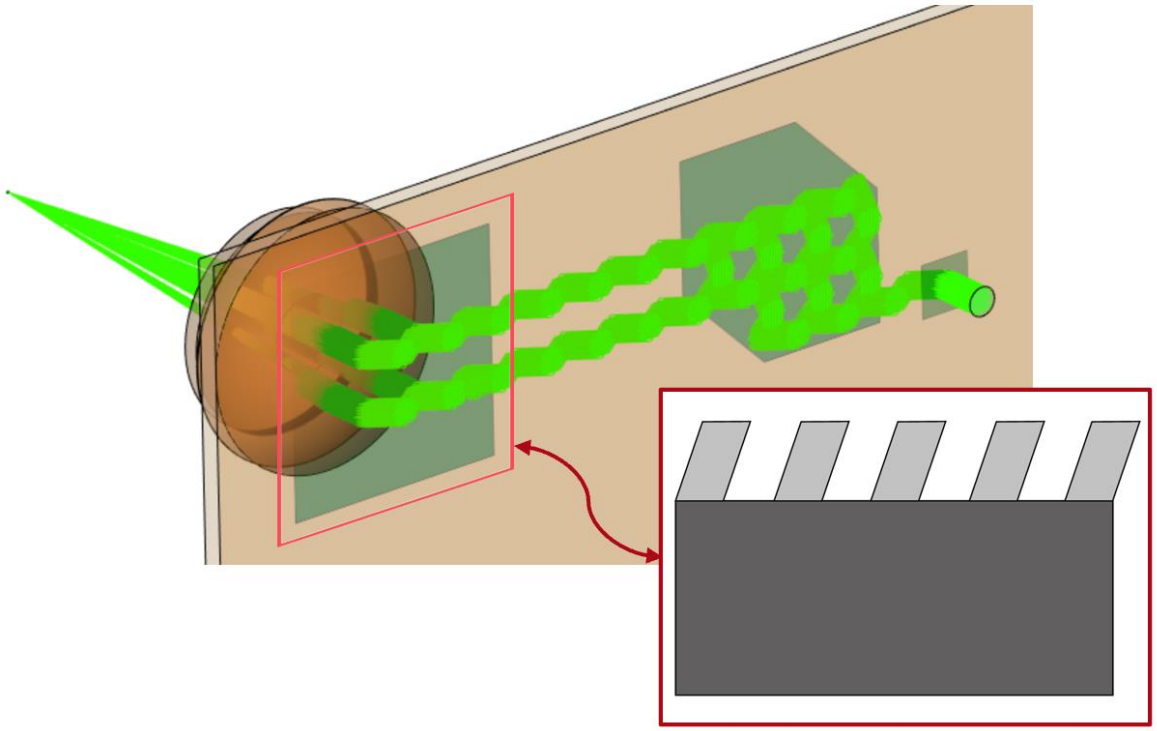
Complex Lightguide System with a 2D Eye Pupil Expansion and Human Eye Model

Abstract



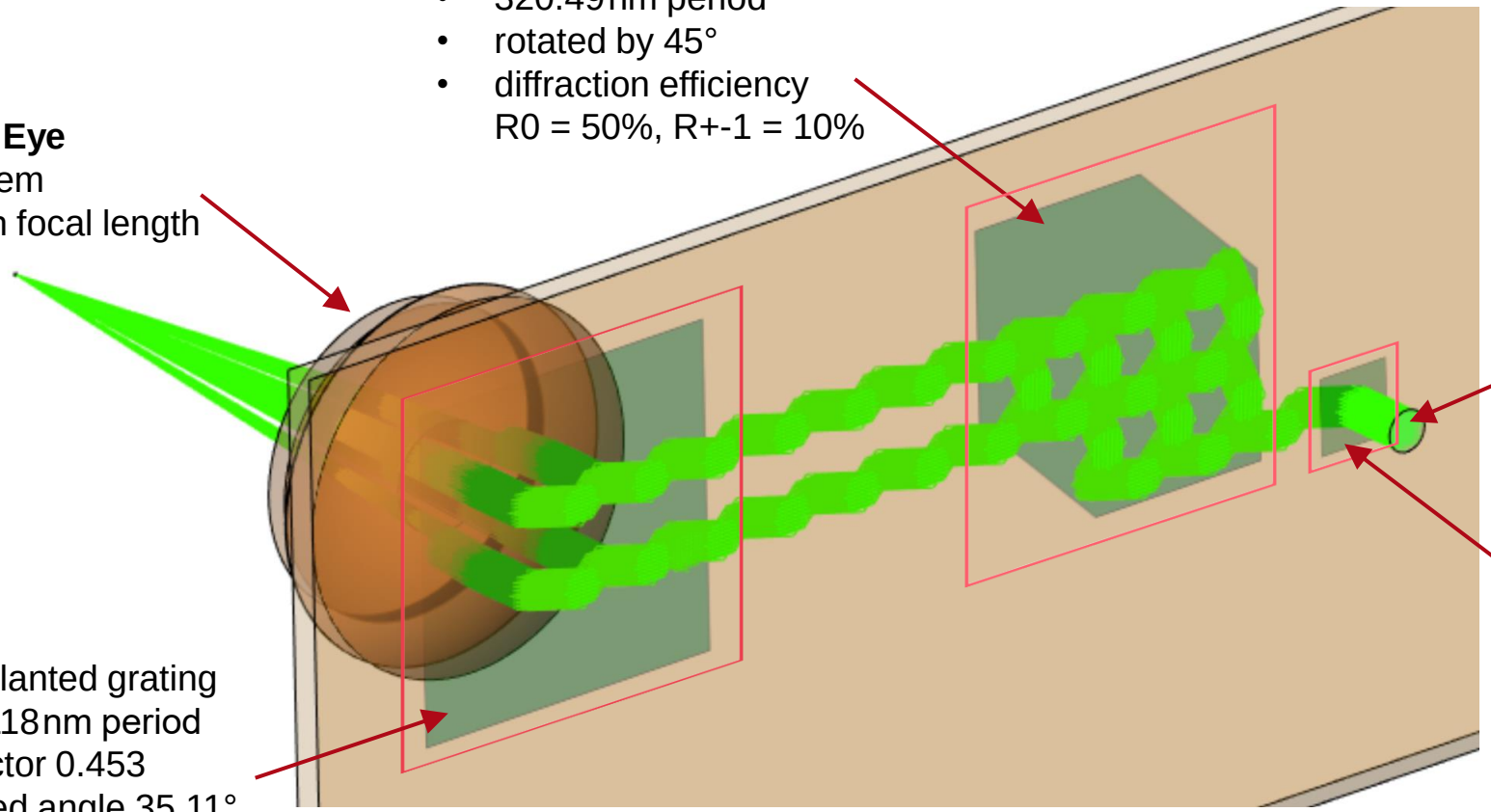
In order to push the limits in the field of augmented and mixed reality (AR/MR), the need for more complex lightguide systems is constantly increasing. VirtualLab Fusion provides a set of tools which enable the design and modeling of such complex systems. To demonstrate the capabilities of VirtualLab 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

System based on: Levola, Tapani. Diffractive Optics for Virtual Reality Displays. Joensuu: University of Joensuu, 2005.

2D Eye Pupil Expander
- idealized grating region
- 320.49 nm period
- rotated by 45°
- diffraction efficiency
  R0 = 50%, R+-1 = 10%

Model of Human Eye
- lens system
- 16.53 mm focal length

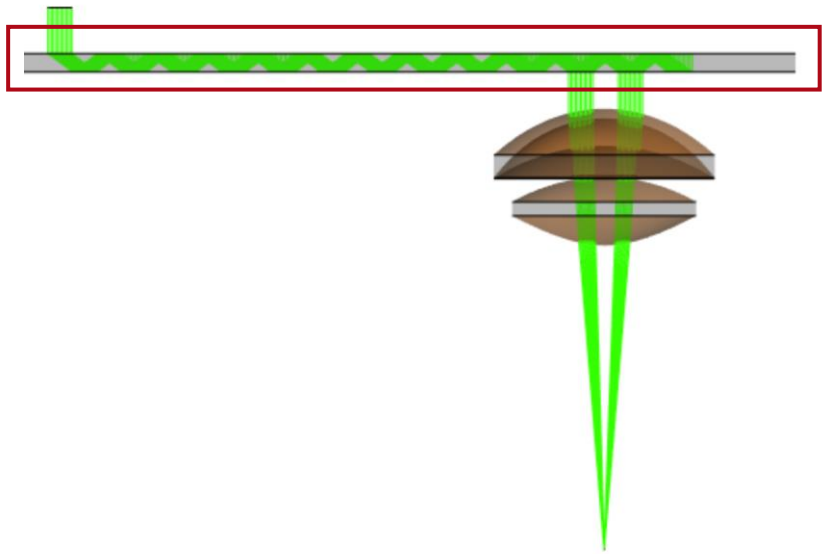


Source
- 532 nm wavelength
- 1 mm × 1 mm diameter

Outcoupler
- real slanted grating
- 453.118 nm period
- fill factor 0.453
- slanted angle 35.11°
- height 400 nm

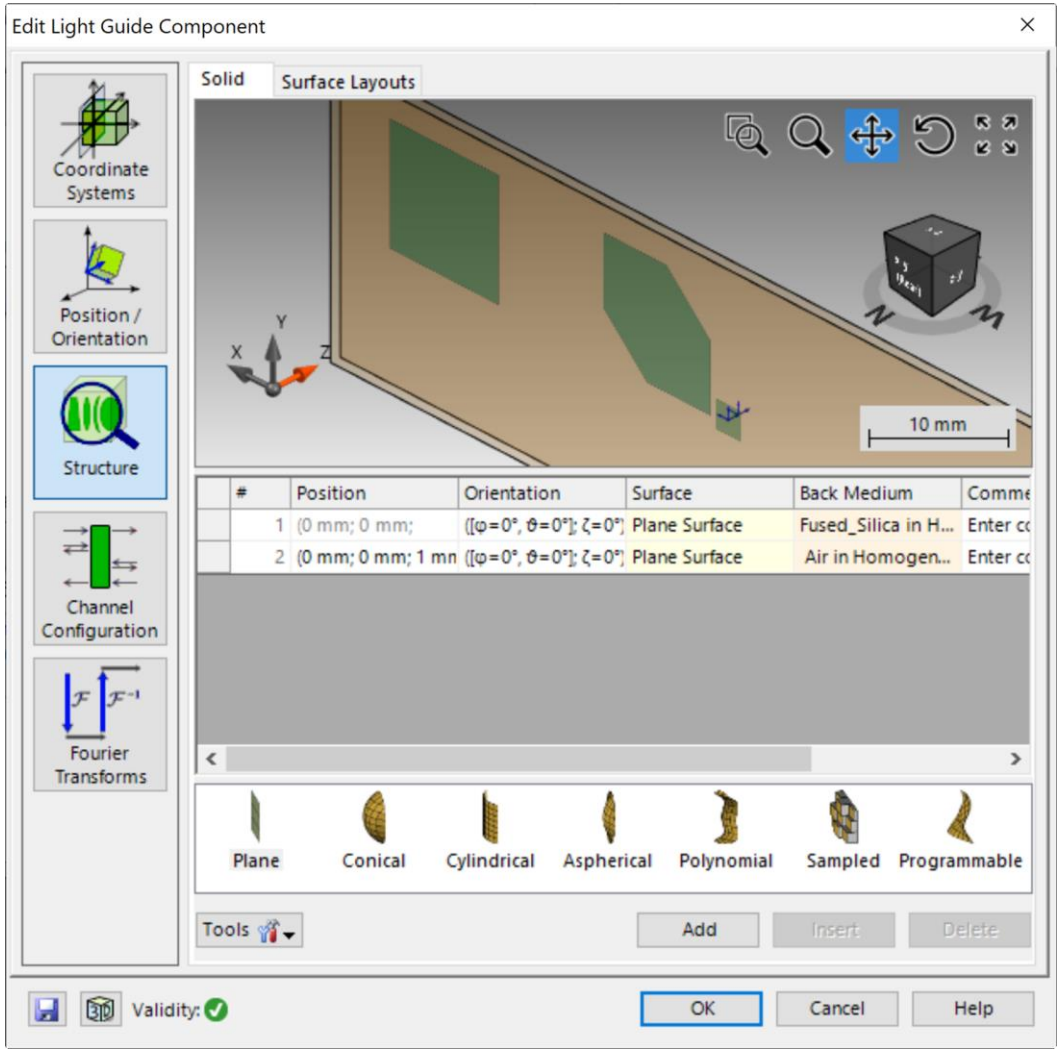
Incoupler
- idealized grating region
- 453.24 nm period
- diffraction efficiency
  T+1 = 80%

Light Guide Component

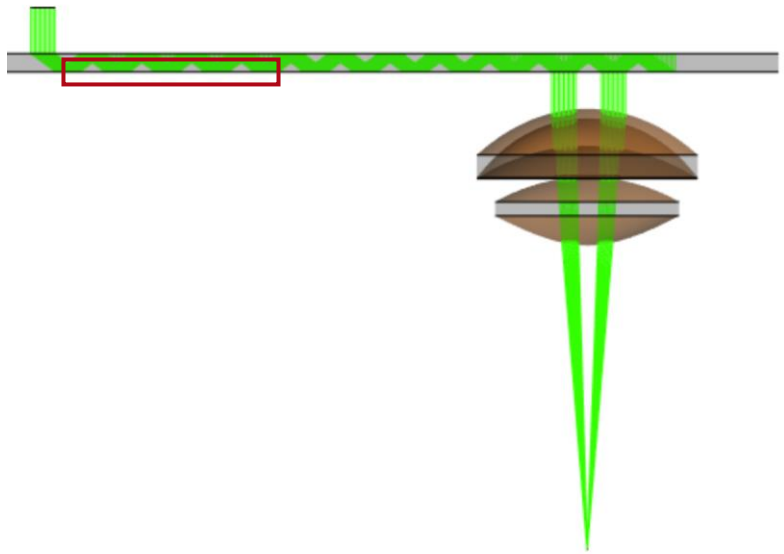


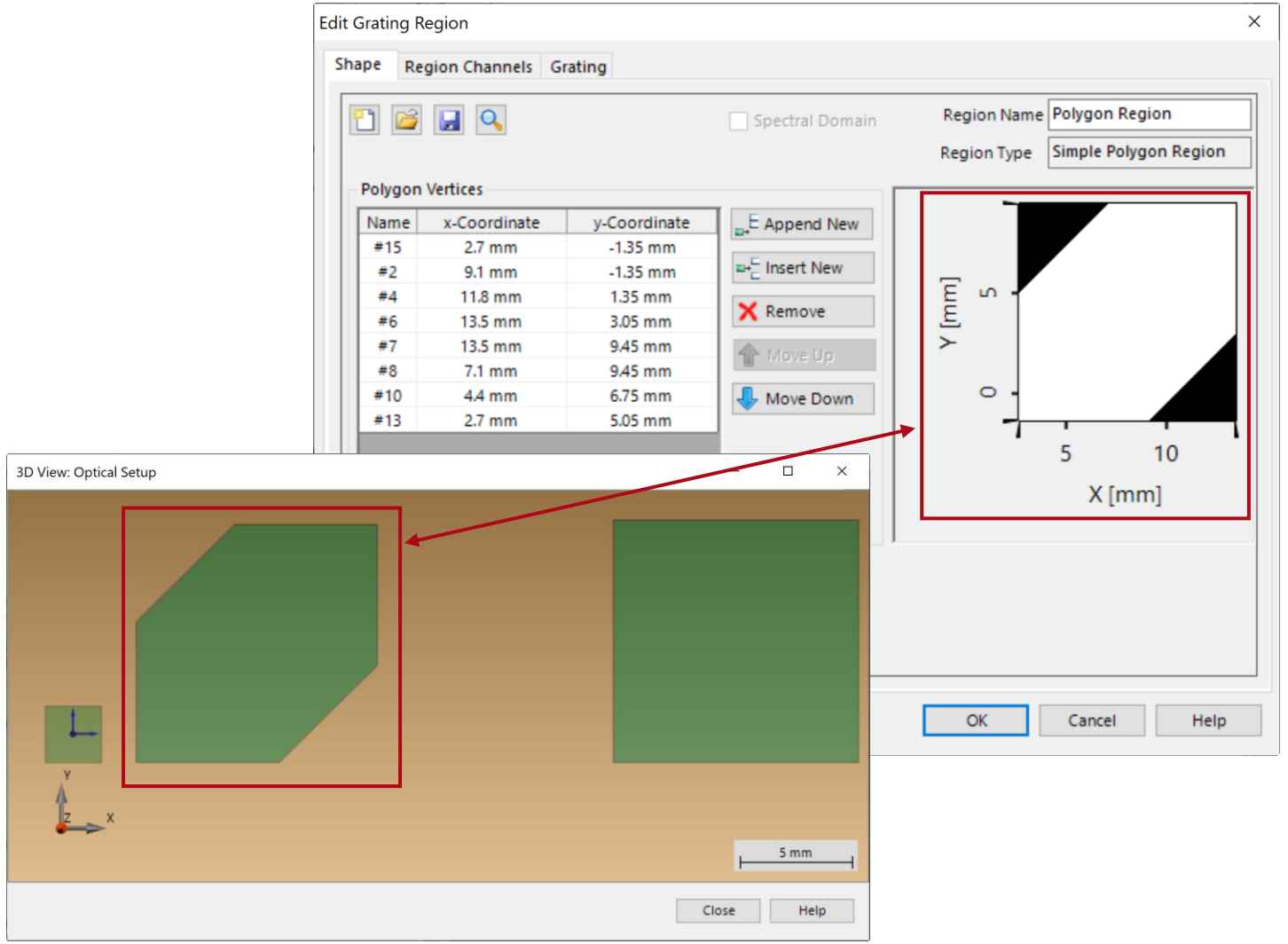
With the *Light Guide Component*, systems with regions with complex shapes can easily be defined. Further, these regions can be equipped with idealized or real grating structures to act as incoupler, outcoupler or exit pupil expanders. More information under:

Construction of a Light Guide



Eye-Pupil-Expander (EPE) Region

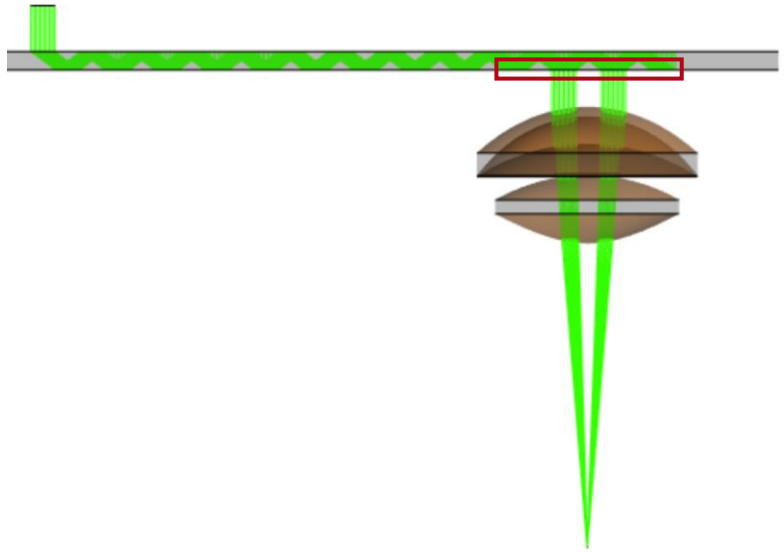


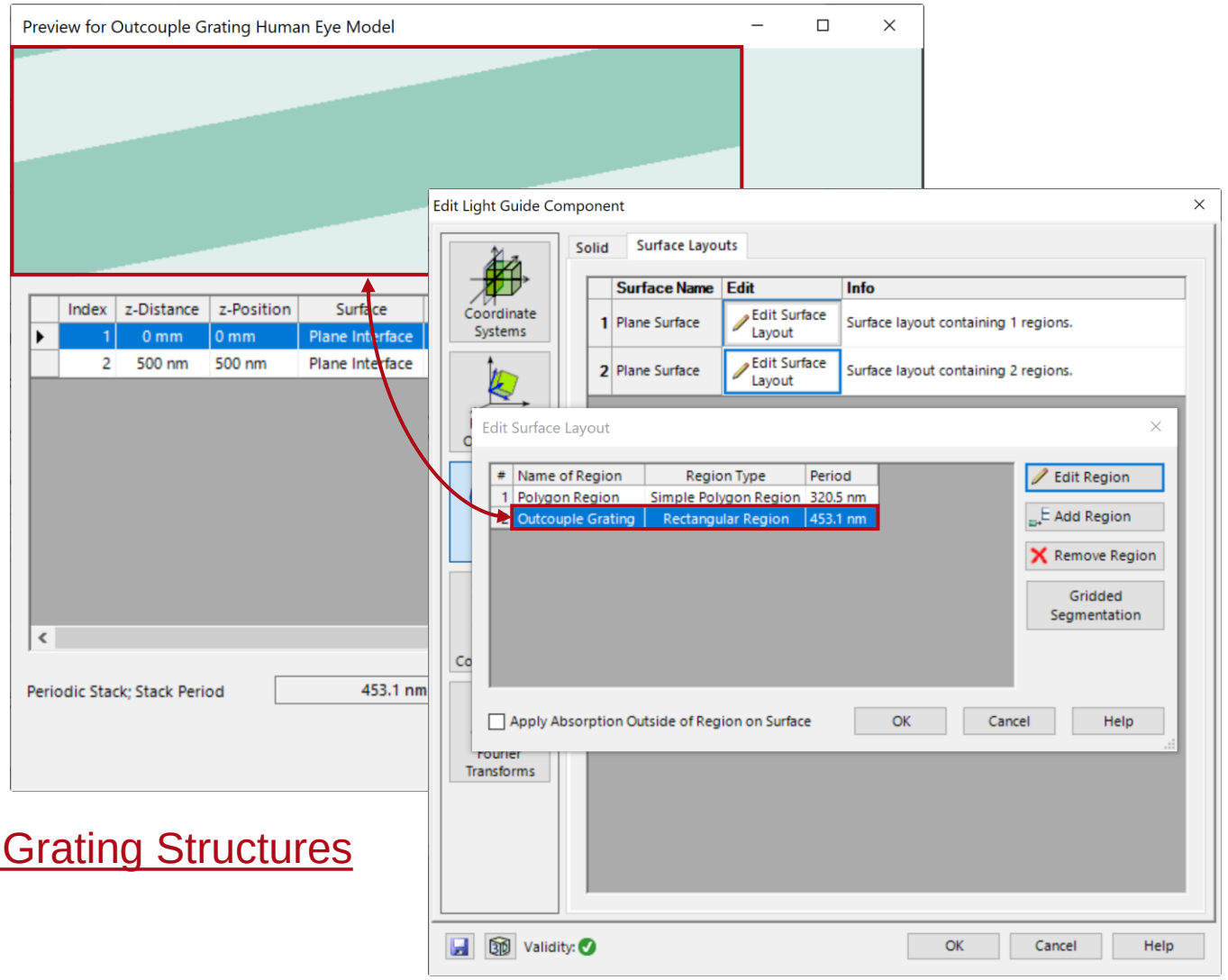


The shape of each region can be defined using different approaches. In this example, in- and outcoupler are rectangular regions, whereas for the EPE a polygonal region is used. More information for region definition under:

Flexible Region Configuration

Outcoupling Region

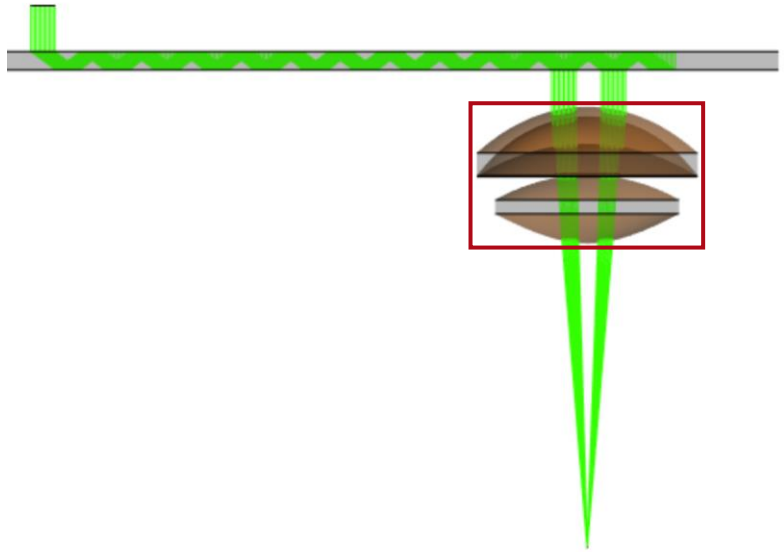




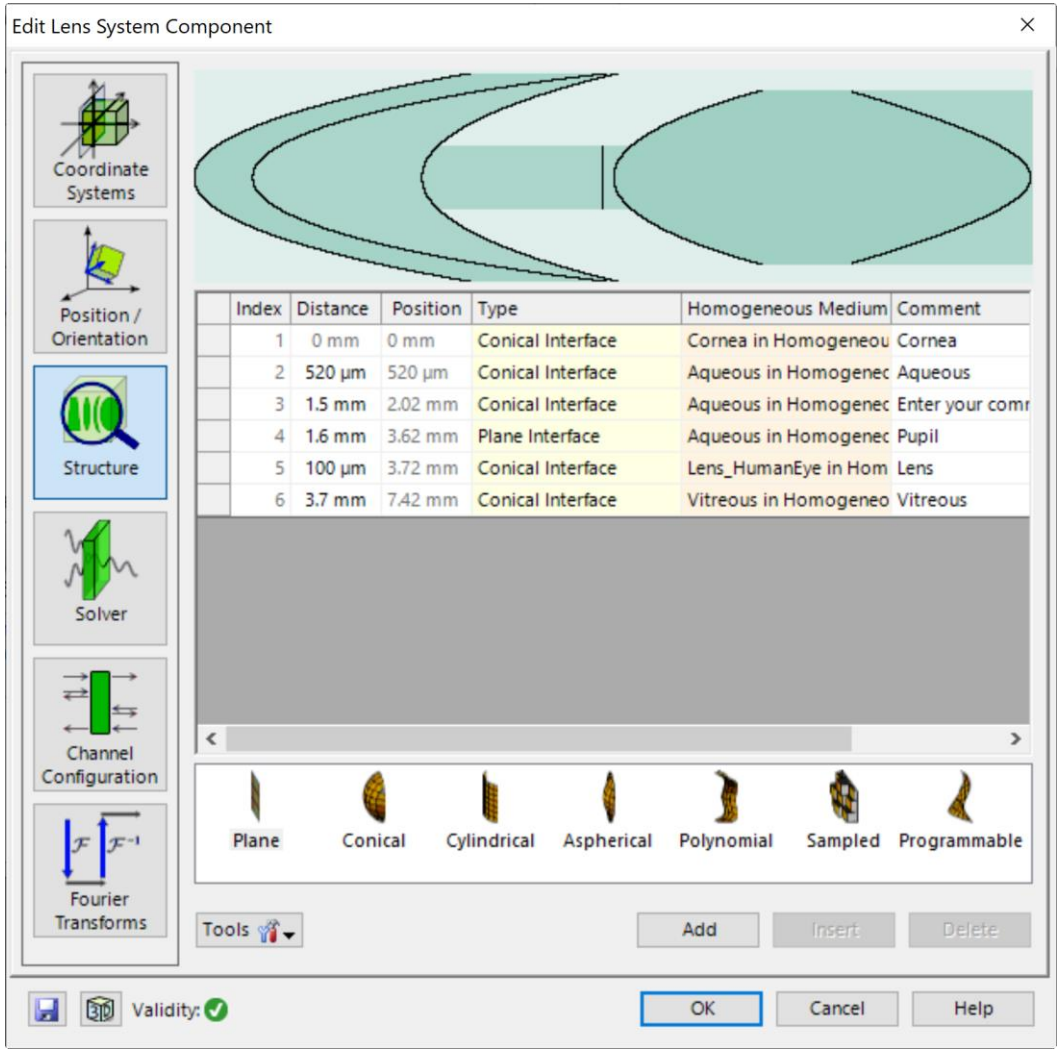
For the outcoupler a slanted grating is used, whose efficiencies are calculated rigorously by applying FMM (RCWA). You can find more information on how to set this up under:

How to Set Up a Lightguide with Real Grating Structures

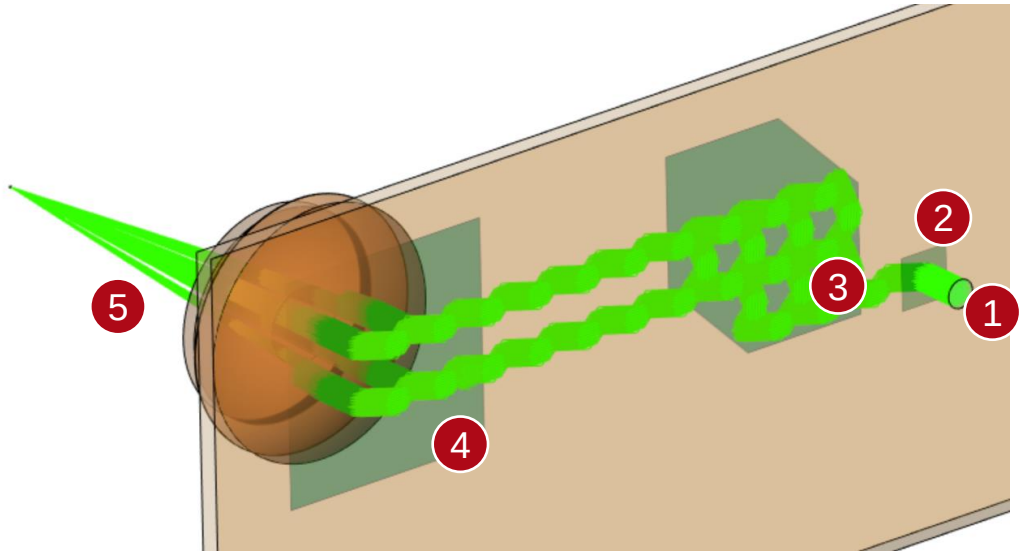
Human Eye Model



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.

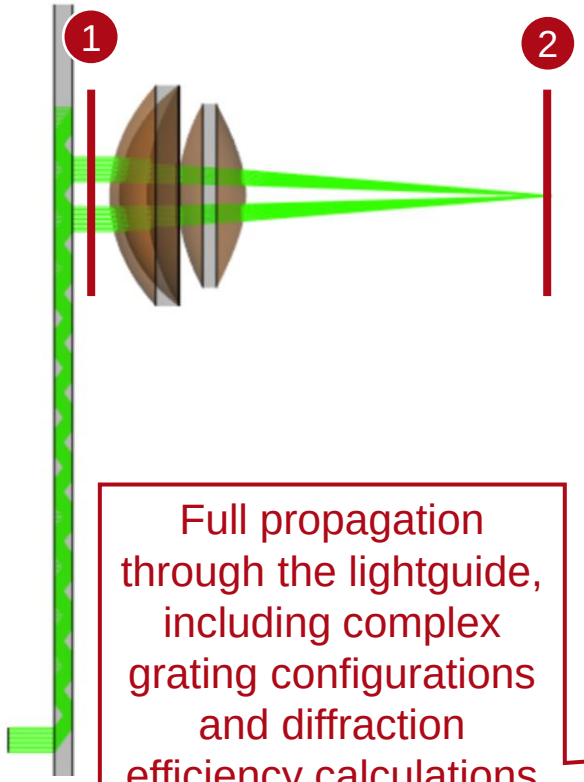


Summary – Components...



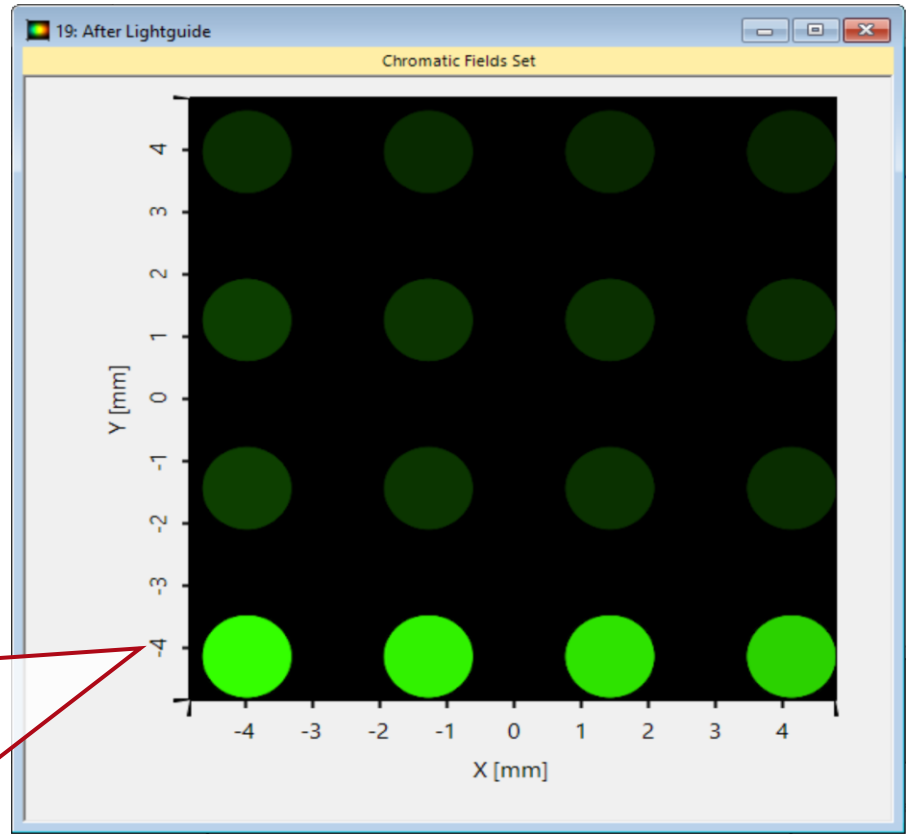
… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. Source	*Plane Wave* source	Truncated Ideal Plane Wave
2. Incoupler	Idealized grating in *Rectangular Region*	Idealized Rayleigh Matrices
3. Eye Pupil Expansion	Idealized grating in *Polygonal Region*	Idealized Rayleigh Matrices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

Field at Different Positions/Planes in the System

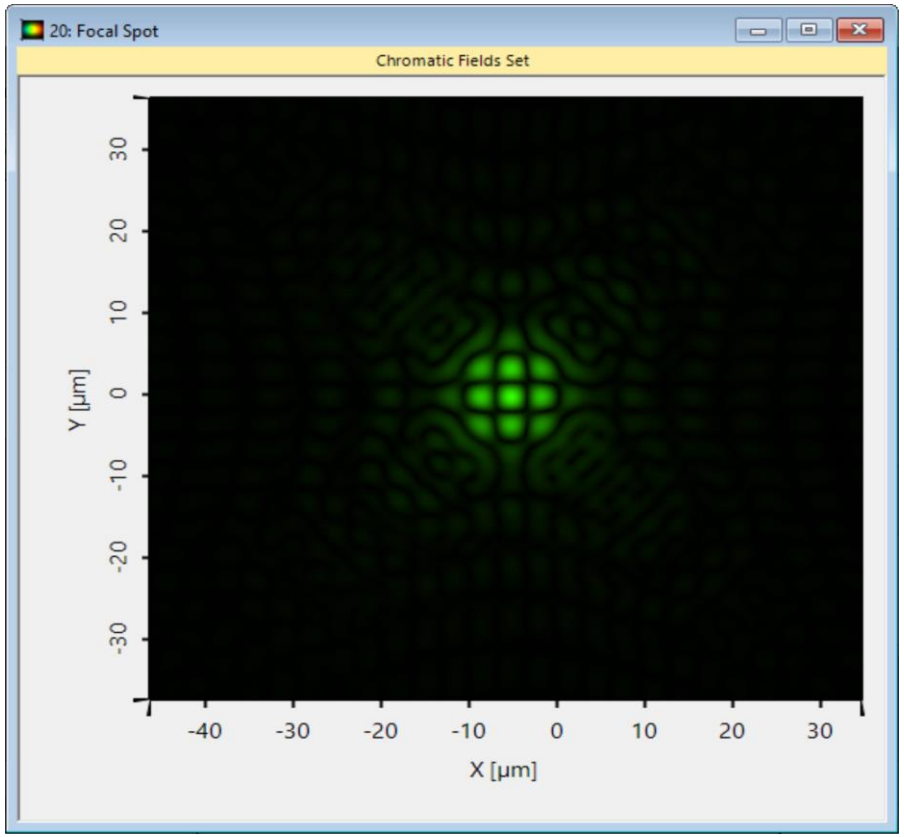


VirtualLab Fusion can calculate the electromagnetic field after the lightguide and in the focal spot.

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

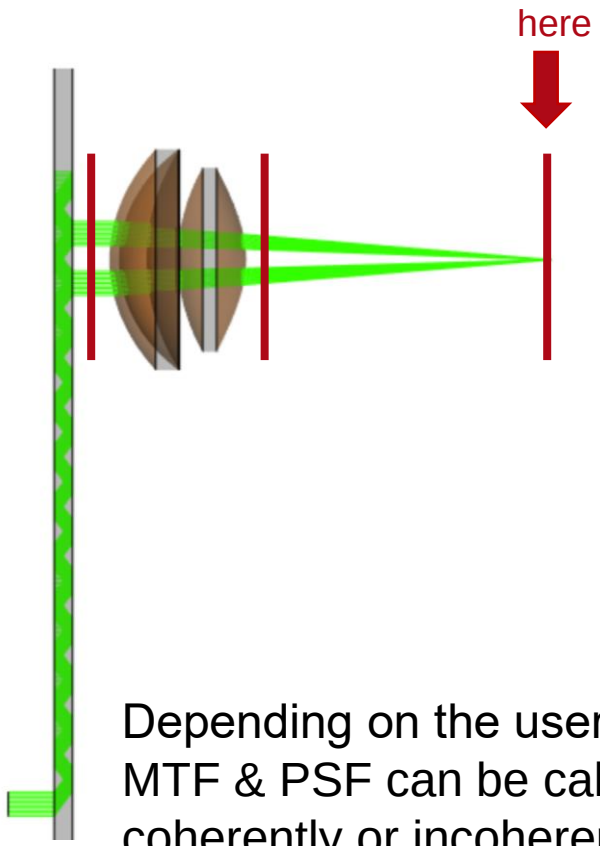


1 field after lightguide

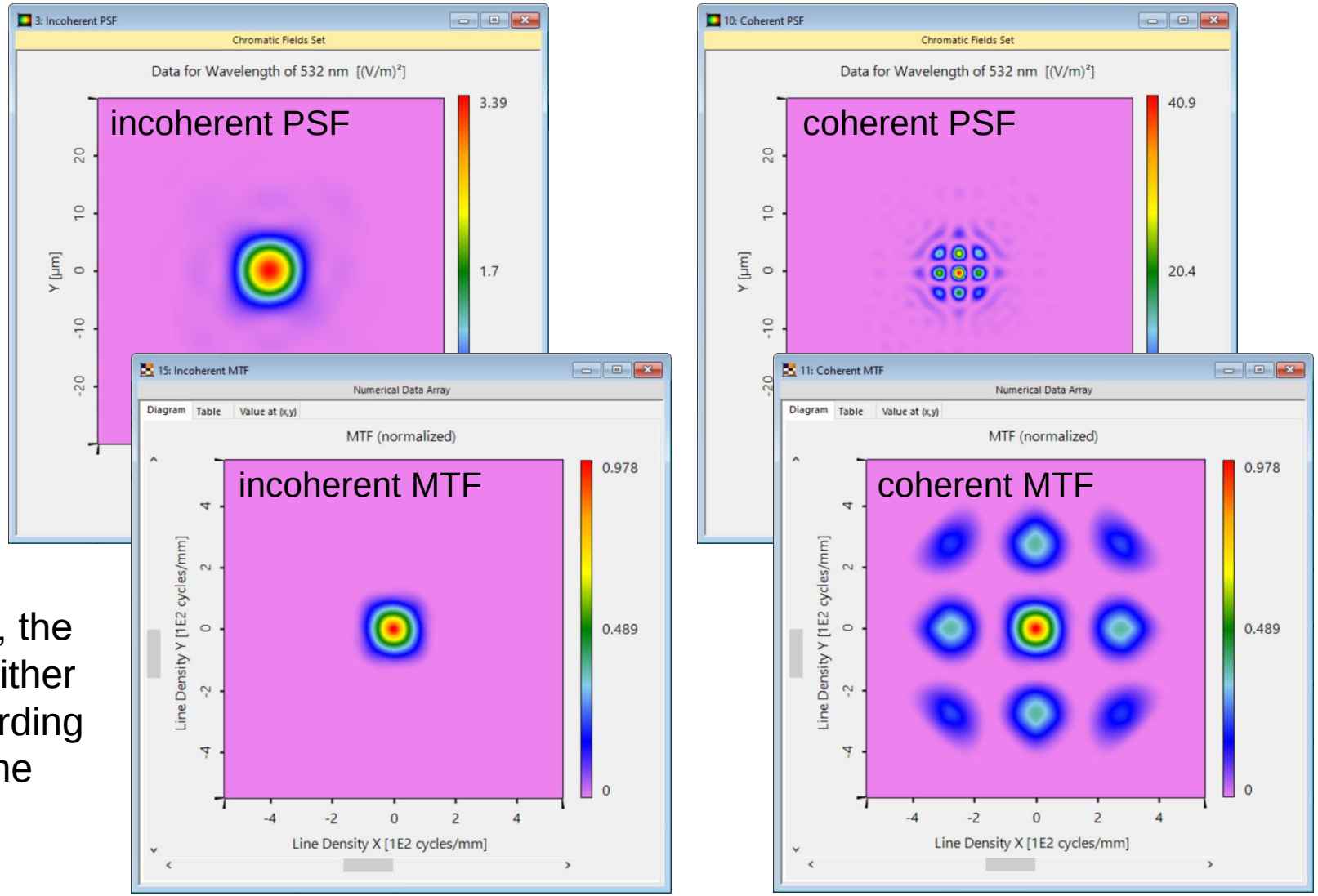


2 field in focal plane

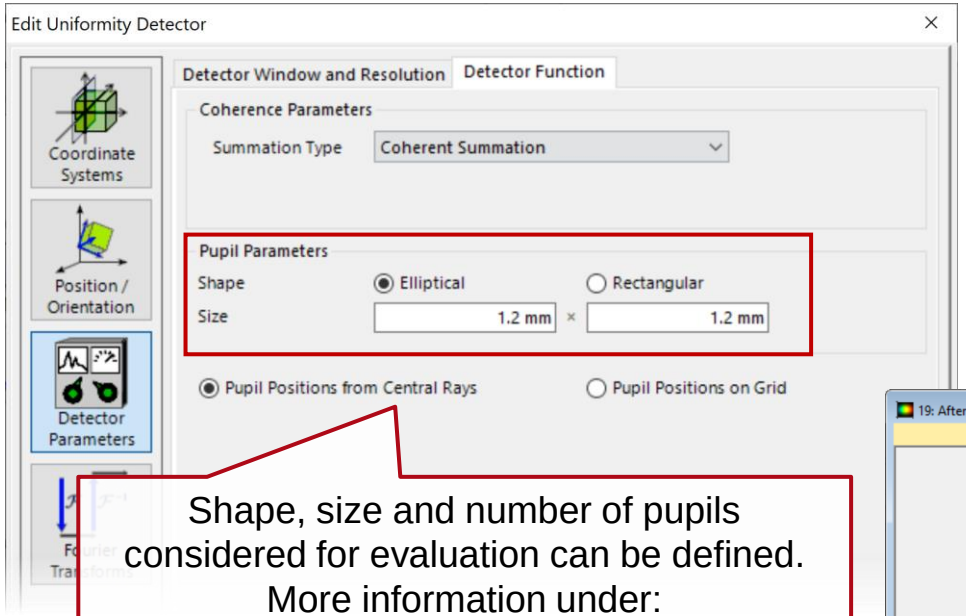
MTF & PSF – Calculation



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



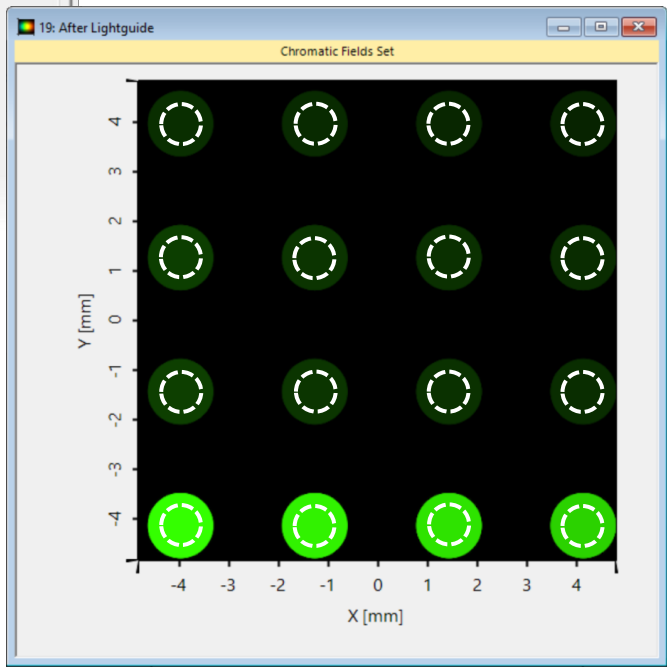
Shape, size and number of pupils considered for evaluation can be defined. More information under:

Uniformity Detector for Lightguide Systems

result of *Uniformity Detector*

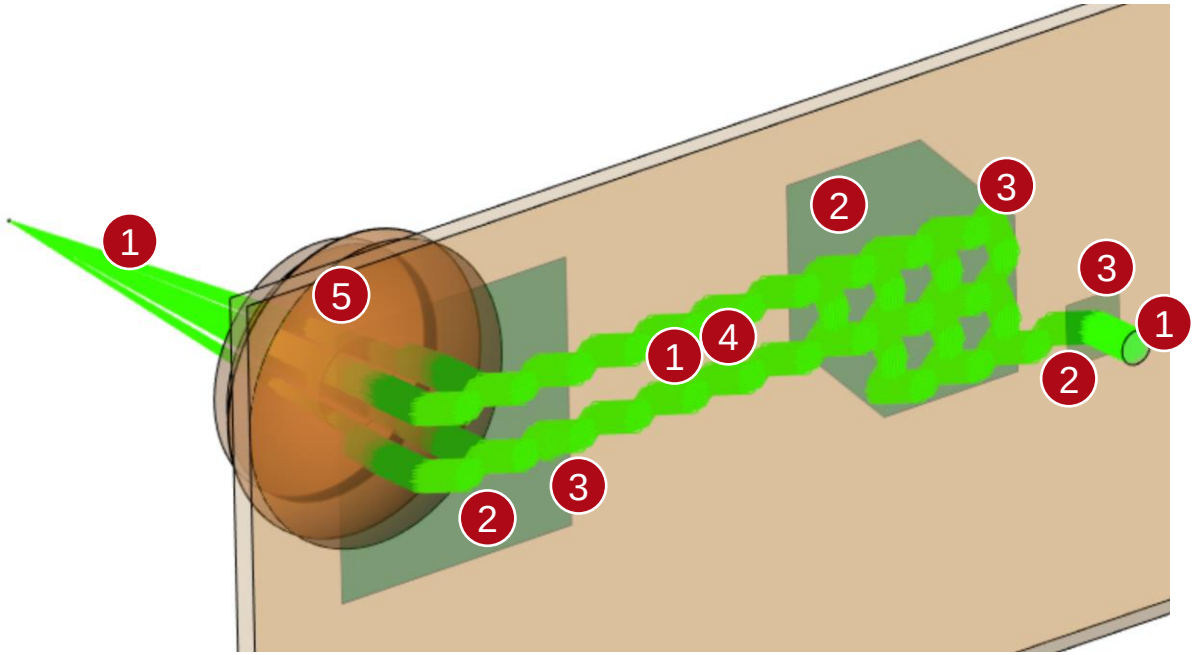
Value for Pupil around (-3.97 mm; -4.15 mm)	0.0122 (V/m)²
Value for Pupil around (-3.97 mm; -1.45 mm)	0.000566 (V/m)²
Value for Pupil around (-1.27 mm; -4.15 mm)	0.0109 (V/m)²
Value for Pupil around (-3.97 mm; 1.25 mm)	0.000533 (V/m)²
Value for Pupil around (-1.27 mm; -1.45 mm)	0.00038 (V/m)²
Value for 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

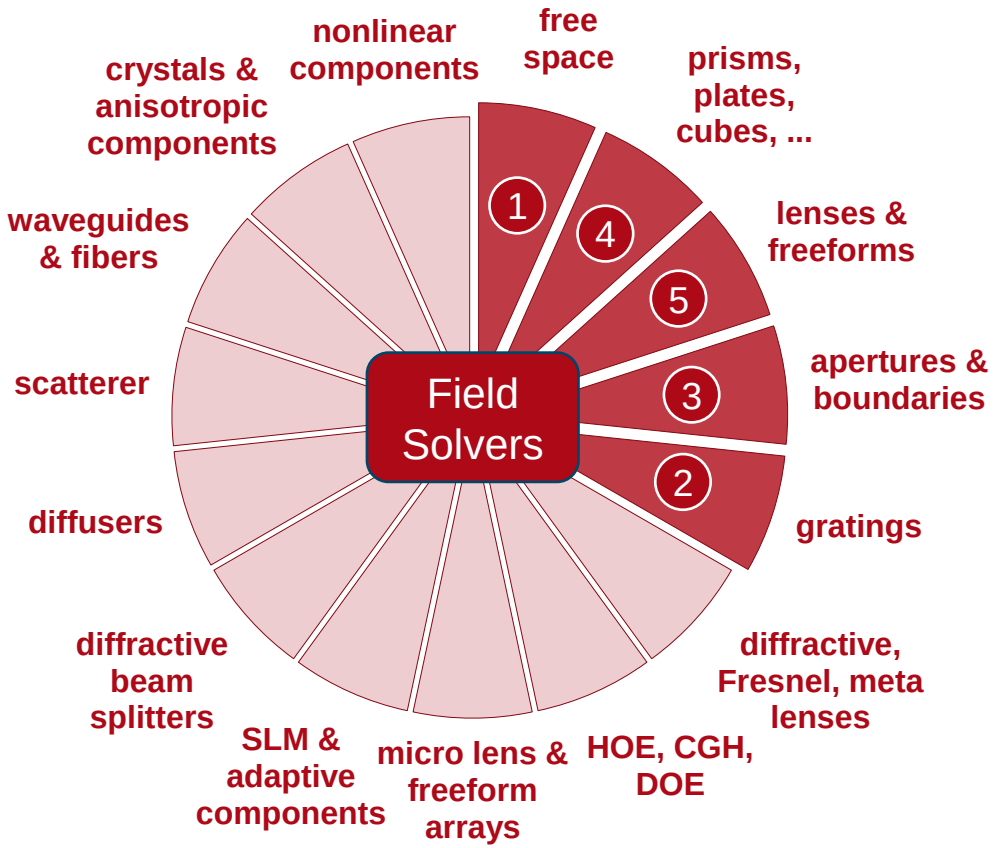
result of *Camera Detector*



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

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	• VirtualLab Fusion Advanced • Light Guide Toolbox Silver Edition
category	Application Use Case
further reading	- Uniformity Detector for Lightguide Systems - Construction of a Light Guide - Light Guide Layout Design Tool - Simulation of Lightguide with 1D-1D Pupil Expander and Real Gratings - Flexible Region Configuration - How to Set Up a Lightguide with Real Grating Structures