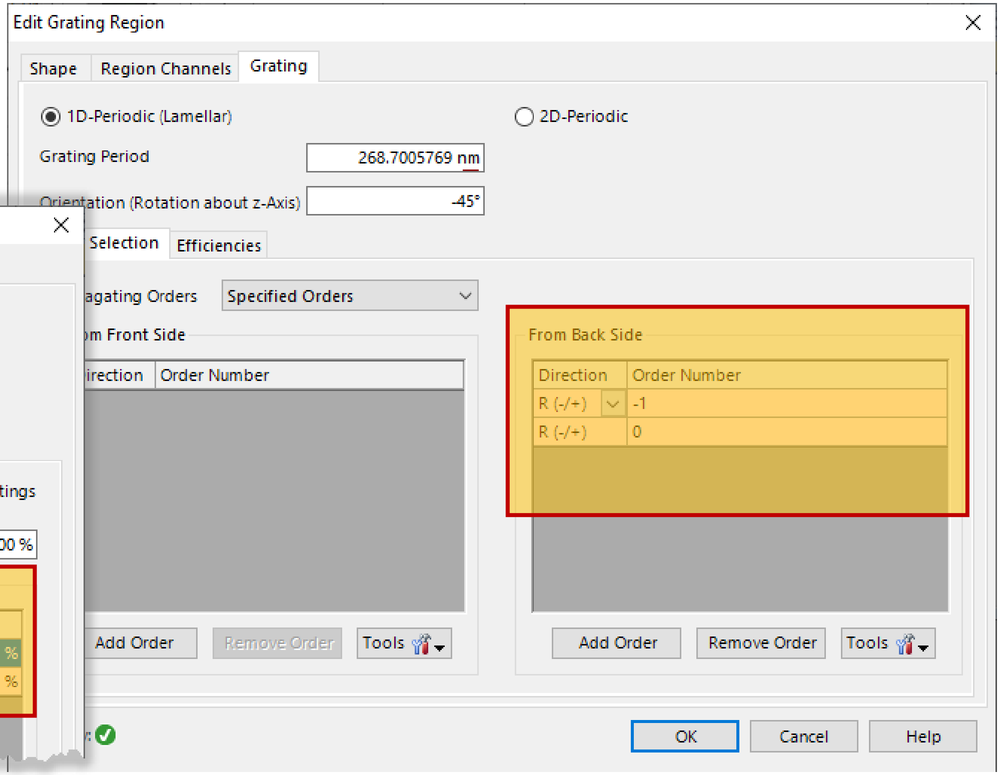
3. define the period and orientation of the grating;
4. specify the propagating orders (from front side and back side);
5. specify the transmission and reflection efficiencies;

Grating #2: Expansion Grating in Simple Polygon Region

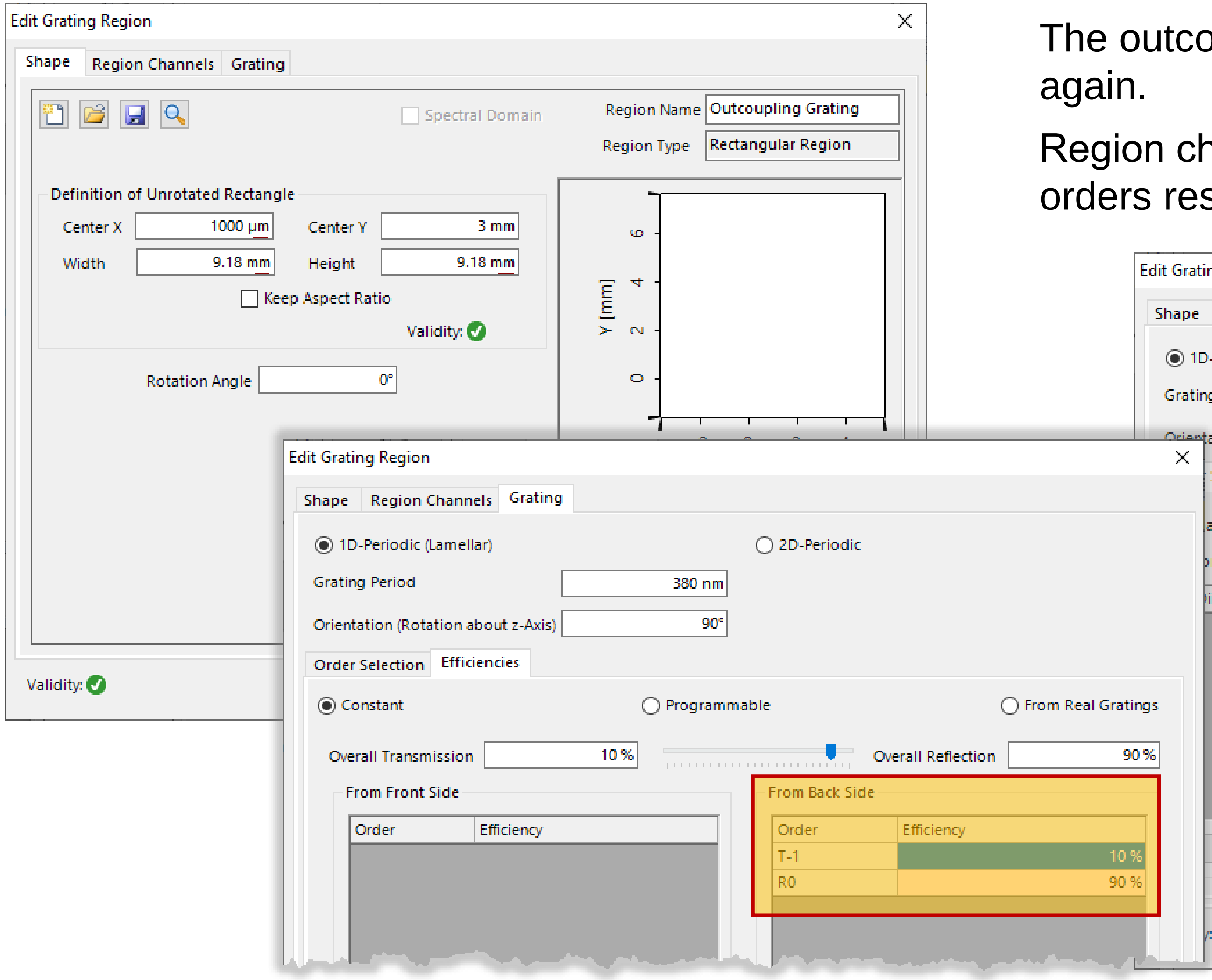


The expansion grating is defined in a polygon-shaped region.

The required region channel is –/+, therefore only reflected orders for light impinging on the back side of the grating are specified.

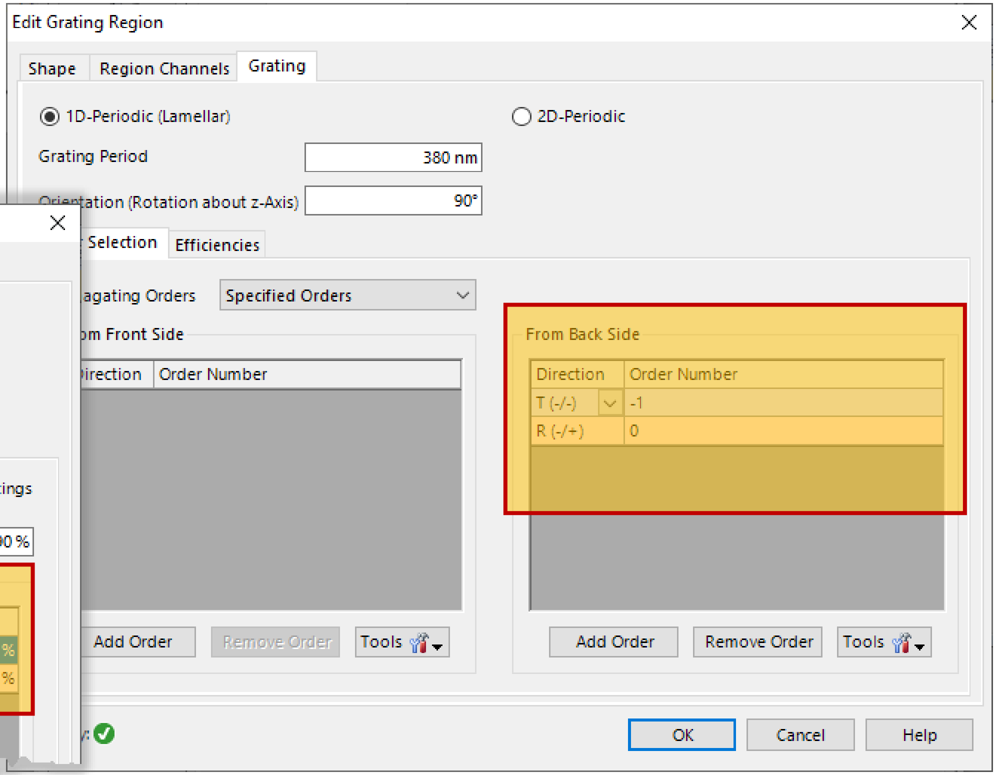


Grating #3: Outcoupling Grating



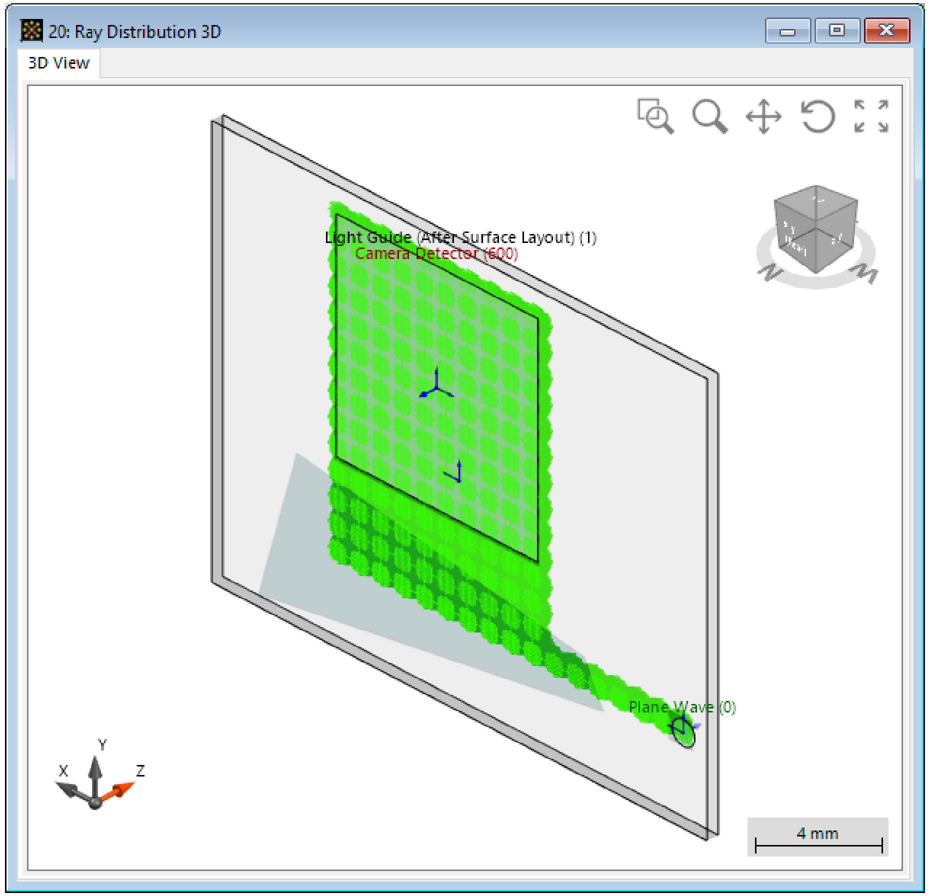
The outcoupling grating is defined in a rectangular region, again.

Region channels –/+ and –/– are required to activate the orders responsible for expansion and outcoupling.

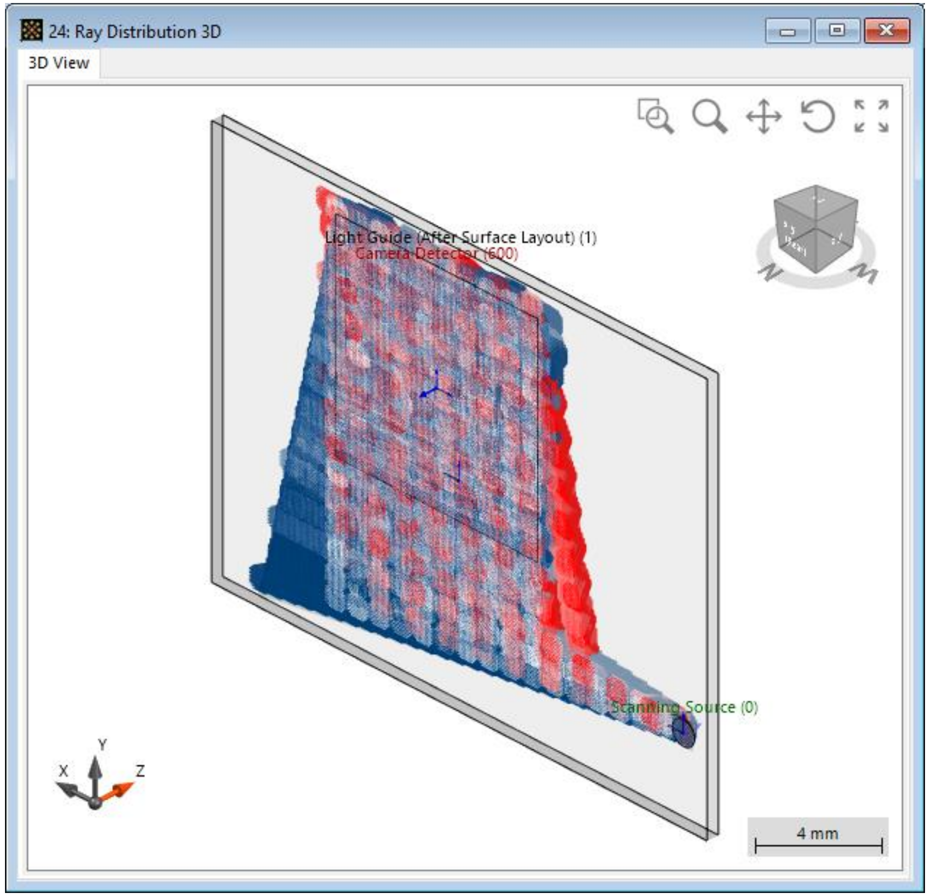


Result: Ray Tracing in 3D System

Rays in System view
with central angle of FoV:



Rays in System view with 32° × 18° scanning source input (9 modes, differently colored):

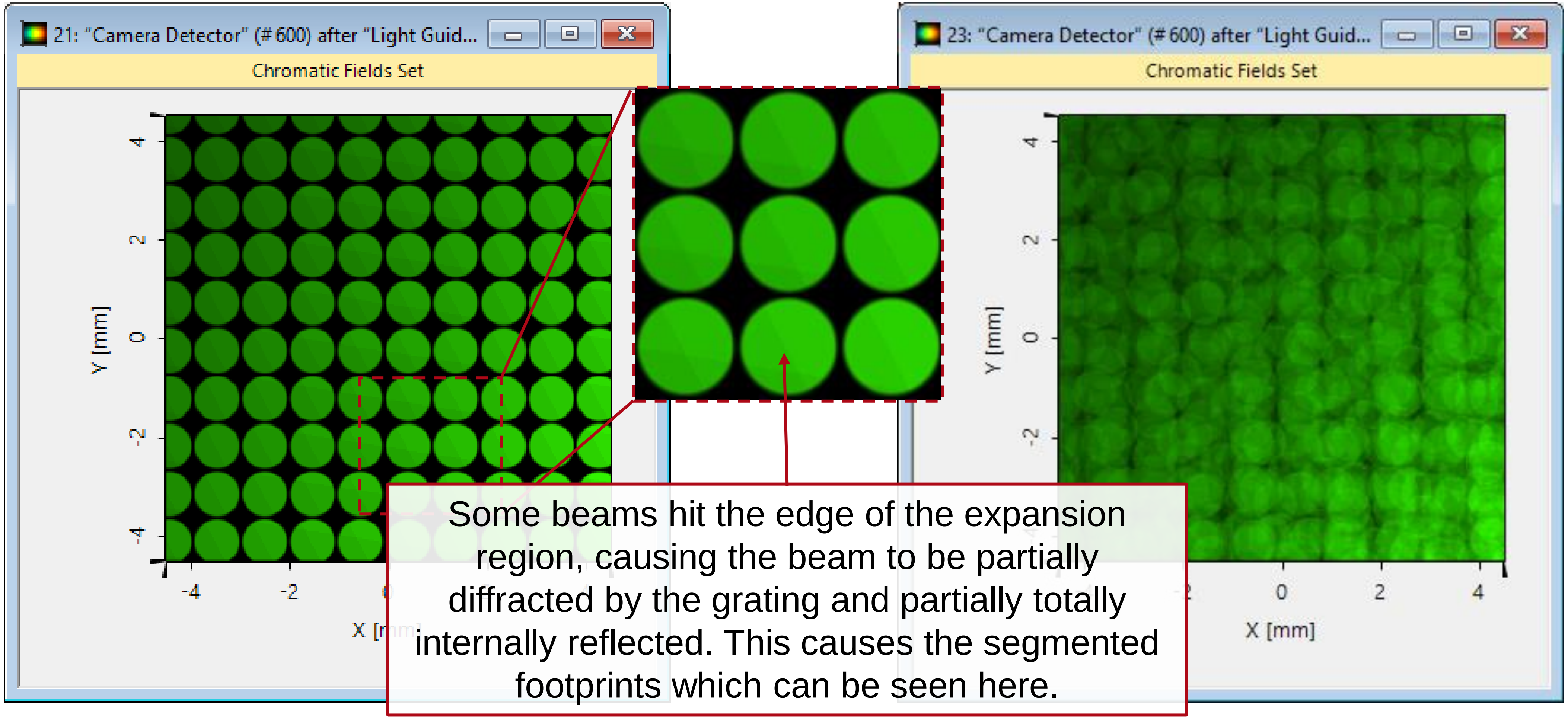


Note: Only rays that hit the detector are displayed.

Result: Field Tracing (Real Color View)

Energy density distribution at eyebox for central FoV mode:

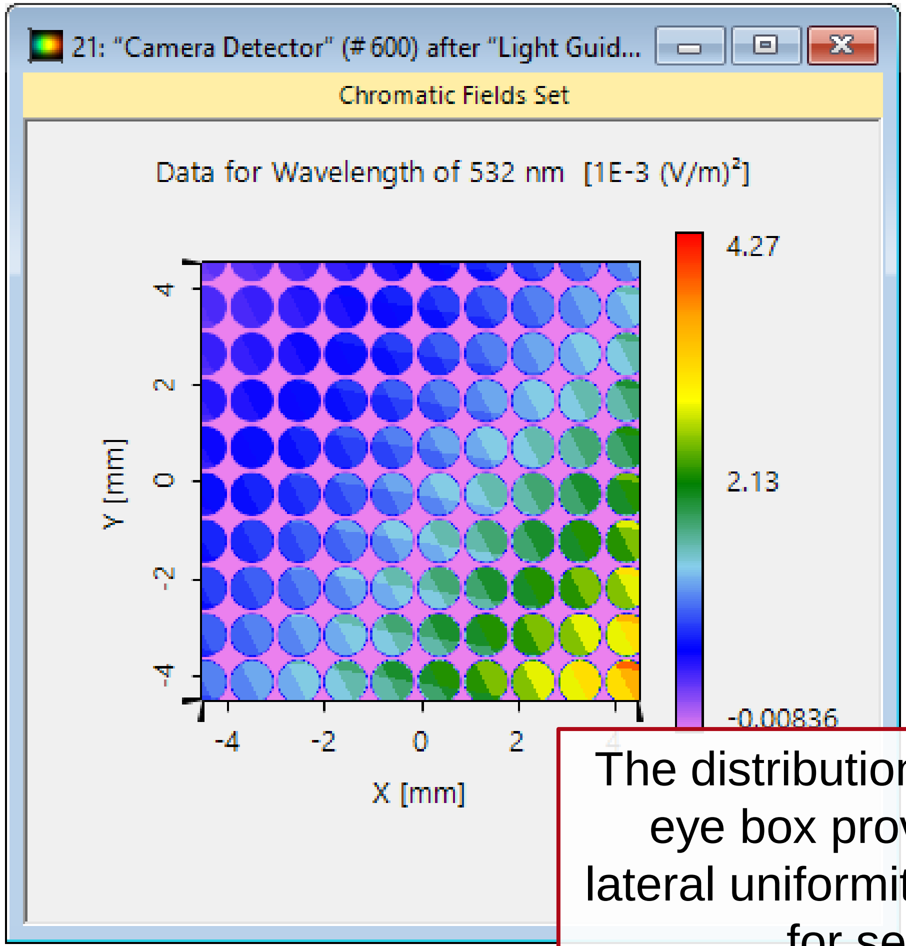
Energy density distribution at eyebox for FoV (32° × 18°) using scanning source (9 modes):



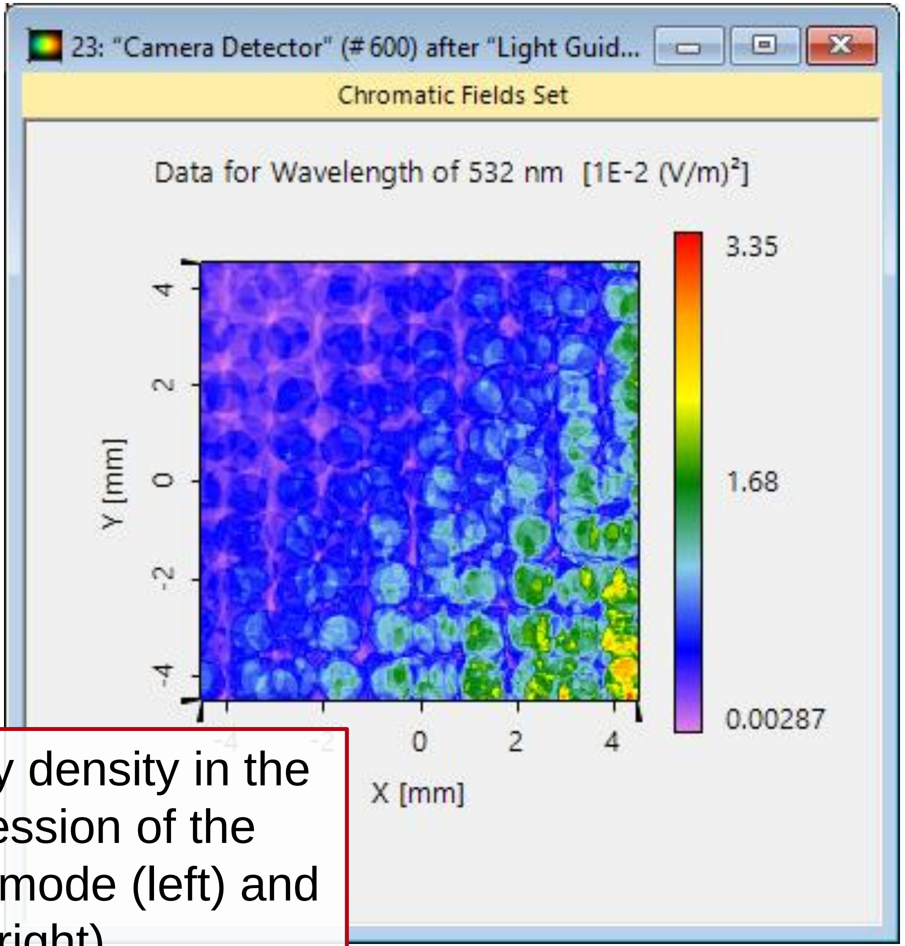
Some beams hit the edge of the expansion region, causing the beam to be partially diffracted by the grating and partially totally internally reflected. This causes the segmented footprints which can be seen here.

Result: Field Tracing (False Color View)

Energy density distribution at eyebox for central FoV mode:

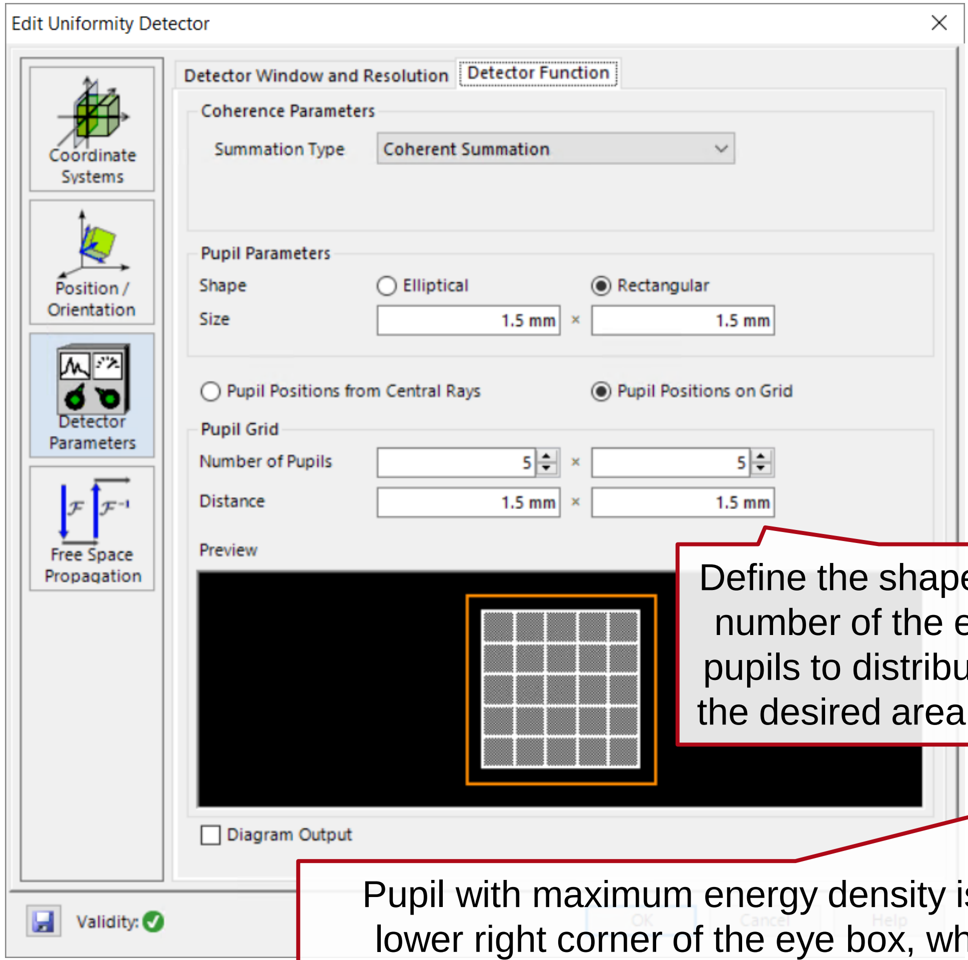


Energy density distribution at eyebox for FoV (32° × 18°) using scanning source (9 modes):



The distribution of the energy density in the eye box provides an impression of the lateral uniformity for a single mode (left) and for several modes (right).

Lateral Uniformity Evaluation



Define the shape, size and number of the evaluation pupils to distribute them in the desired area (eye box).

Pupil with maximum energy density is at the lower right corner of the eye box, while the minimum is at the top left corner.

In order to evaluate the lateral uniformity in the eye box, the *Uniformity Detector* is provided, which can be found in the element tree (under *Detectors > Merit Functions > Uniformity Detector).* This detector is capable of investigating the lateral energy density distribution in a specific area (e.g., eye box) at defined positions.

Uniformity detector result at eye box for center FoV mode:

Sub - Detector	Result
Value for Pupil around (-3 mm; -3 mm)	0.000779183172 (V/m)²
Value for Pupil around (-1.5 mm; -3 mm)	0.0007544503184 (V/m)²
Value for Pupil around (0 mm; -3 mm)	0.001129097948 (V/m)²
Value for Pupil around (1.5 mm; -3 mm)	0.001179932017 (V/m)²
Value for Pupil around (3 mm; -3 mm)	0.001573417476 (V/m)²
Value for Pupil around (-3 mm; -1.5 mm)	0.0007193513751 (V/m)²
…	
Value for Pupil around (3 mm; 1.5 mm)	0.0009634105481 (V/m)²
Value for Pupil around (-3 mm; 3 mm)	0.0004506572263 (V/m)²
Value for Pupil around (-1.5 mm; 3 mm)	0.0004524512959 (V/m)²
Value for Pupil around (0 mm; 3 mm)	0.0006608664454 (V/m)²
Value for Pupil around (1.5 mm; 3 mm)	0.0007043912157 (V/m)²
Value for Pupil around (3 mm; 3 mm)	0.0009239519941 (V/m)²
Minimum	0.0004506572263 (V/m)²
Maximum	0.001573417476 (V/m)²
Uniformity Error	55.47029704 %
Arithmetic Mean	0.0008485993309 (V/m)²
Standard Deviation	[illegible]

maximum

minimum

Uniformity detector result at eye box for 9 modes :

Sub - Detector	Result
Value for Pupil around (-3 mm; -3 mm)	0.006252847886 (V/m)²
Value for Pupil around (-1.5 mm; -3 mm)	0.007141749301 (V/m)²
Value for Pupil around (0 mm; -3 mm)	0.009177798294 (V/m)²
Value for Pupil around (1.5 mm; -3 mm)	0.0108014801 (V/m)²
Value for Pupil around (3 mm; -3 mm)	0.0135333255 (V/m)²
Value for Pupil around (-3 mm; -1.5 mm)	0.005689209893 (V/m)²
…	
Value for Pupil around (3 mm; 1.5 mm)	0.008326057797 (V/m)²
Value for Pupil around (-3 mm; 3 mm)	0.003291909373 (V/m)²
Value for Pupil around (-1.5 mm; 3 mm)	0.003681477125 (V/m)²
Value for Pupil around (0 mm; 3 mm)	0.004817293561 (V/m)²
Value for Pupil around (1.5 mm; 3 mm)	0.00570376368 (V/m)²
Value for Pupil around (3 mm; 3 mm)	0.007040062448 (V/m)²
Minimum	0.003291909373 (V/m)²
Maximum	0.0135333255 (V/m)²
Uniformity Error	60.86937986 %
Arithmetic Mean	0.007110109468 (V/m)²
Standard Deviation	0.01293611313 (V/m)²

resulting uniformity error

Document Information

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category	Application Use Case
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