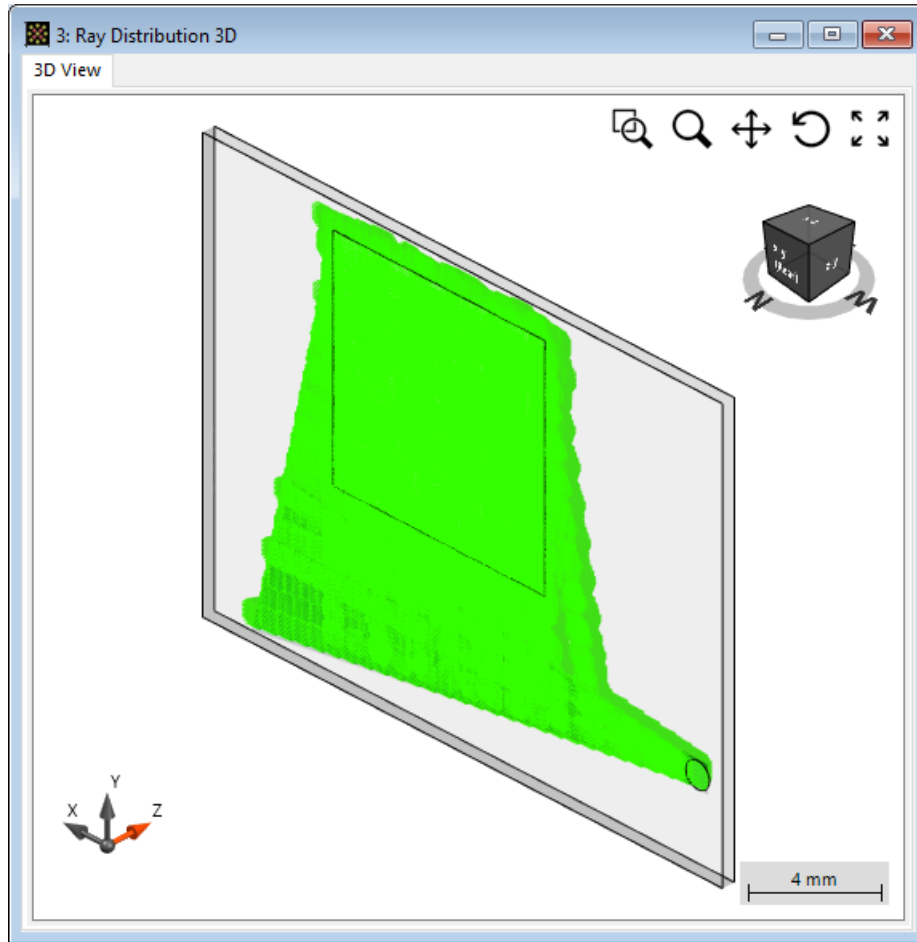


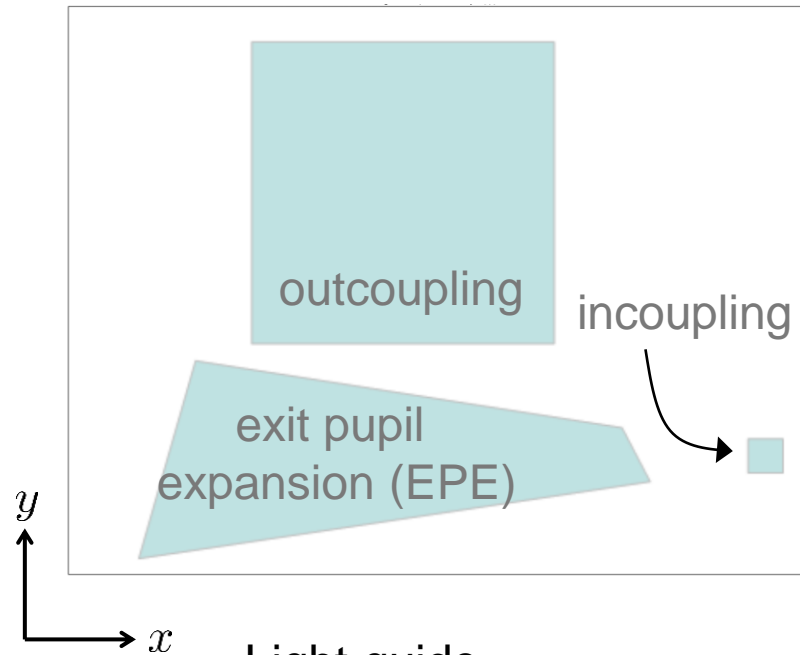
Modeling of a “HoloLens 1”-Type Layout with Light Guide Component

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 of a simple “HoloLens 1”-type (1D-1D pupil expander) layout with a Light Guide component capable of guiding light with a $32^\circ \times 18^\circ$ field of view.

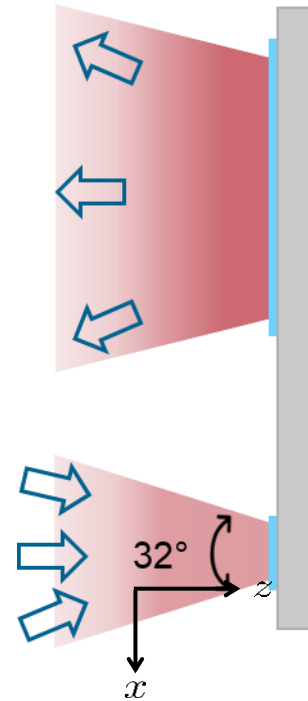
Modeling Task



Light guide

consisting of diffractive

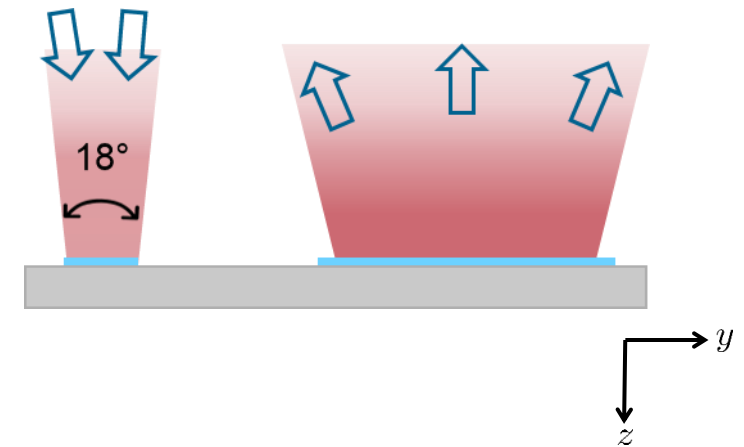
- incoupling region
- eye pupil expansion region
- outcoupling region



source: Scanning source

- FoV $32^\circ \times 18^\circ$ (cartesian angles)
- wavelength 532nm

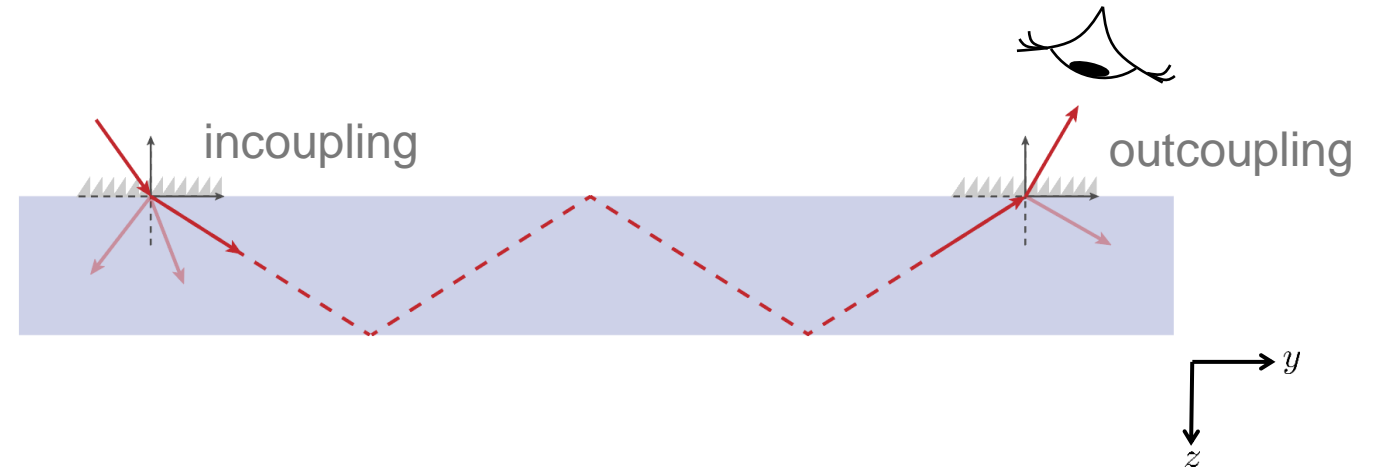
How to model a light guide that can guide a certain field of view (FoV)?



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

Working Principle of Light Guide

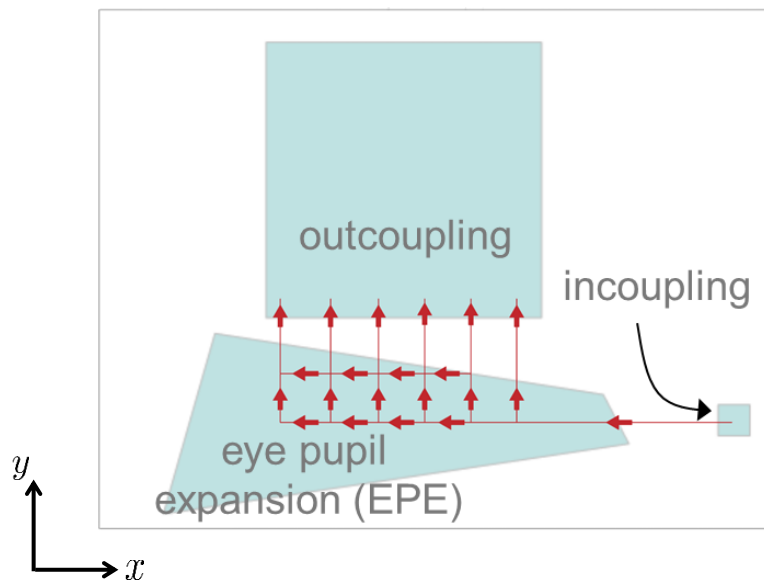
In order to “trap” the light inside the light guide slab, total internal reflection (TIR) is used. For this purpose, gratings are applied to couple the incident light in and out and to ensure that conditions for TIR are fulfilled.



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

The screenshot shows the 'Layout Design Tool' interface within the 'Wyrowski VirtualLab Fusion 2021.1 (Build 1.180)' application. The top menu bar includes 'File', 'Start', 'Sources', 'Functions', 'Catalogs', and 'Windows'. The 'Light Guides' menu is open, showing options like 'Simulation', 'Light Guide Optical Setup', 'General Design', 'Footprint and Grating Analysis', 'Design (Hololens 1 Type Layout)', 'K-Layout Visualization', 'Layout Design', and 'Grating Design'. A red arrow points from the 'Layout Design' menu item to the 'Layout Design' panel. The 'Layout Design' panel has three tabs: 'Incident Light', 'Light Guide', and 'Outgoing Light'. The 'Outgoing Light' tab is selected and highlighted with a red box and a red circle containing the number '4'. The 'Incident Light' tab is highlighted with a red box and a red circle containing the number '2'. The 'Light Guide' tab is highlighted with a red box and a red circle containing the number '3'. A red hand icon points to the 'Create Result' button in the 'Light Guide' panel, which is highlighted with a red box and a red circle containing the number '5'. The 'Incident Light' panel shows parameters: Wavelength (532 nm), Beam Size (1 mm x 1 mm), Distance Source to Light Guide (0 mm), Surrounding Medium (Air in Homogeneous Medium), and Field of View (Extension: 32° x 18°, Offset: 0° x 0°). The 'Light Guide' panel shows parameters: Absolute Position (of Incoupling Grating) (-10 mm, -5 mm), Position Outcoupling Grating (11 mm, 8 mm), Thickness of Light Guide (500 μm), Design for Reflection (checked), Light Guide Medium (S-LAH79_Ohara_2016 in Homogeneous Medium), Grating Parameters (Orientation Incoupling Grating: 0°, Fixed Incoupling Period: checked, Period Incoupling Grating: 380 nm), and Deflection Angle of Eye Pupil Expander (90°). The 'Outgoing Light' panel shows parameters: Distance Light Guide to Eye (0 mm) and Size of Eye Box (9 mm x 9 mm). A 'Create Result' button is visible at the bottom of each panel. The 'Validity' indicator is green with a checkmark.

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

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 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.

47: k-Layout Visualization

Physical Settings View Settings

Environment

Wavelength

Surrounding Medium: Air in Homogeneous Medium

Light Guide Medium: S-LAH79_Ohara_2016 in Homogeneous Medium

Field of View

Width x Height: x

Offset: x

Grating Parameters

	Period	Rotation Angle	Grating Order
Incoupling Grating	<input type="text" value="380 nm"/>	<input type="text" value="0°"/>	<input type="text" value="1"/>
Eye Pupil Expander	<input type="text" value="268.7005769 nm"/>	<input type="text" value="-45°"/>	<input type="text" value="-1"/>
Outcoupling Grating	<input type="text" value="380 nm"/>	<input type="text" value="90°"/>	<input type="text" value="-1"/>

Validity:

k-Layout

FoV box

TIR

$\Delta\kappa^{\text{out}}$

$\Delta\kappa^{\text{EPE}}$

$\Delta\kappa^{\text{in}}$

ky [1E7 m⁻¹]

kx [1E7 m⁻¹]

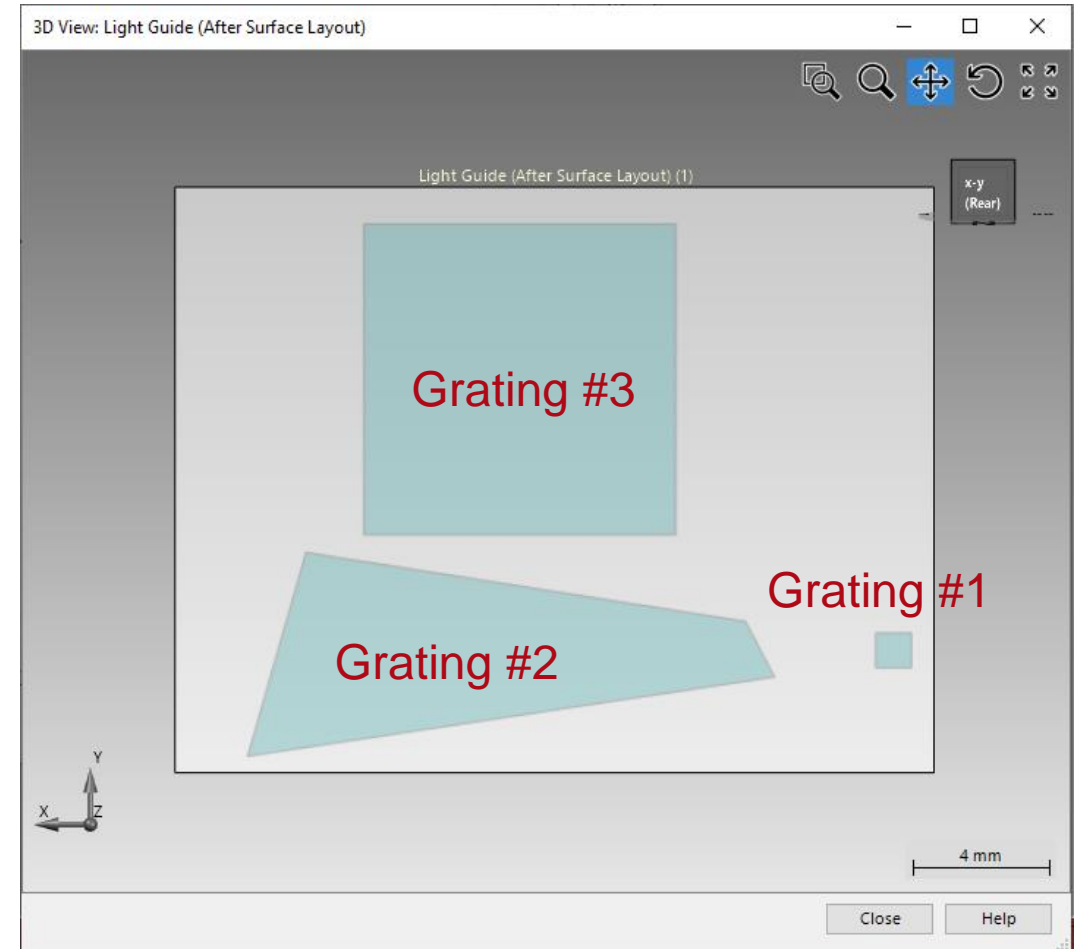
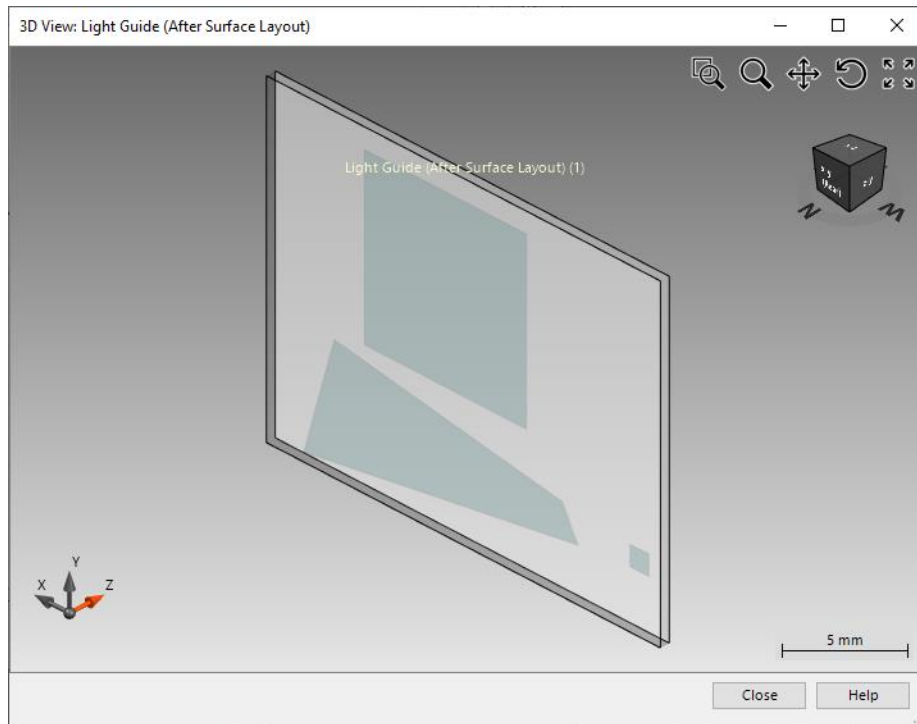
Close Help

The adjustment of any parameter will change the figure accordingly.

Light Guide Surface Layout

Geometric layout exhibits 3 gratings on the first plane surface:

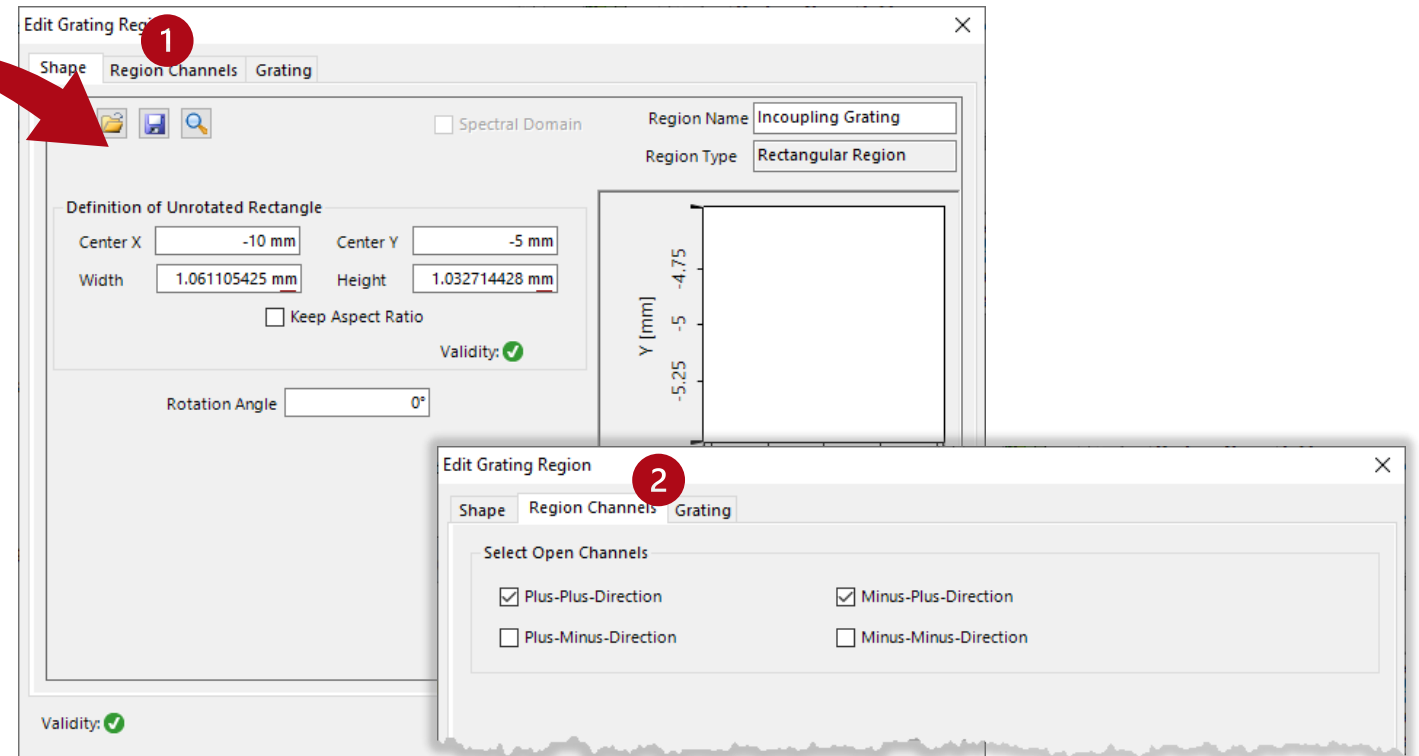
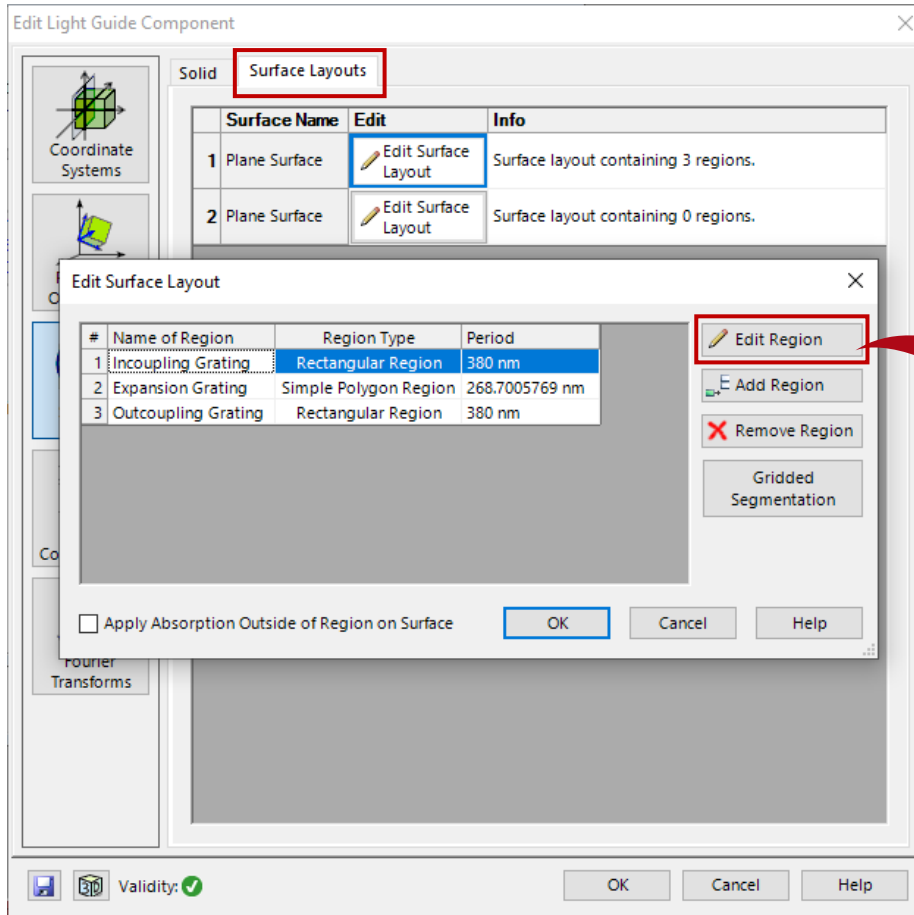
- Grating #1: incoupling grating
- Grating #2: expansion grating
- Grating #3: outcoupling grating



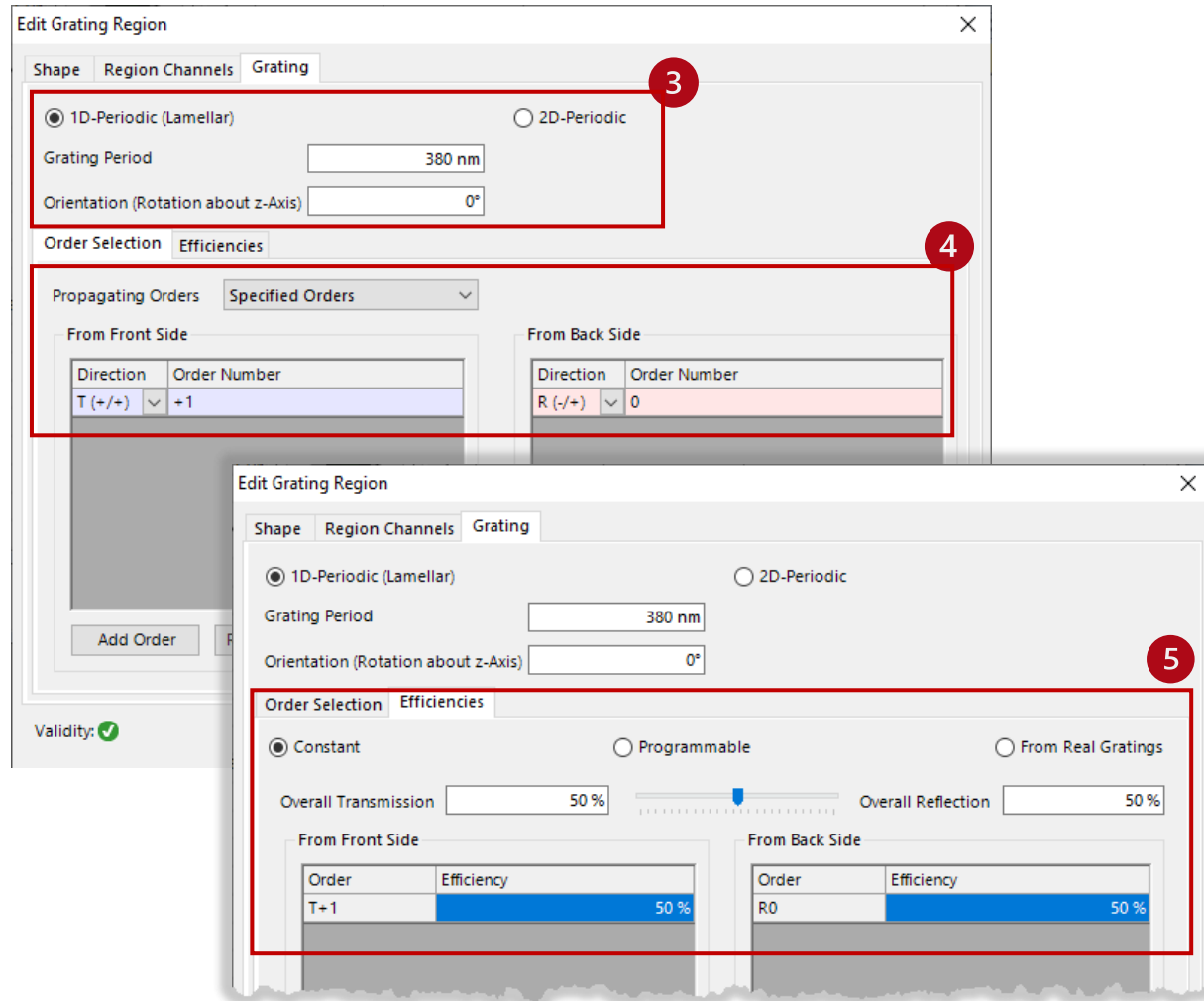
Grating #1: Incoupling Grating

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

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



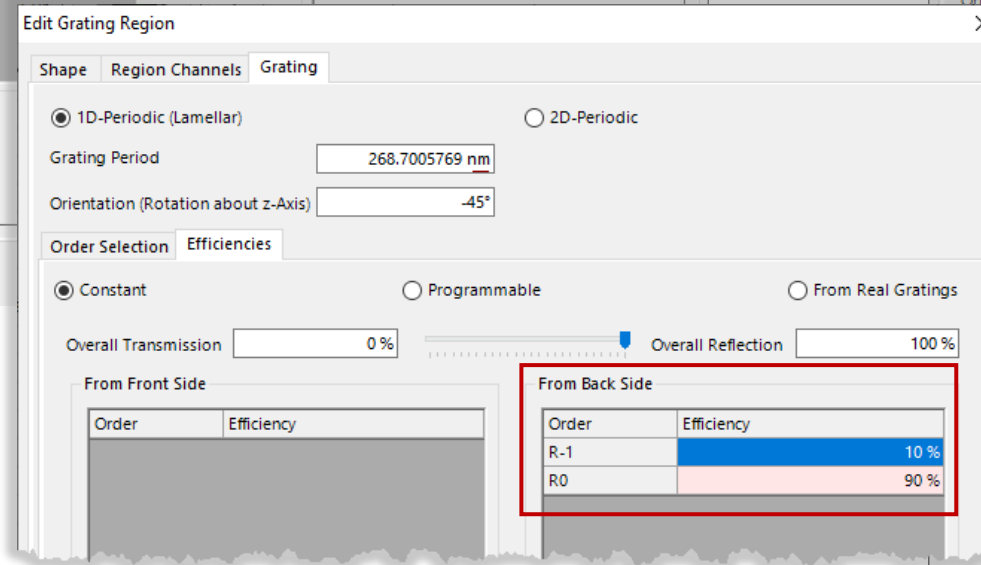
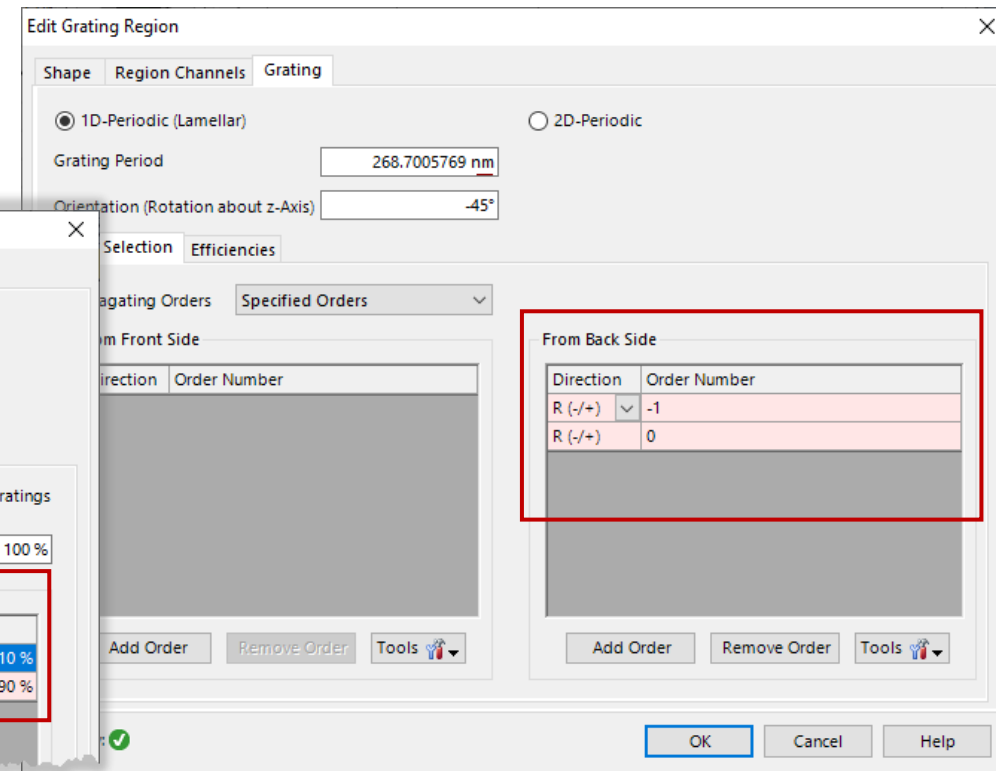
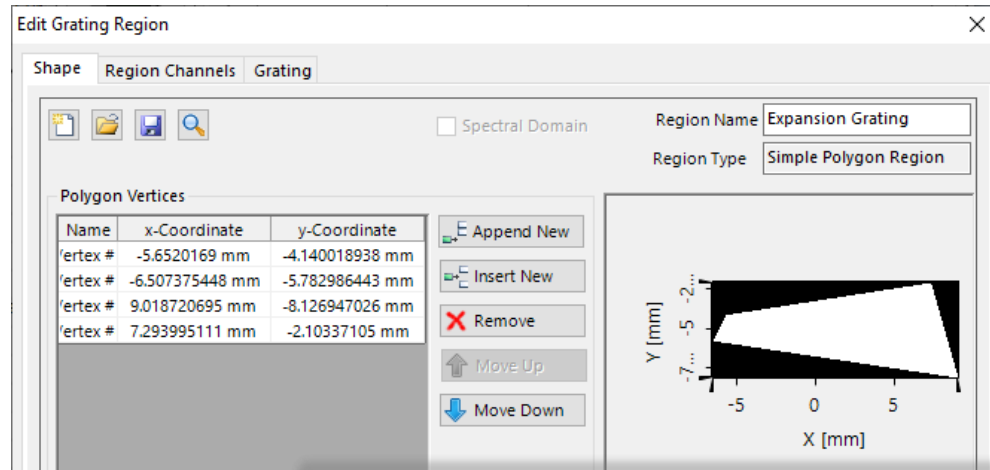
Grating #1: Incoupling Grating



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

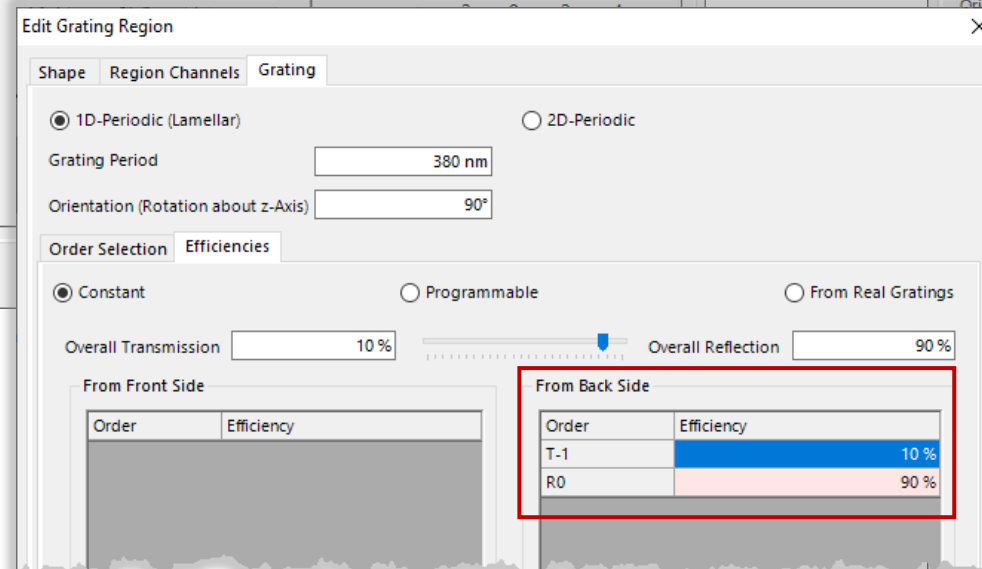
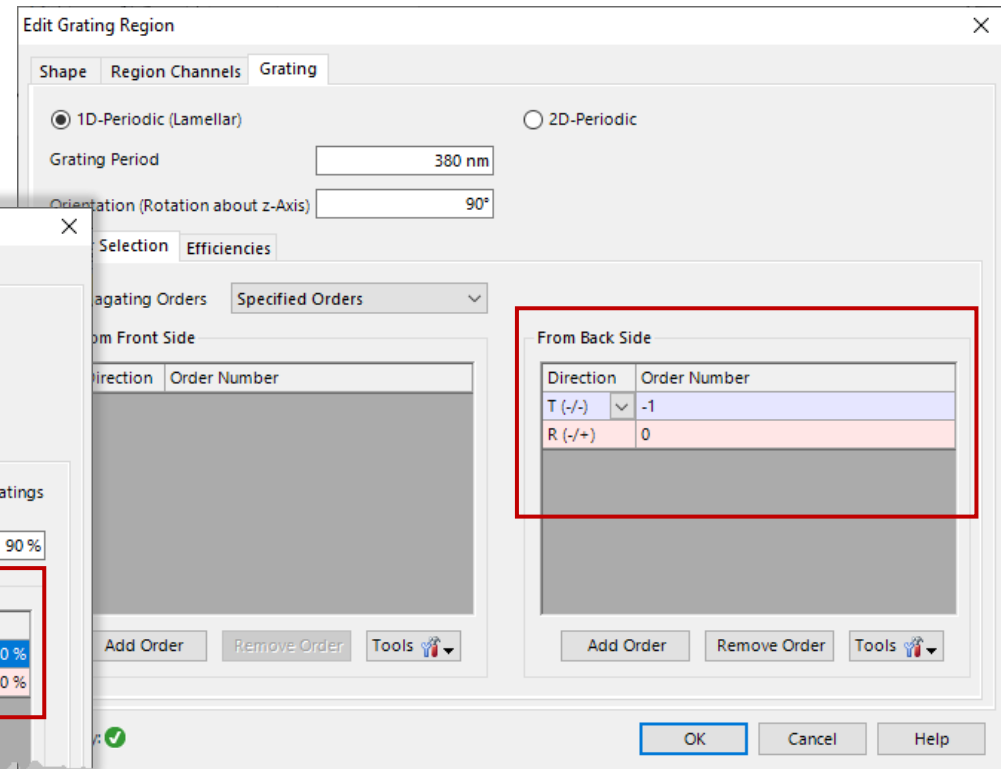
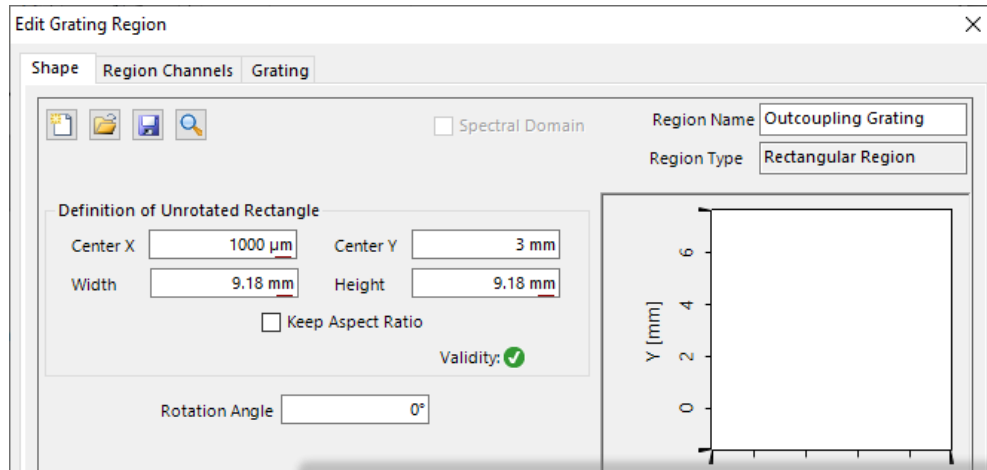
The expansion grating is defined in a polygon-shaped region. The required region channel is $-/+$, therefore only reflected orders for light impinging on the back side of the grating are specified.



Grating #3: Outcoupling Grating

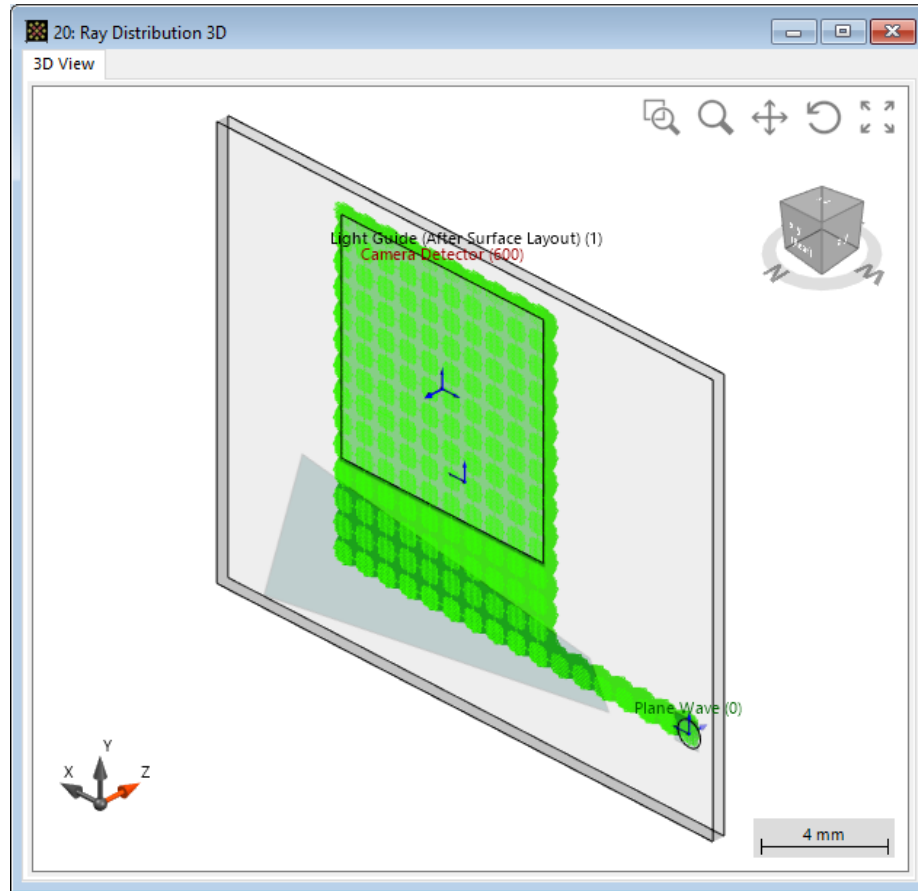
The outcoupling grating is defined in a rectangular region, again.

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

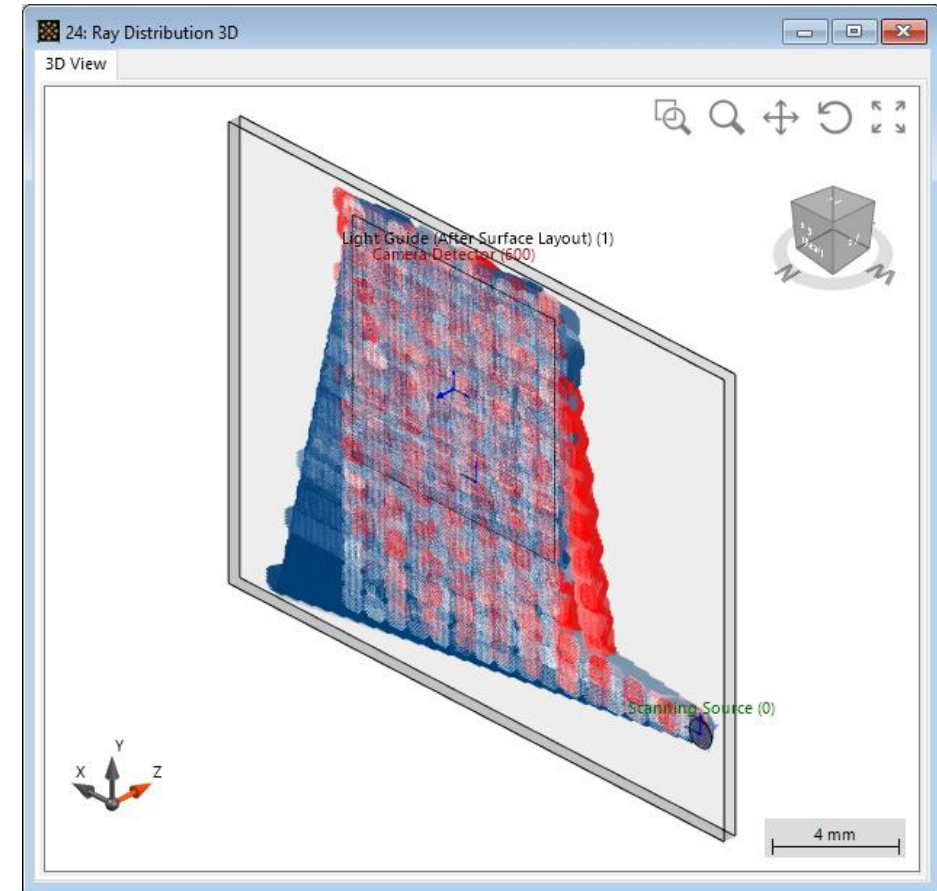


Result: Ray Tracing in 3D System

Rays in System view with central angle of FoV:



Rays in System view with $32^\circ \times 18^\circ$ scanning source input (9 modes, differently colored):



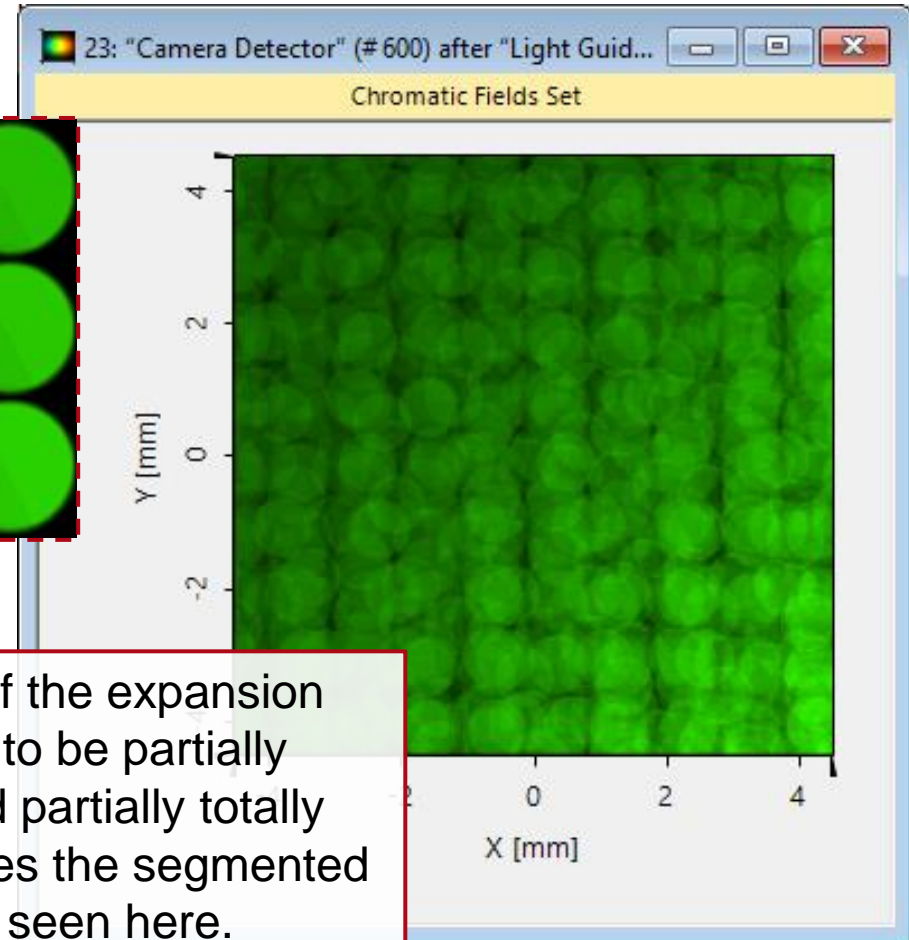
Note: Only rays that hit the detector are displayed.

Result: Field Tracing (Real Color View)

Energy density distribution at eyebox for central FoV mode:



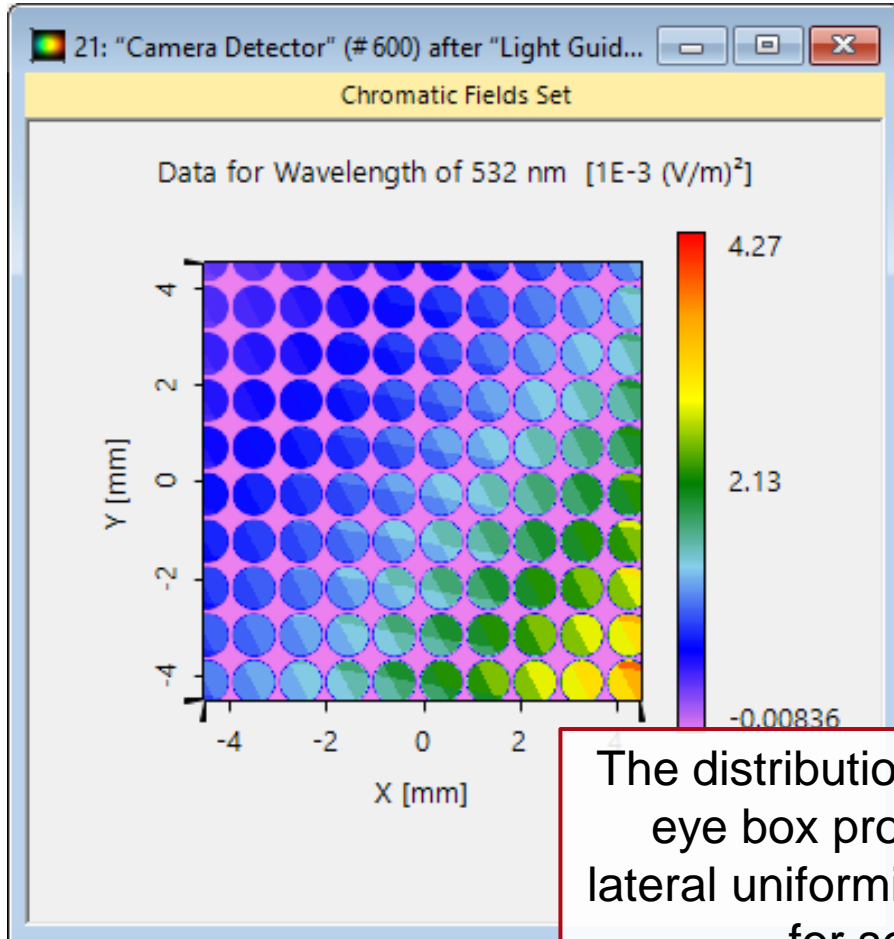
Energy density distribution at eyebox for FoV ($32^\circ \times 18^\circ$) using scanning source (9 modes):



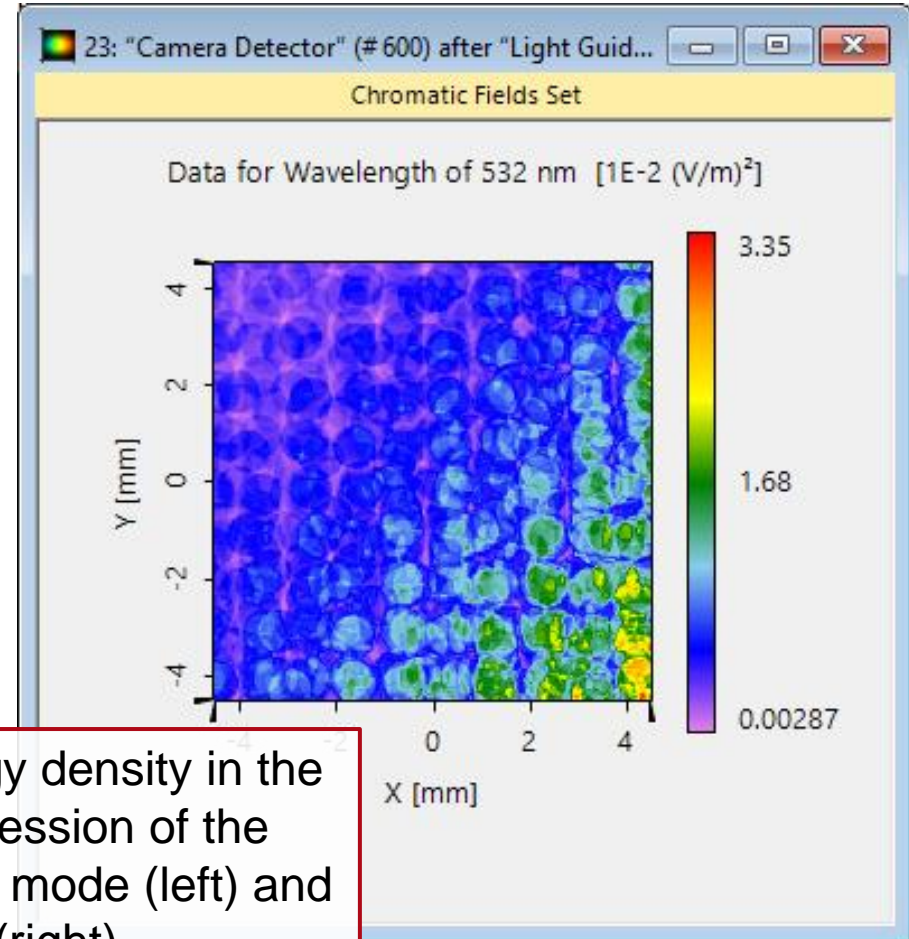
Some beams hit the edge of the expansion region, causing the beam to be partially diffracted by the grating and partially totally internally reflected. This causes the segmented footprints which can be seen here.

Result: Field Tracing (False Color View)

Energy density distribution at eyebox for central FoV mode:

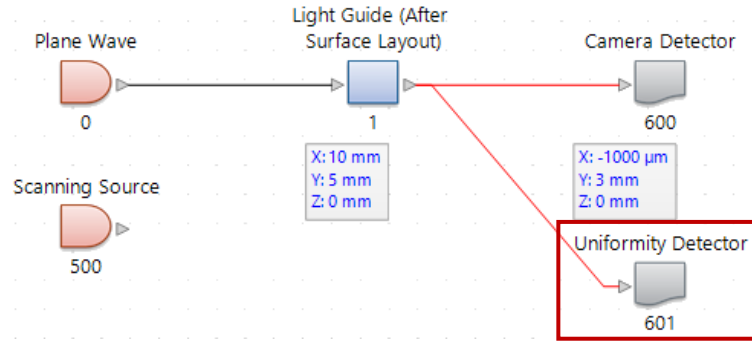


Energy density distribution at eyebox for FoV (32° × 18°) using scanning source (9 modes):

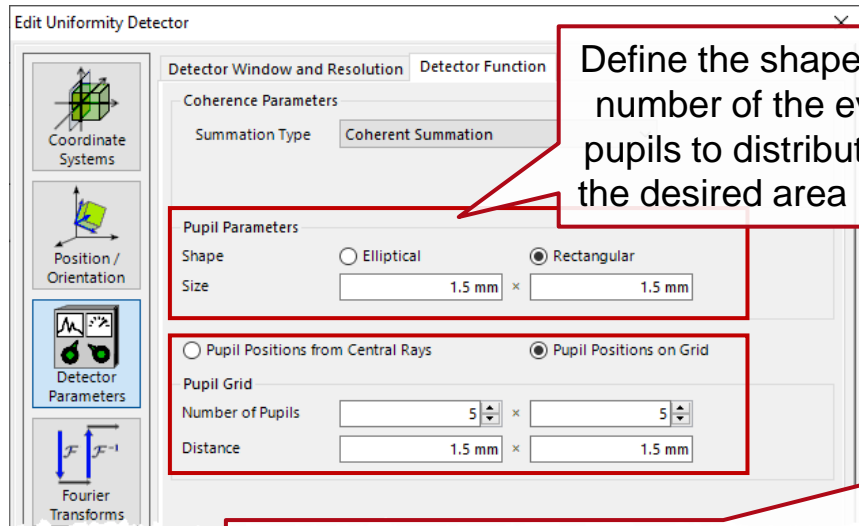


The distribution of the energy density in the eye box provides an impression of the lateral uniformity for a single mode (left) and for several modes (right).

Lateral Uniformity Evaluation



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.



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.

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	

maximum

minimum

resulting uniformity error

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

Document Information

title	Modeling of a “HoloLens 1”-Type Layout with Light Guide Component
document code	LIG.0002
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VL version used for simulations	VirtualLab Fusion Advanced 2021.1 (Build 1.180)
category	Application Use Case
further reading	- <u>Construction of a Light Guide</u>
