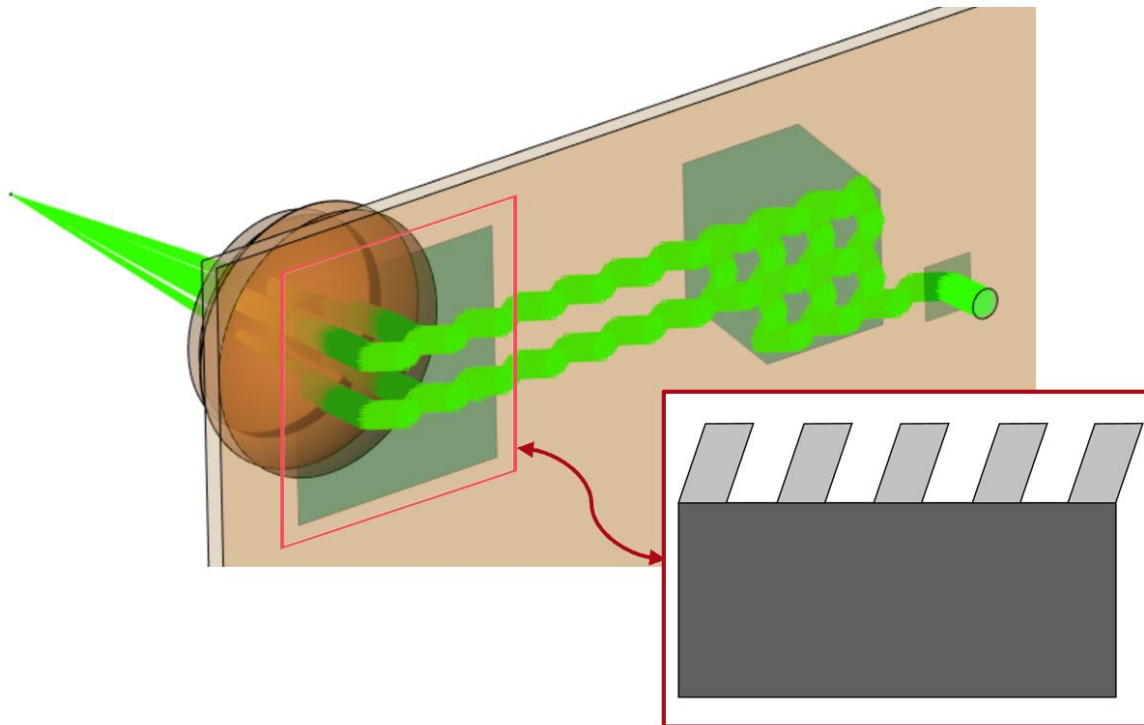


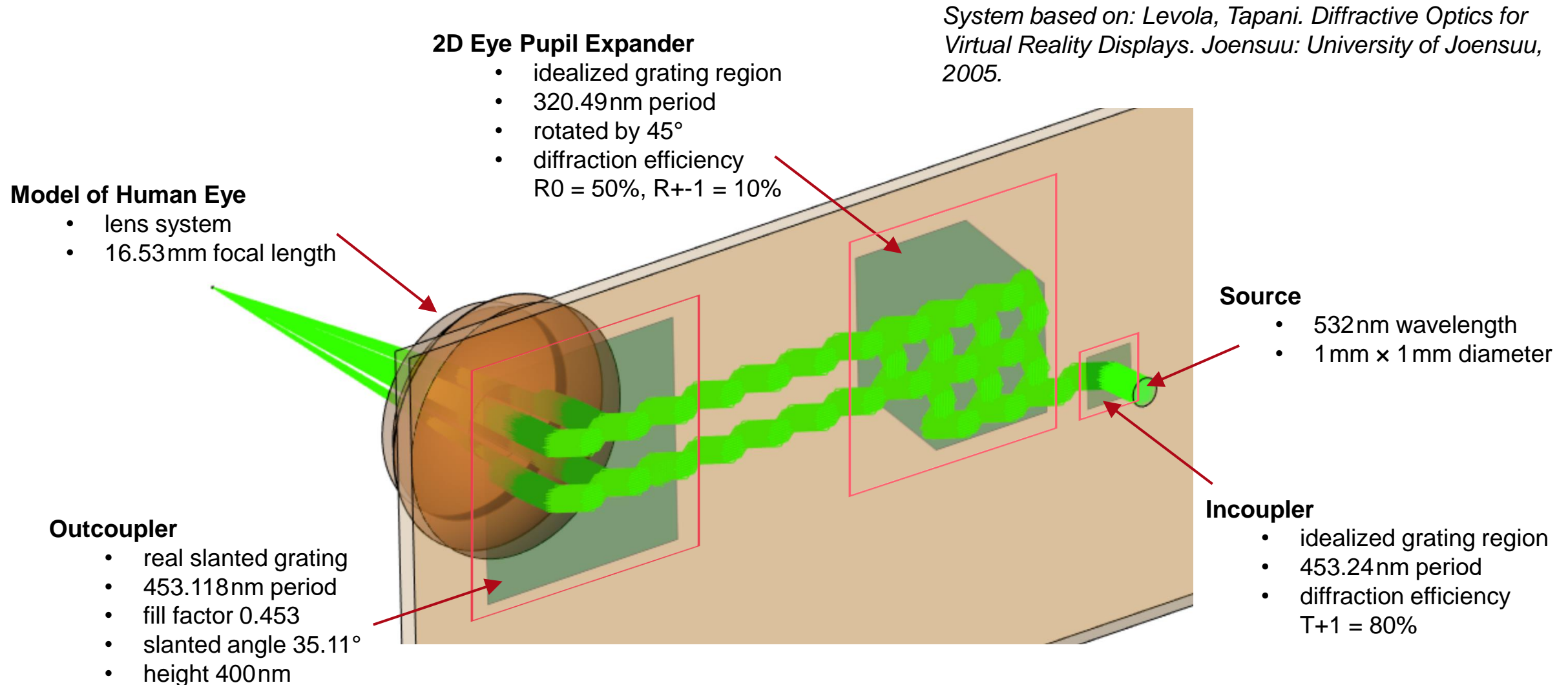
Complex Lightguide System with a 2D Eye Pupil Expansion and Human Eye Model

Abstract

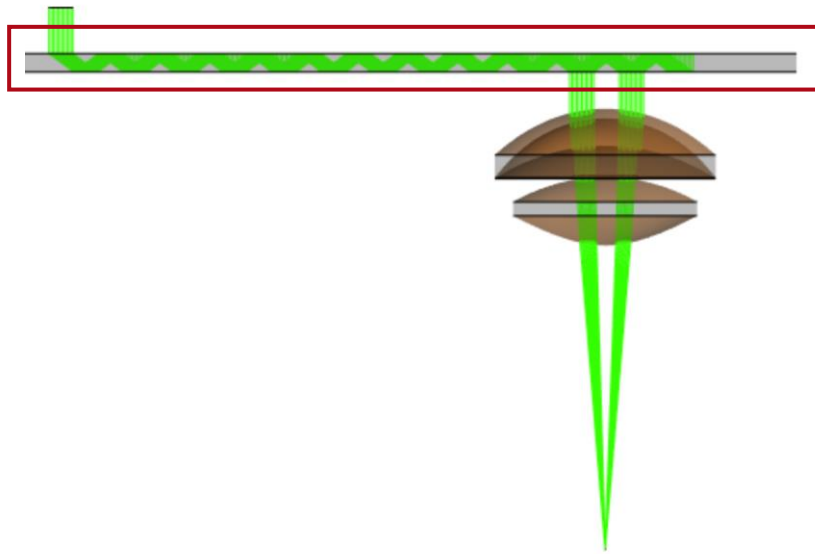


In order to push the limits in the field of augmented and mixed reality (AR/MR), the need for more complex lightguide systems is constantly increasing. VirtualLab Fusion provides a set of tools which enable the design and modeling of such complex systems. To demonstrate the capabilities of VirtualLab Fusion, an exemplary lightguide system with a 2D exit pupil expander in combination with a slanted grating in the outcoupler is presented. In addition, the point spread function (PSF) and modulation transfer function (MTF) are evaluated by applying a model of the human eye. Finally, an assessment of the lateral uniformity in the eyebox is demonstrated.

Task Description

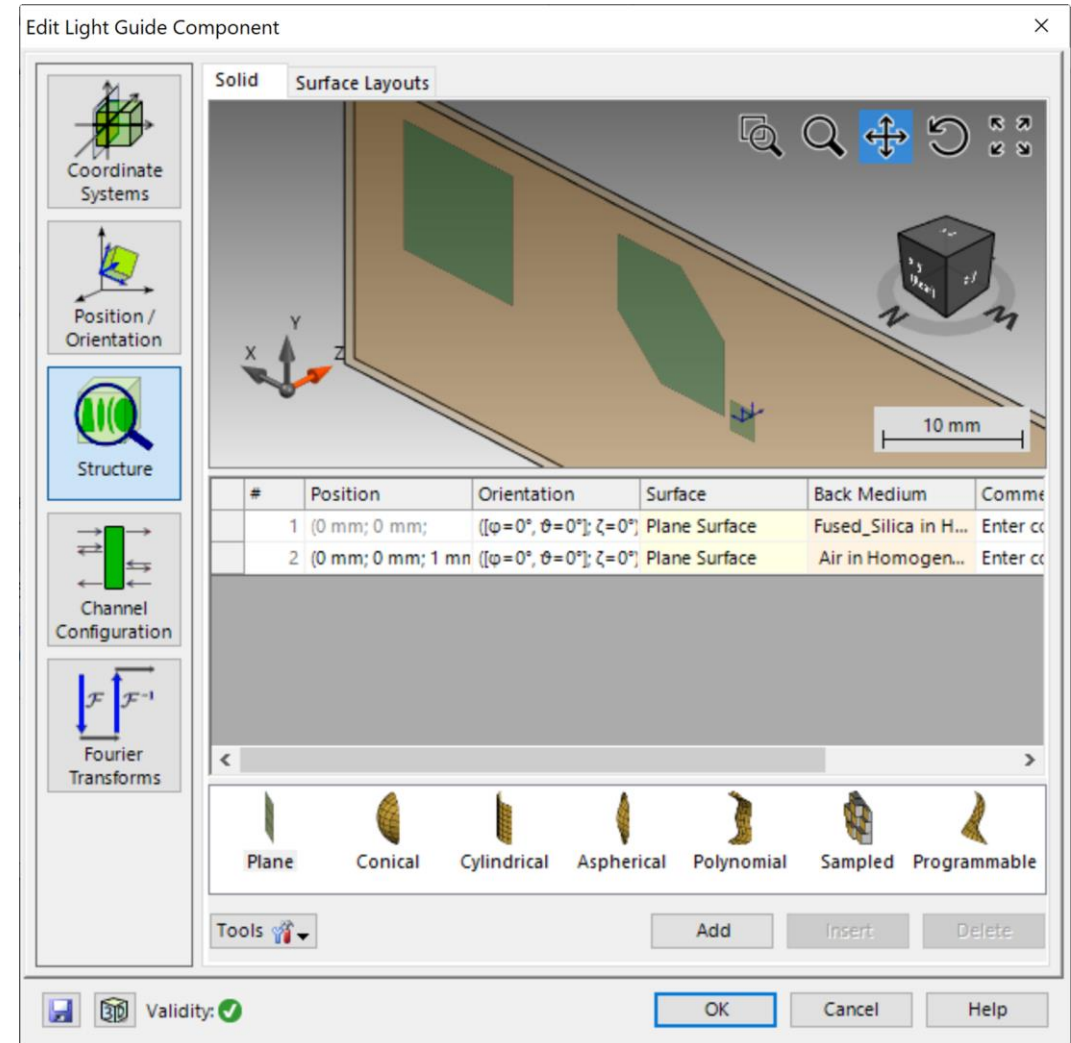


Light Guide Component

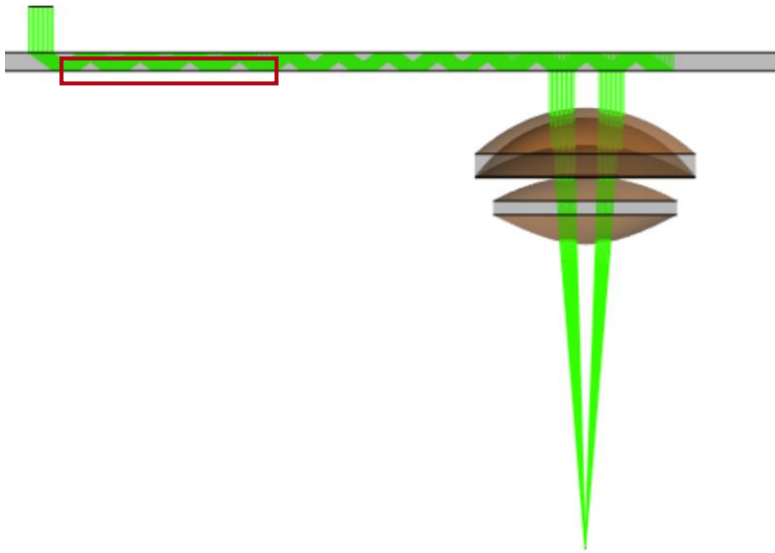


With the *Light Guide Component*, systems with regions with complex shapes can easily be defined. Further, these regions can be equipped with idealized or real grating structures to act as incoupler, outcoupler or exit pupil expanders. More information under:

[Construction of a Light Guide](#)



Eye-Pupil-Expander (EPE) Region



The shape of each region can be defined using different approaches. In this example, in- and outcoupler are rectangular regions, whereas for the EPE a polygonal region is used. More information for region definition under:

[Flexible Region Configuration](#)

Edit Grating Region

Shape: Region Channels Grating

Spectral Domain

Region Name: Polygon Region

Region Type: Simple Polygon Region

Name	x-Coordinate	y-Coordinate
#15	2.7 mm	-1.35 mm
#2	9.1 mm	-1.35 mm
#4	11.8 mm	1.35 mm
#6	13.5 mm	3.05 mm
#7	13.5 mm	9.45 mm
#8	7.1 mm	9.45 mm
#10	4.4 mm	6.75 mm
#13	2.7 mm	5.05 mm

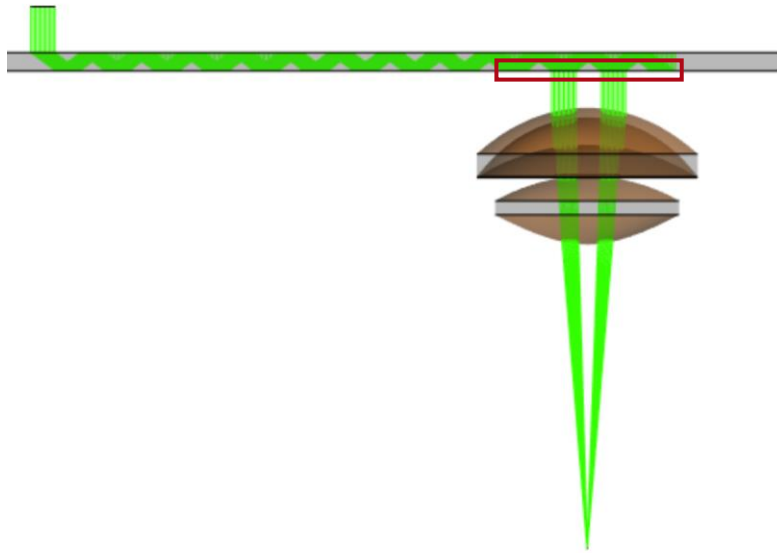
Buttons: Append New, Insert New, Remove, Move Up, Move Down

2D Plot: Y [mm] vs X [mm]

3D View: Optical Setup

Close Help

Outcoupling Region



For the outcoupler a slanted grating is used, whose efficiencies are calculated rigorously by applying FMM (RCWA). You can find more information on how to set this up under:

[!\[\]\(eafc244b53721dd1ec133f0772f70fc7_img.jpg\) How to Set Up a Lightguide with Real Grating Structures](#)

The screenshot displays the software interface for setting up a light guide component. The main window is titled "Preview for Outcouple Grating Human Eye Model". Below the preview area, there is a table with the following data:

Index	z-Distance	z-Position	Surface
1	0 mm	0 mm	Plane Interface
2	500 nm	500 nm	Plane Interface

Below the table, there is a section for "Periodic Stack; Stack Period" with a value of 453.1 nm. Overlaid on the interface are two dialog boxes. The "Edit Light Guide Component" dialog box has a "Surface Layouts" tab with the following table:

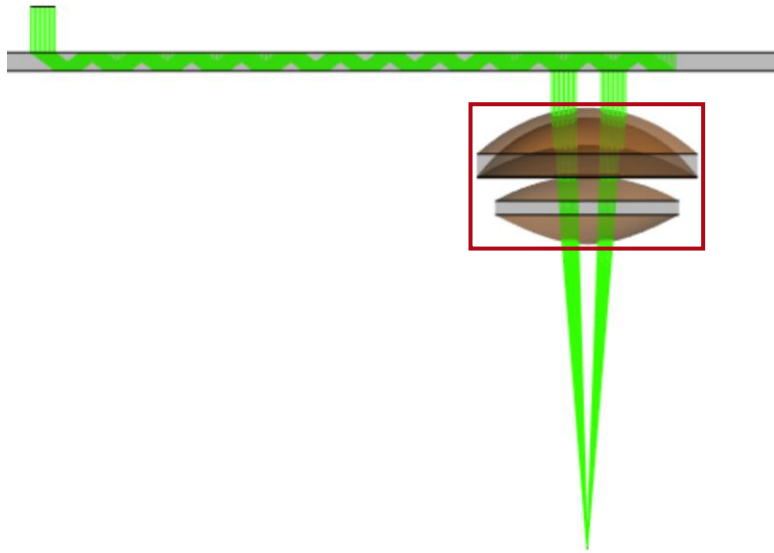
Surface Name	Edit	Info
1 Plane Surface	Edit Surface Layout	Surface layout containing 1 regions.
2 Plane Surface	Edit Surface Layout	Surface layout containing 2 regions.

The "Edit Surface Layout" dialog box is open for the second surface layout, showing a table with the following data:

#	Name of Region	Region Type	Period
1	Polygon Region	Simple Polygon Region	320.5 nm
	Outcouple Grating	Rectangular Region	453.1 nm

The "Outcouple Grating" region is highlighted in red in the table. The dialog box also includes buttons for "Edit Region", "Add Region", "Remove Region", and "Gridded Segmentation". At the bottom of the dialog box, there is a checkbox for "Apply Absorption Outside of Region on Surface" and buttons for "OK", "Cancel", and "Help".

Human Eye Model



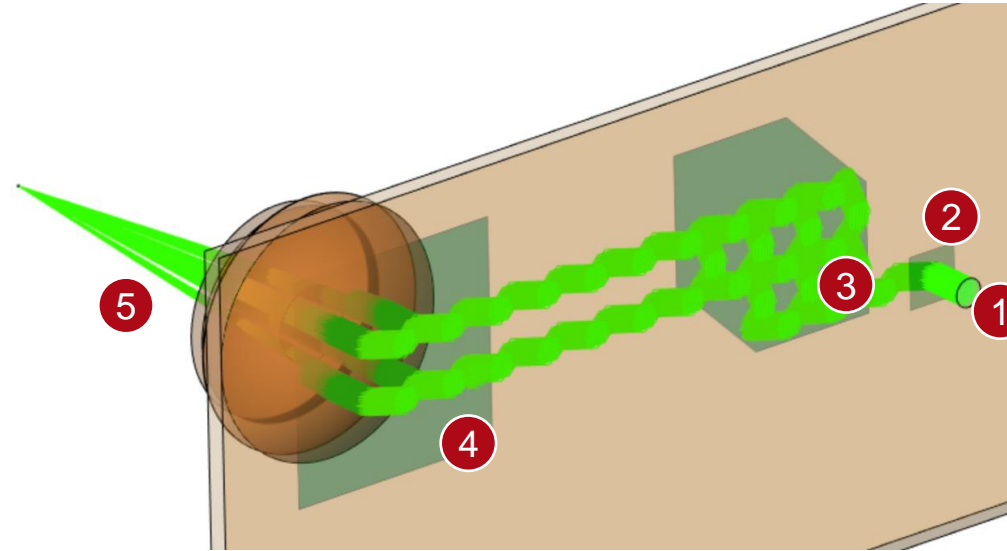
In order to evaluate the PSF and MTF accurately, one possible model of the complex optical system that is the human eye is used, represented by a sequence of surfaces and materials. For the configuration, these surfaces and materials can be loaded from VirtualLab's inbuilt catalogs.

The screenshot shows the 'Edit Lens System Component' window. At the top, there is a 3D visualization of the eye model. Below it is a table with the following data:

Index	Distance	Position	Type	Homogeneous Medium	Comment
1	0 mm	0 mm	Conical Interface	Cornea in Homogeneous	Cornea
2	520 μ m	520 μ m	Conical Interface	Aqueous in Homogeneous	Aqueous
3	1.5 mm	2.02 mm	Conical Interface	Aqueous in Homogeneous	Enter your comr
4	1.6 mm	3.62 mm	Plane Interface	Aqueous in Homogeneous	Pupil
5	100 μ m	3.72 mm	Conical Interface	Lens_HumanEye in Hom	Lens
6	3.7 mm	7.42 mm	Conical Interface	Vitreous in Homogeneo	Vitreous

The interface also includes a toolbar on the left with icons for Coordinate Systems, Position / Orientation, Structure, Solver, Channel Configuration, and Fourier Transforms. At the bottom, there is a 'Tools' dropdown menu, 'Add', 'Insert', and 'Delete' buttons, and a 'Validity' indicator showing a green checkmark. The 'OK', 'Cancel', and 'Help' buttons are at the bottom right.

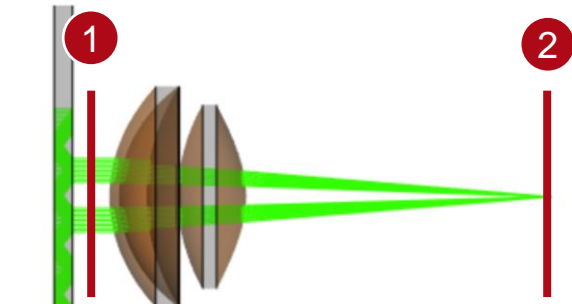
Summary – Components...



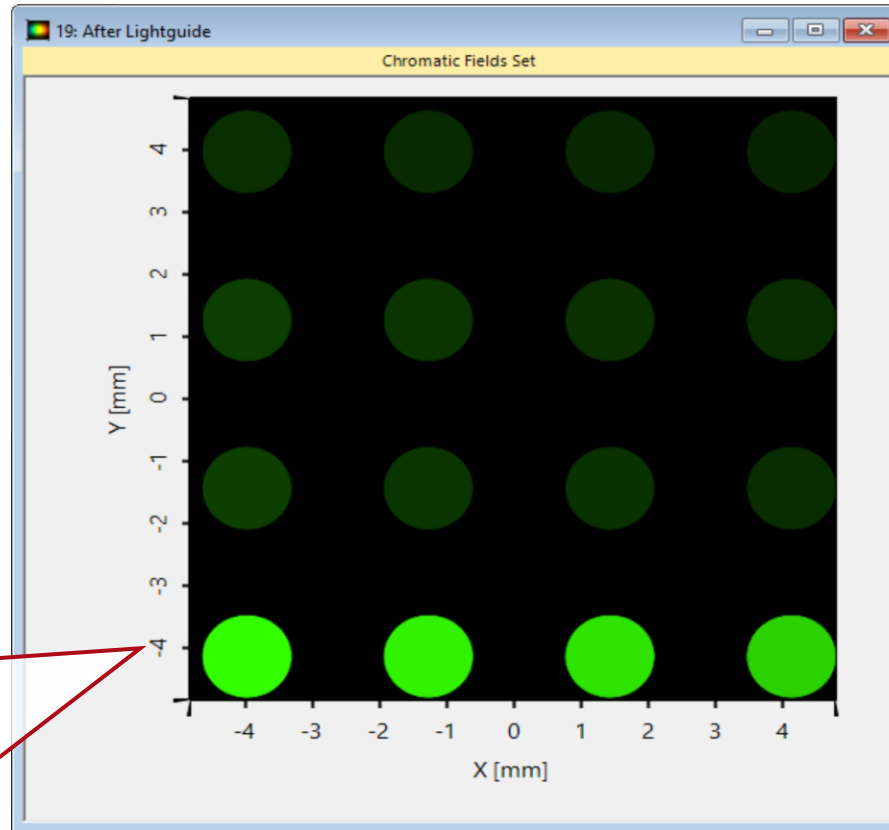
... of Optical System	... in VirtualLab Fusion	Model/Solver/Detected Value
1. Source	<i>Plane Wave</i> source	Truncated Ideal Plane Wave
2. Incoupler	Idealized grating in <i>Rectangular Region</i>	Idealized Rayleigh Matrices
3. Eye Pupil Expansion	Idealized grating in <i>Polygonal Region</i>	Idealized Rayleigh Matrices
4. Outcoupler	Slanted grating in <i>Rectangular Region</i>	Fourier Modal Method (FMM)/RCWA
5. Eye	<i>Lens System Component, PSF&MTF Detector, Camera Detector, Uniformity Detector</i>	Local Plane Interface Approximation & energy density measurement

Field at Different Positions/Planes in the System

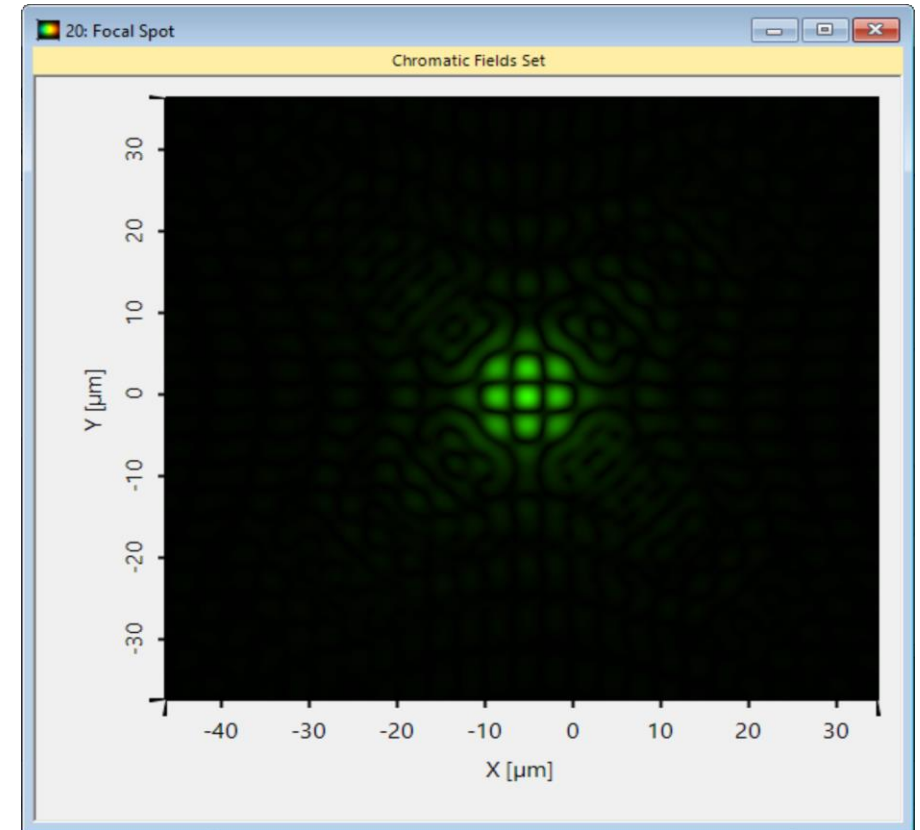
VirtualLab Fusion can calculate the electromagnetic field after the lightguide and in the focal spot.



Full propagation through the lightguide, including complex grating configurations and diffraction efficiency calculations at real gratings by FMM is performed in a few seconds!

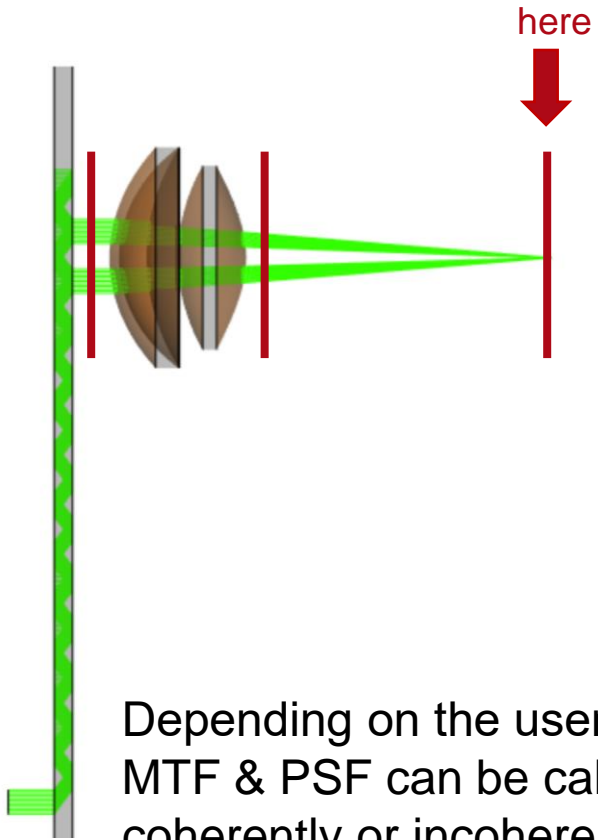


1 field after lightguide

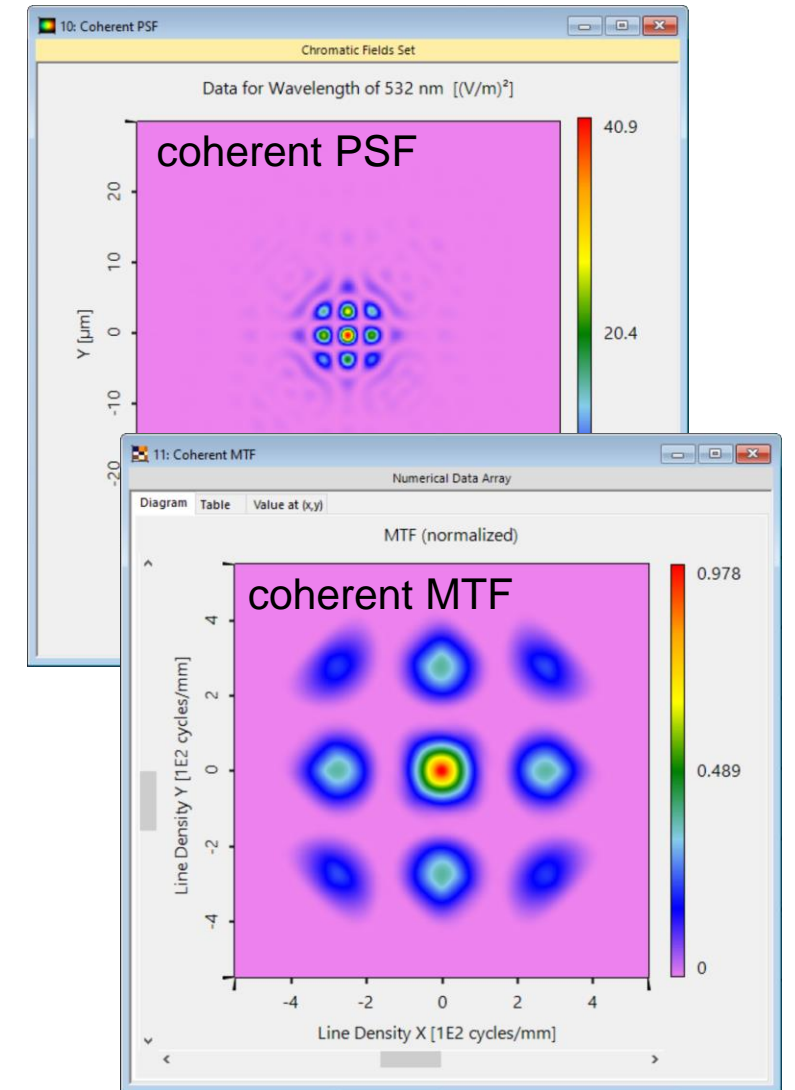
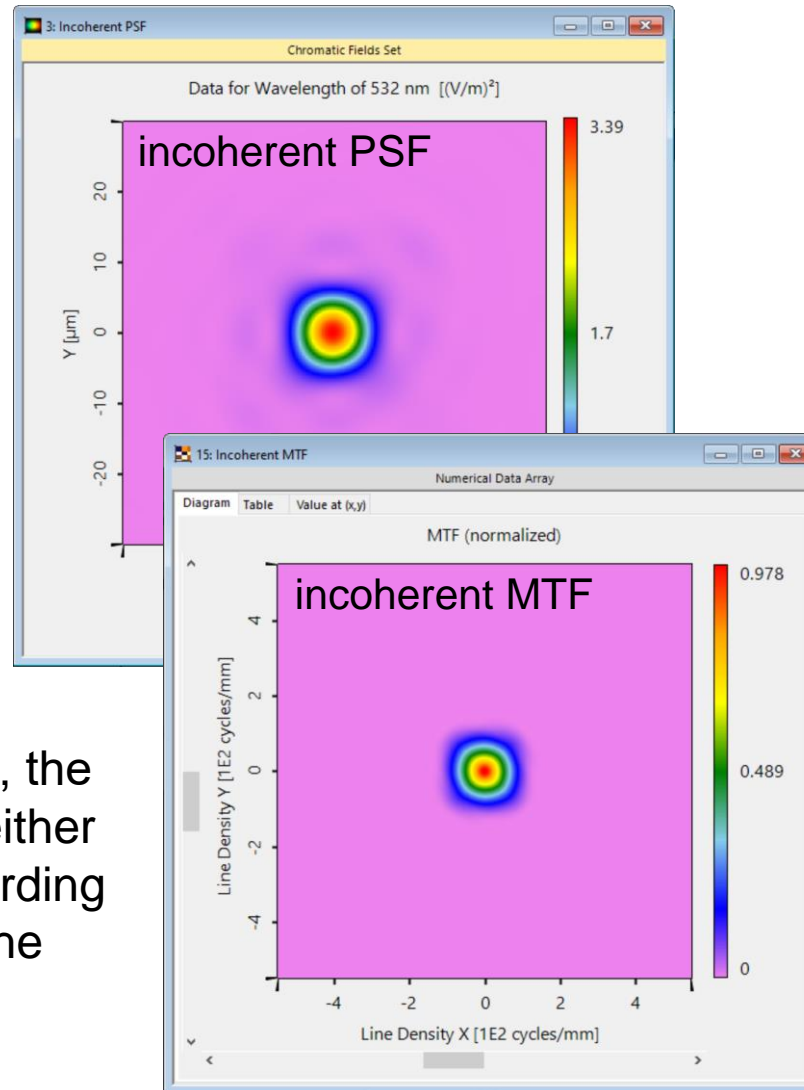


2 field in focal plane

MTF & PSF – Calculation



Depending on the user's choice, the MTF & PSF can be calculated either coherently or incoherently, according to the coherence properties of the actual light source.



Lateral Uniformity Evaluation after the Lightguide

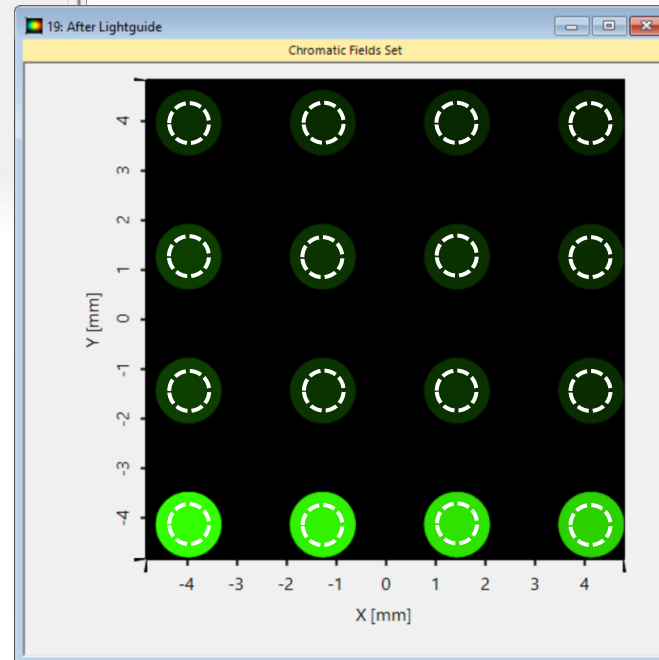
Shape, size and number of pupils considered for evaluation can be defined.
More information under:
[Uniformity Detector for Lightguide Systems](#)

Note: The dashed circles are just for illustration of the pupils, these are not shown in the simulation result.

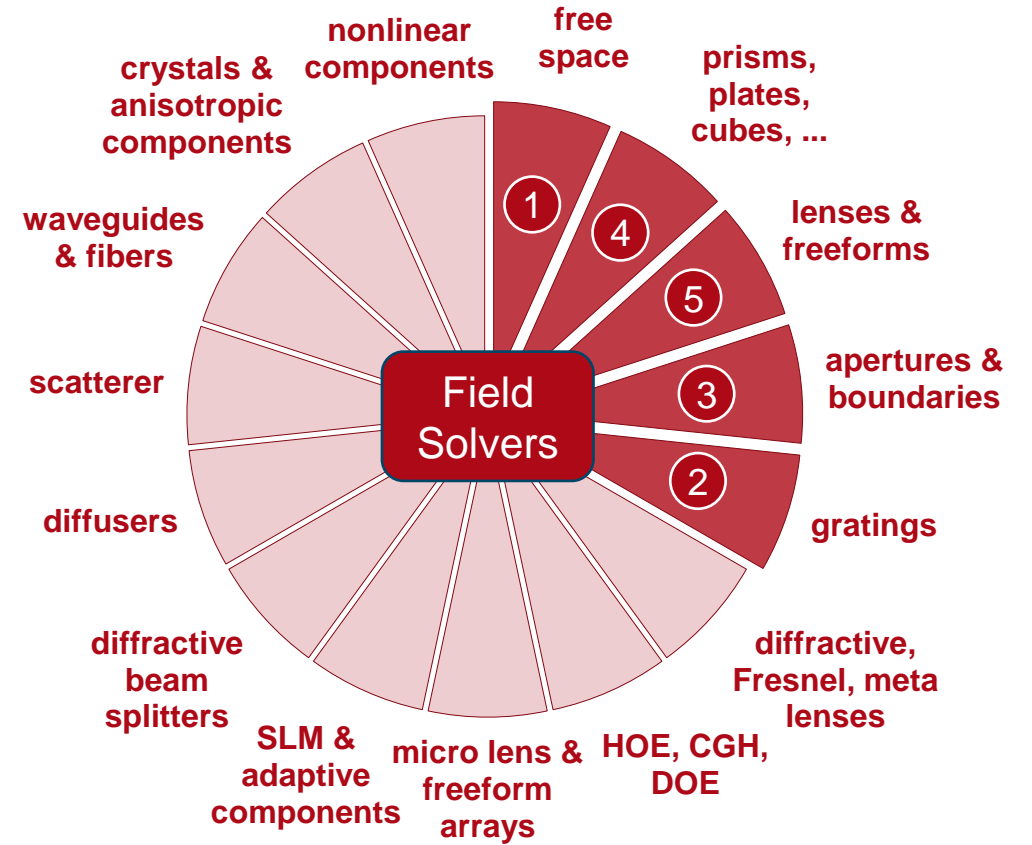
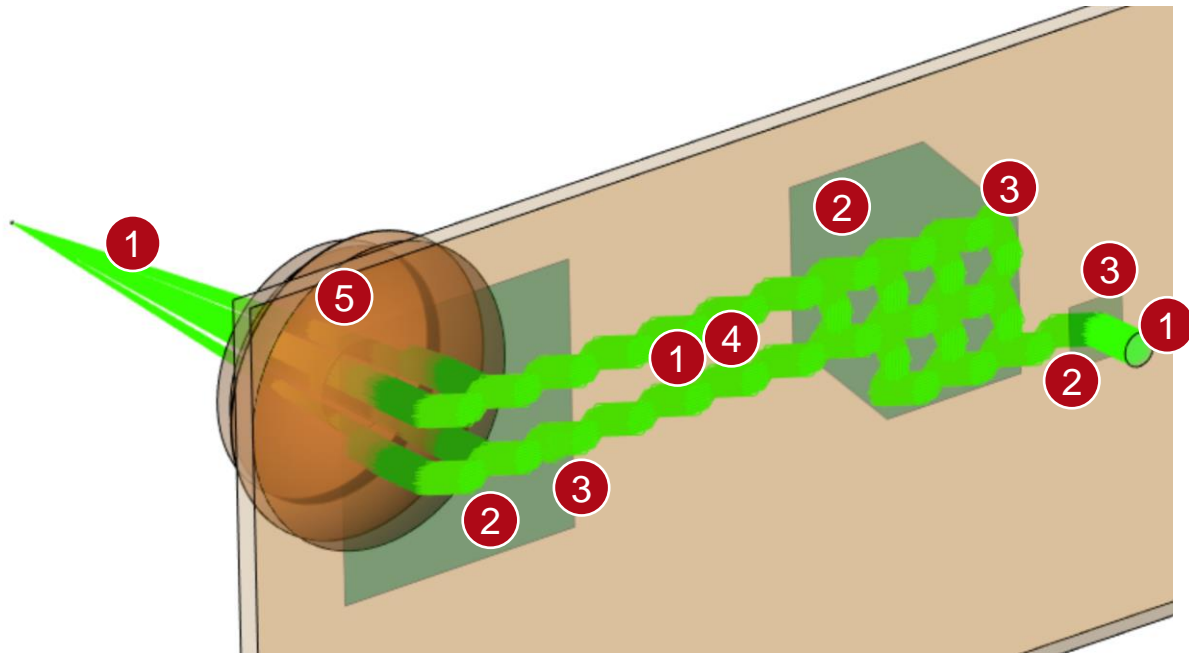
result of *Uniformity Detector*

Value for Pupil around (-3.97 mm; -4.15 mm)	0.0122 (V/m) ²
Value for Pupil around (-3.97 mm; -1.45 mm)	0.000566 (V/m) ²
Value for Pupil around (-1.27 mm; -4.15 mm)	0.0109 (V/m) ²
Value for Pupil around (-3.97 mm; 1.25 mm)	0.000533 (V/m) ²
Value for Pupil around (-1.27 mm; -1.45 mm)	0.00038 (V/m) ²
Value for Pupil around (1.43 mm; -4.15 mm)	0.00943 (V/m) ²
Value for Pupil around (-3.97 mm; 3.94 mm)	0.000282 (V/m) ²
Value for Pupil around (-1.27 mm; 1.25 mm)	0.000375 (V/m) ²
Value for Pupil around (1.43 mm; -1.45 mm)	0.000317 (V/m) ²
Value for Pupil around (4.12 mm; -4.15 mm)	0.00797 (V/m) ²
Value for Pupil around (-1.27 mm; 3.94 mm)	0.000227 (V/m) ²
Value for Pupil around (1.43 mm; 1.25 mm)	0.000312 (V/m) ²
Value for Pupil around (4.12 mm; -1.45 mm)	0.000264 (V/m) ²
Value for Pupil around (1.43 mm; 3.94 mm)	0.000189 (V/m) ²
Value for Pupil around (4.12 mm; 1.25 mm)	0.00026 (V/m) ²
Value for Pupil around (4.12 mm; 3.94 mm)	0.000158 (V/m) ²
Minimum	0.000158 (V/m) ²
Maximum	0.0122 (V/m) ²
Uniformity Error	97.4 %
Arithmetic Mean	0.00277 (V/m) ²
Standard Deviation	0.0172 (V/m) ²

result of *Camera Detector*



VirtualLab Fusion Technologies



Document Information

title	Complex Lightguide System with a 2D Eye Pupil Expansion and Human Eye Model
document code	LIG.0011
document version	1.0
software version	2021.1 (Build 1.180)
software edition	<ul style="list-style-type: none">• VirtualLab Fusion Advanced• Light Guide Toolbox Silver Edition
category	Application Use Case
further reading	<ul style="list-style-type: none">- <u>Uniformity Detector for Lightguide Systems</u>- <u>Construction of a Light Guide</u>- <u>Light Guide Layout Design Tool</u>- <u>Simulation of Lightguide with 1D-1D Pupil Expander and Real Gratings</u>- <u>Flexible Region Configuration</u>- <u>How to Set Up a Lightguide with Real Grating Structures</u>