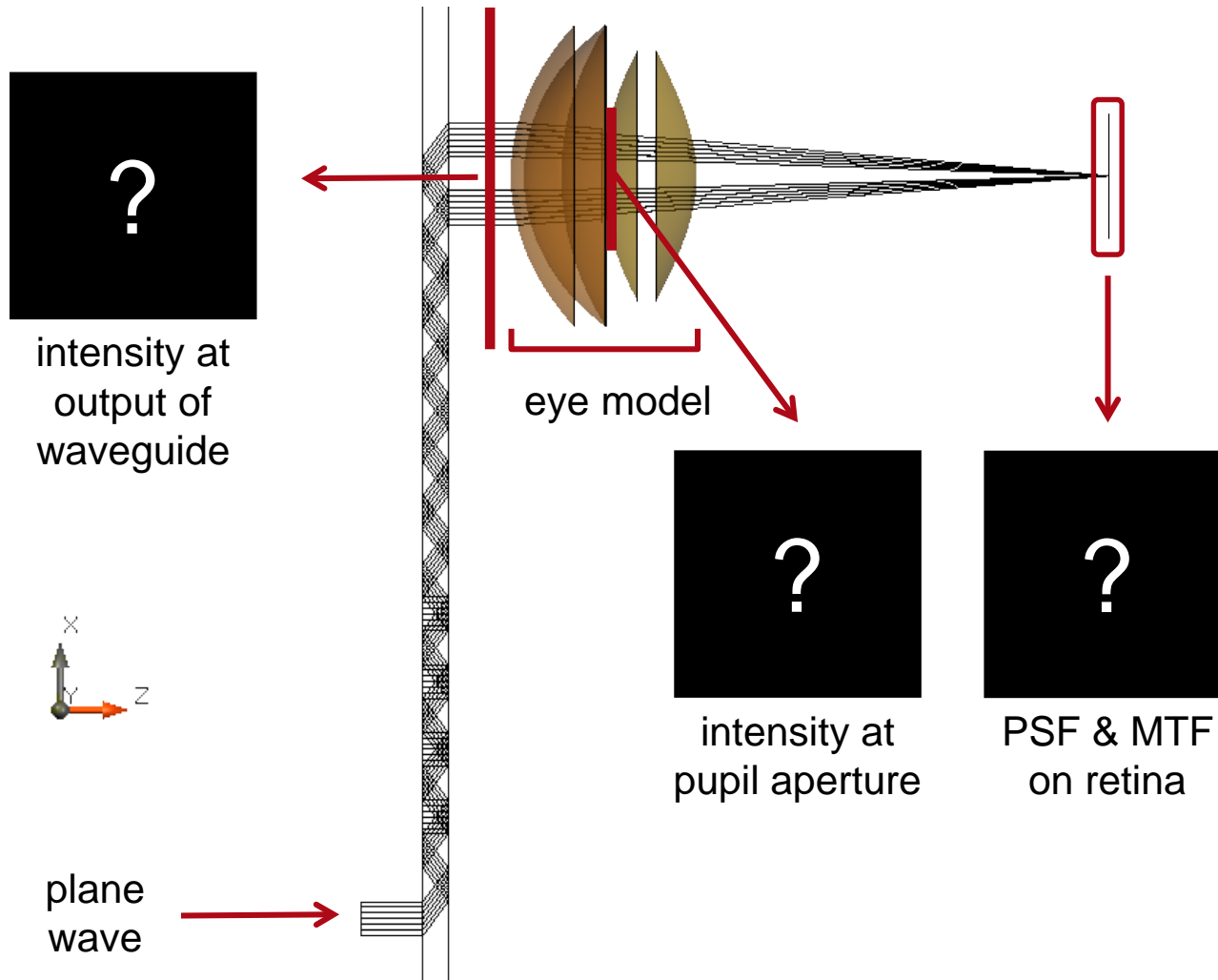


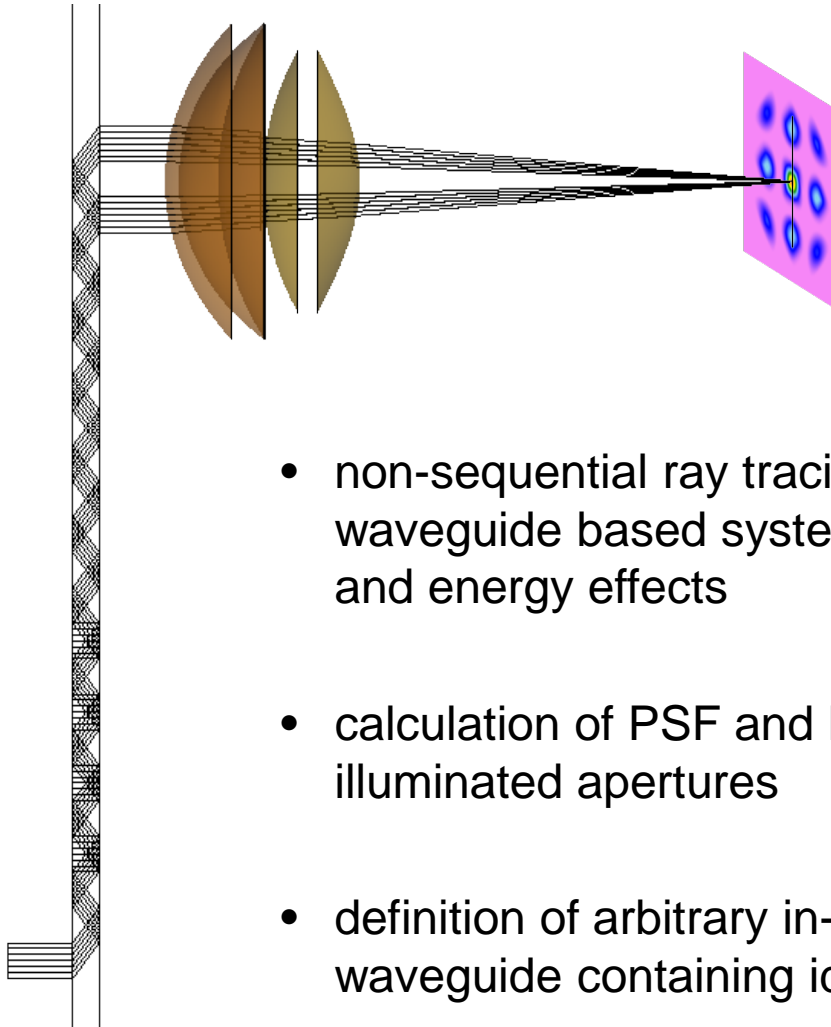
Virtual and Mixed Reality > Near-Eye Displays

## **Simulation of Waveguide System containing a Complex 2D Exit Pupil Expansion**

# Task/System Illustration

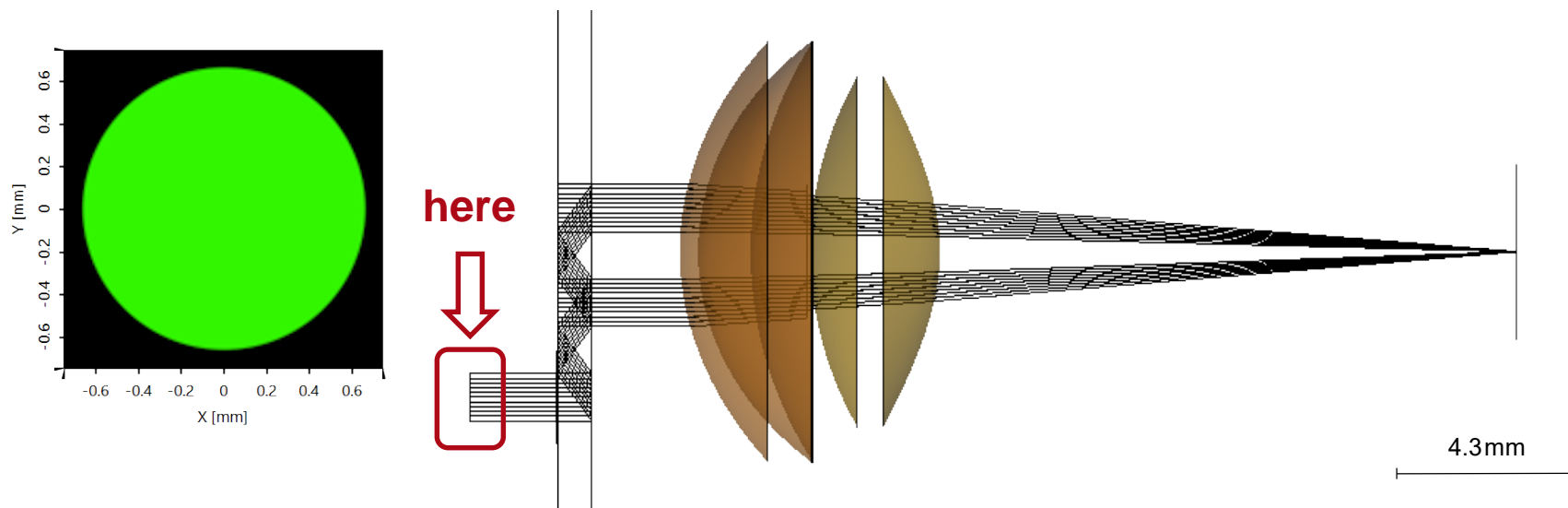


# Highlights



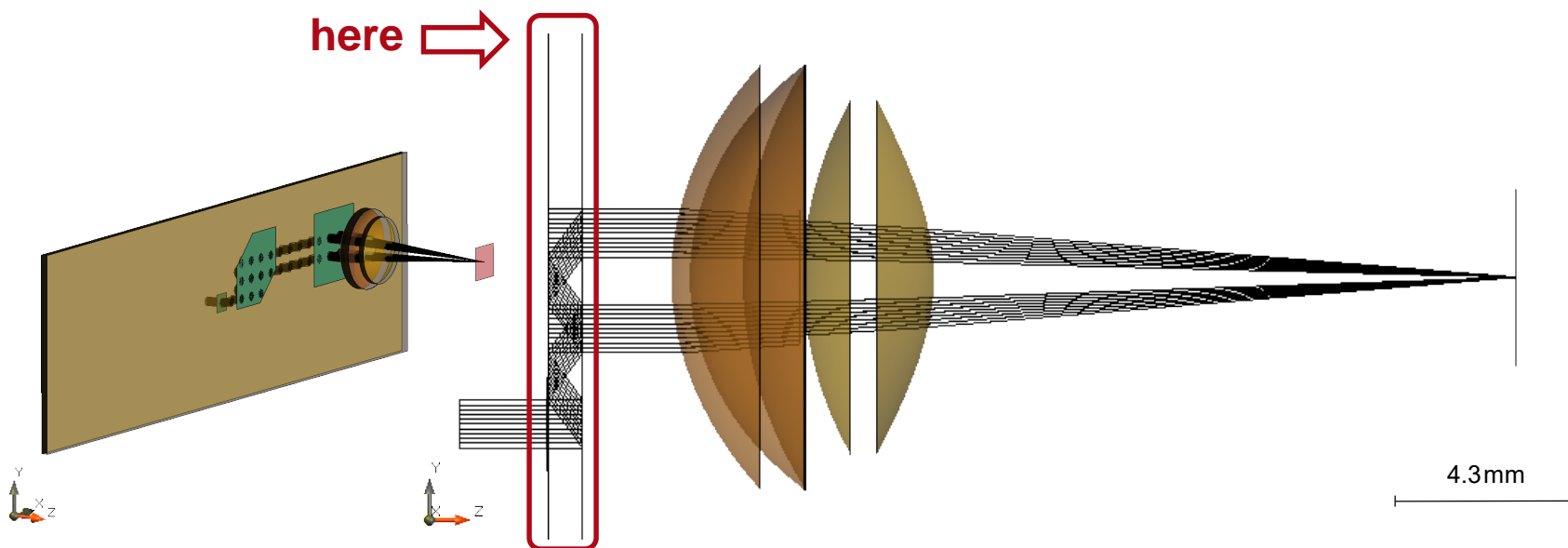
- non-sequential ray tracing and field tracing analysis of waveguide based systems including coherence, polarization and energy effects
- calculation of PSF and MTF of arbitrary shaped and illuminated apertures
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or real grating surfaces

# Specification: Light Source



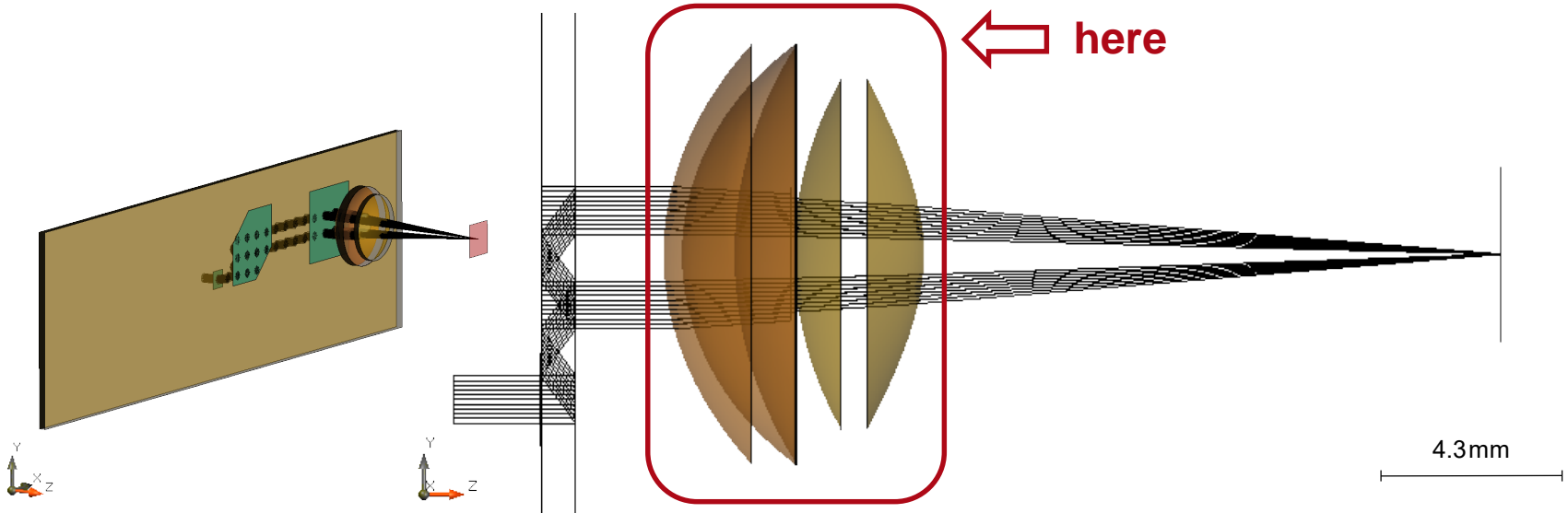
Parameter	Description / Value & Unit
name/type	plane wave
aperture	1.3mm×1.3mm (circular)
wavelength	532nm
polarization	linear in x-direction (0°)

# Specification: Waveguide



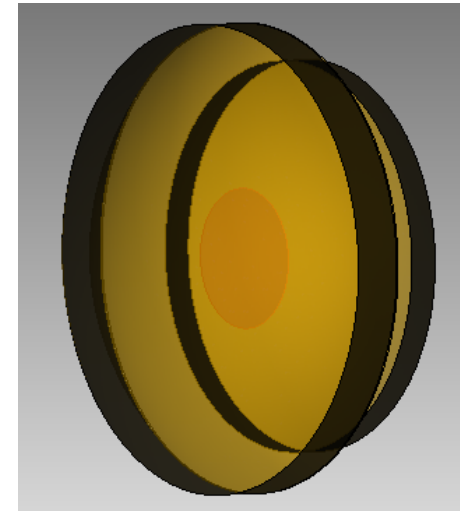
Parameter	Description / Value & Unit
waveguide thickness	1 mm
waveguide material	fused silica
waveguide geometry	parallel plane interfaces
number of regions	3

# Specification: Model of Human Eye

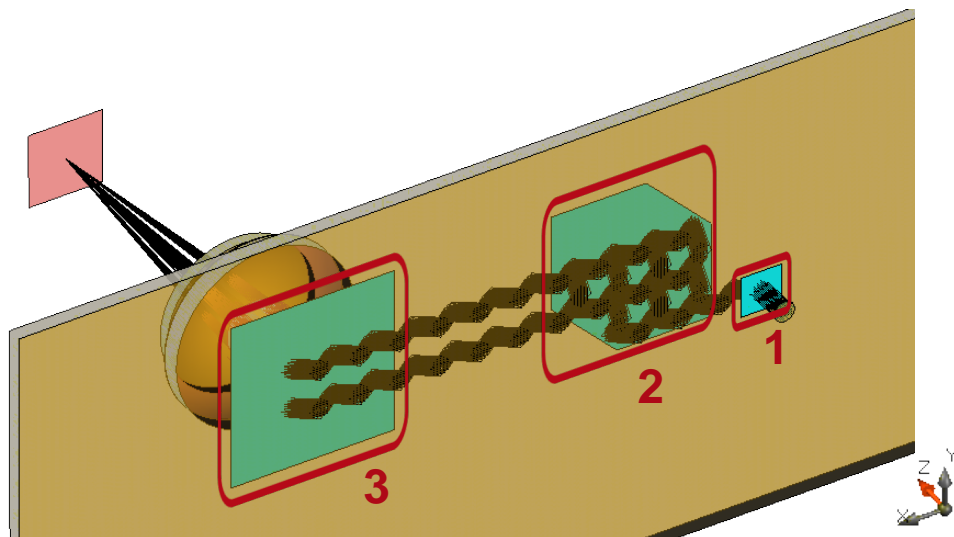


model of human eye contains:

- cornea
- aqueous
- pupil (incl. diameter)
- lens
- vitreous



# Specification: Regions

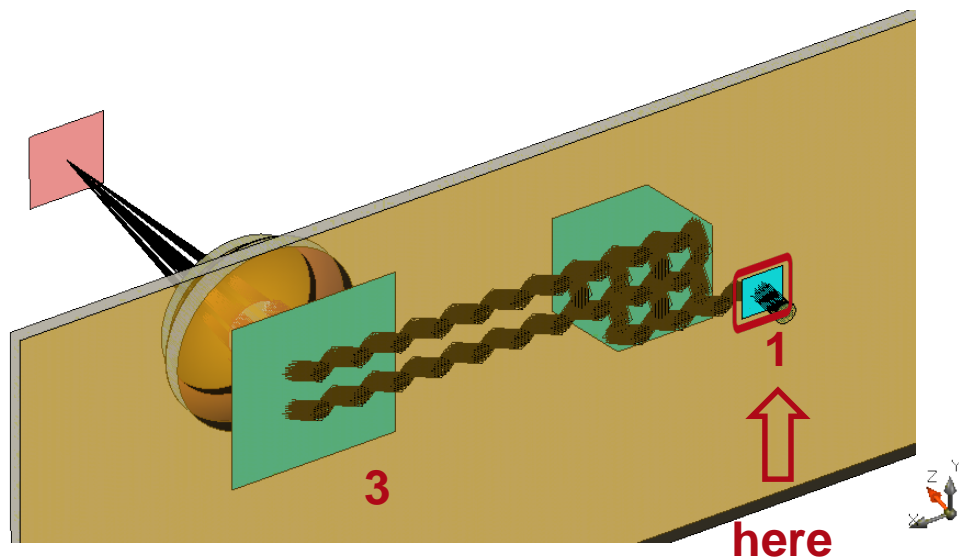


## Highlights

- **non-sequential** ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or **real grating** surfaces

Region	Description / Value & Unit
1	incoupling region
2	2D exit pupil expansion region
3	outcoupling region

# Specification: Incoupling Grating



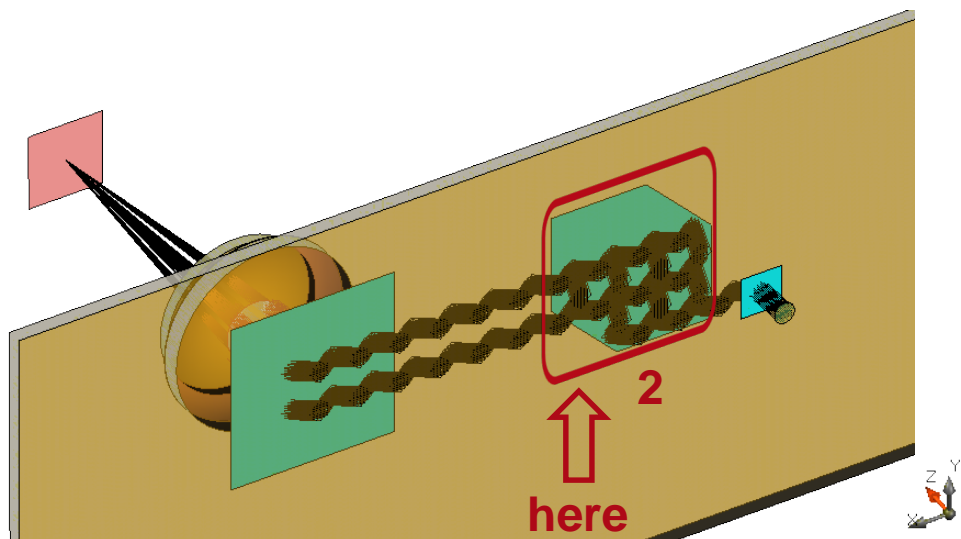
## Highlights

- **non-sequential** ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or **real grating** surfaces

Parameter	Description / Value & Unit
grating type	ideal grating
grating period	453.24 nm
rotation angle	0°
region shape	rectangular
region size	2.7x2.7 mm



# Specification: 2D Expansion Grating

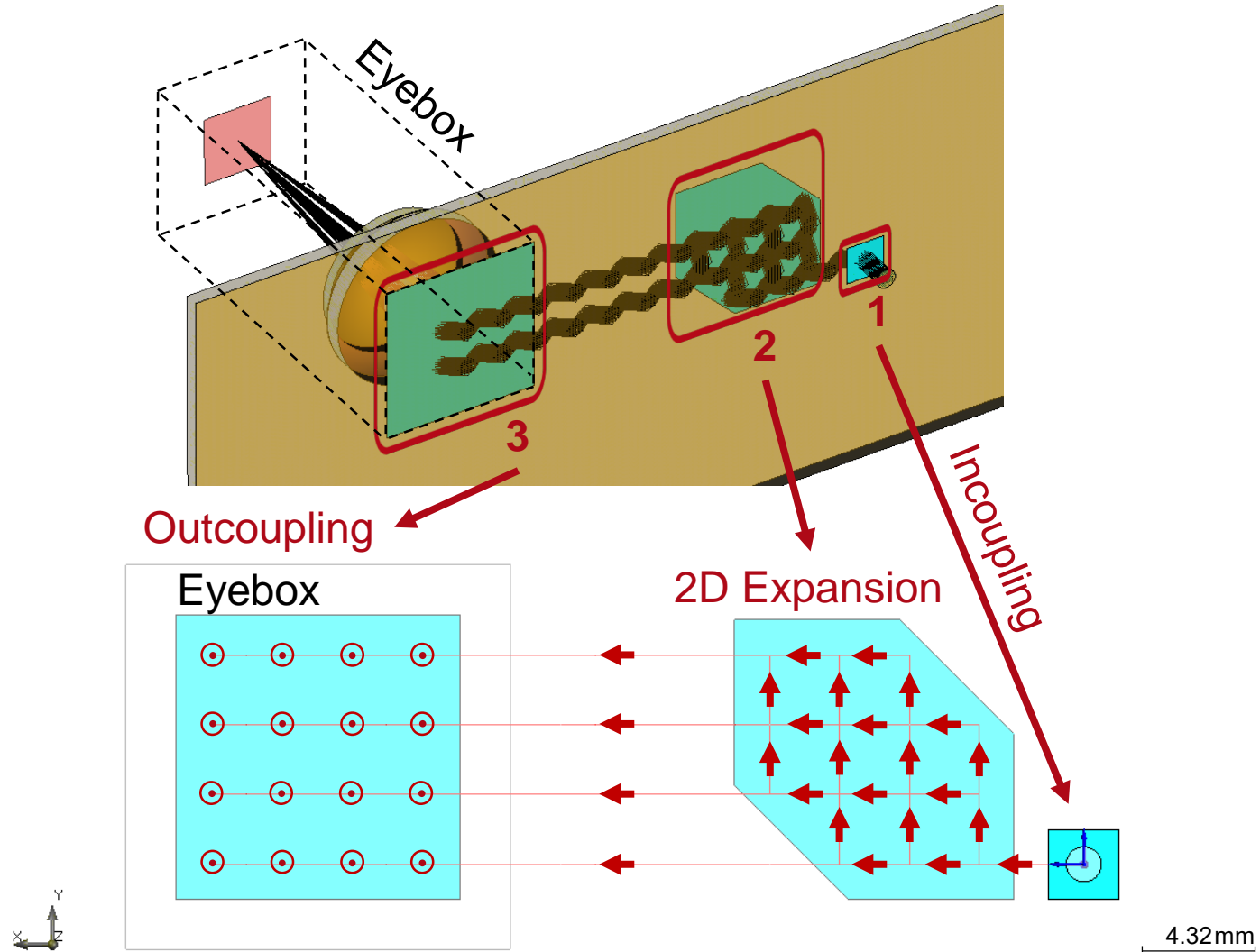


## Highlights

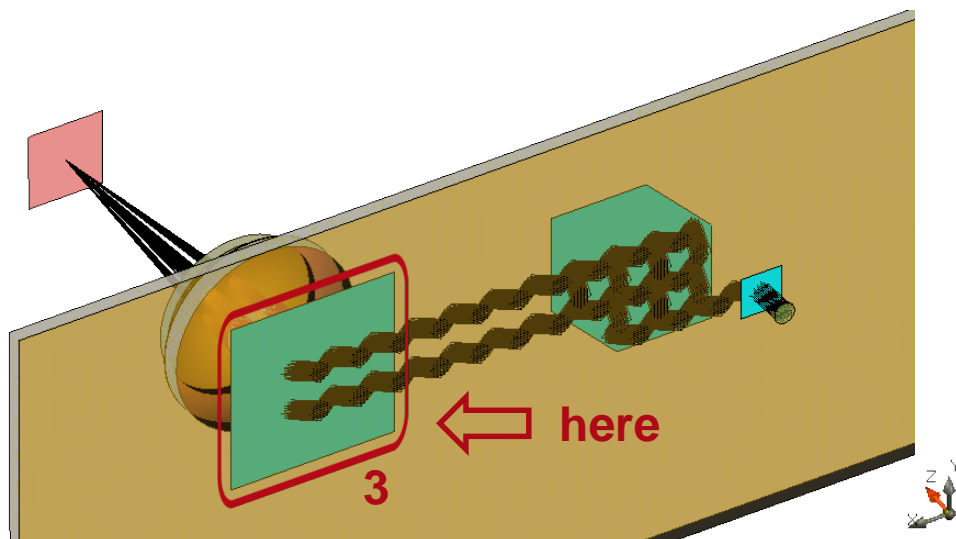
- non-sequential ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or real grating surfaces

Parameter	Description / Value & Unit
grating type	ideal grating
grating period	320.49 nm
rotation angle	-45°
region shape	polygon

# Concept: 2D Exit Pupil Expansion



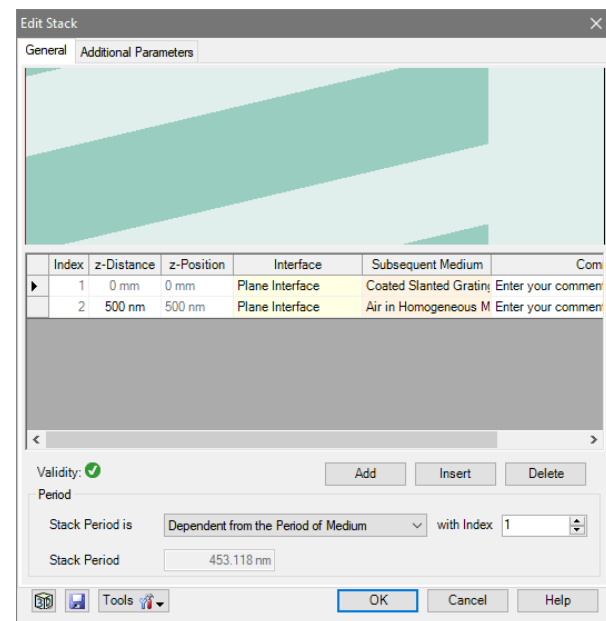
# Specification: Outcouling Grating



## Highlights

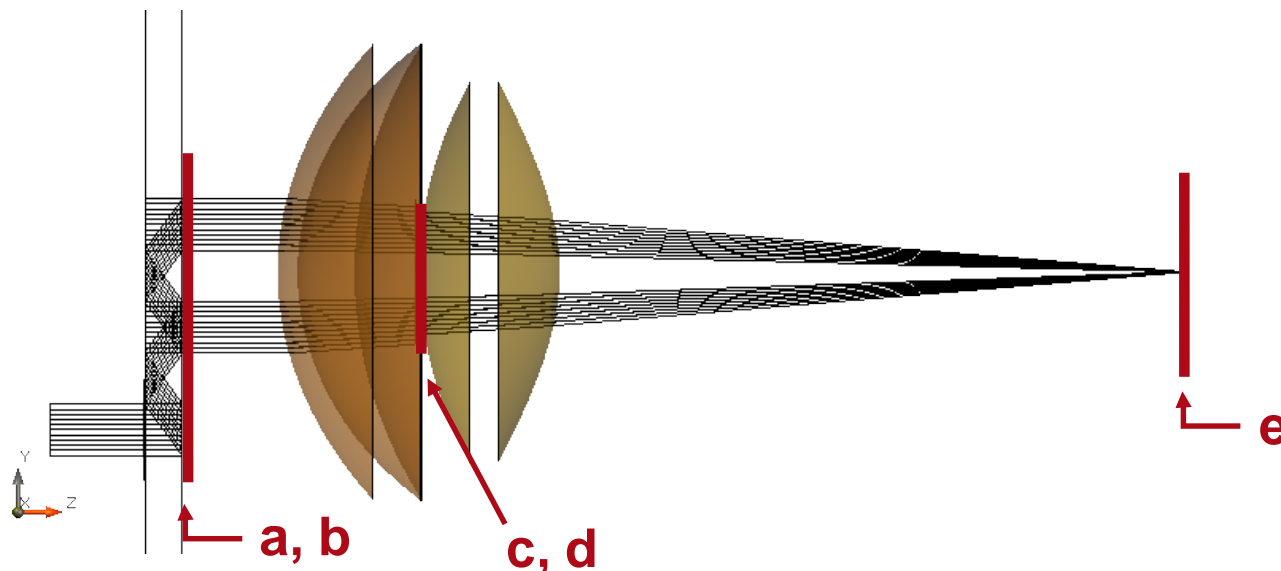
- **non-sequential** ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or **real grating** surfaces

## definition of a slanted grating



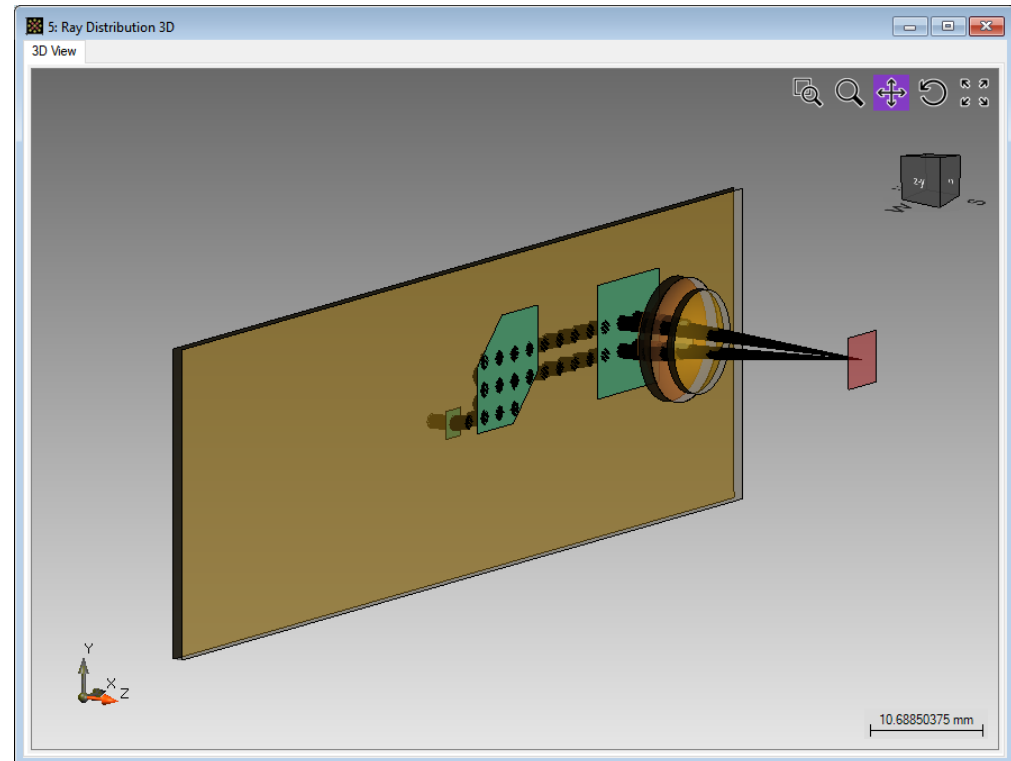
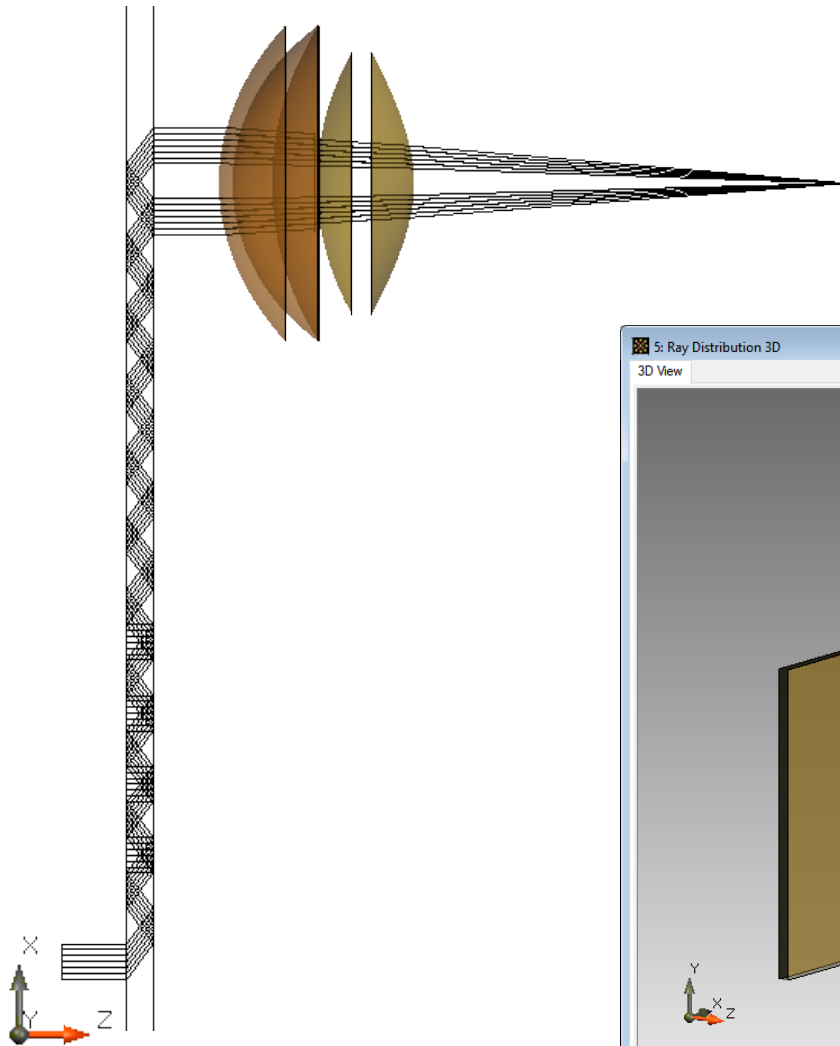
Parameter	Description / Value & Unit
grating type	real grating
grating period	453.118 nm
rotation angle	0°
region shape	rectangular
region size	11 x 11 mm

# Specification: Detectors

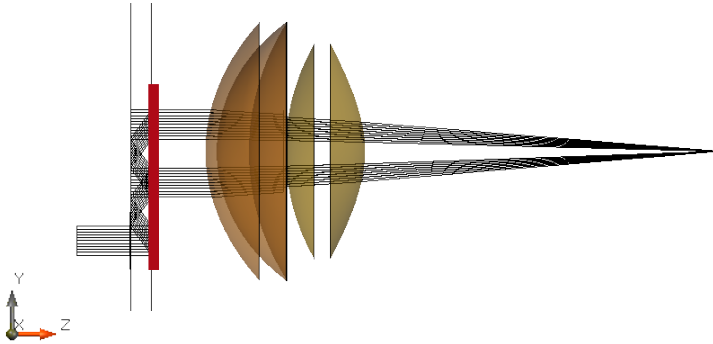


Position	Modeling Technique	Detector/Analyzer
full system	3D ray tracing	3D ray tracing system visualization
a	ray tracing	spot diagram
b	field tracing	intensity pattern
c	ray tracing	spot diagram
d	field tracing	intensity pattern
e	field tracing	2D PSF and MTF calculation

# Result: 3D Ray Tracing



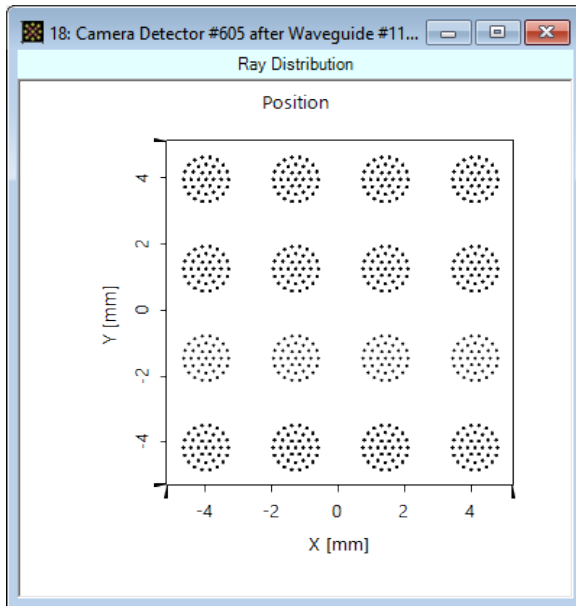
# Result: Spots & Intensity after Outcoupling



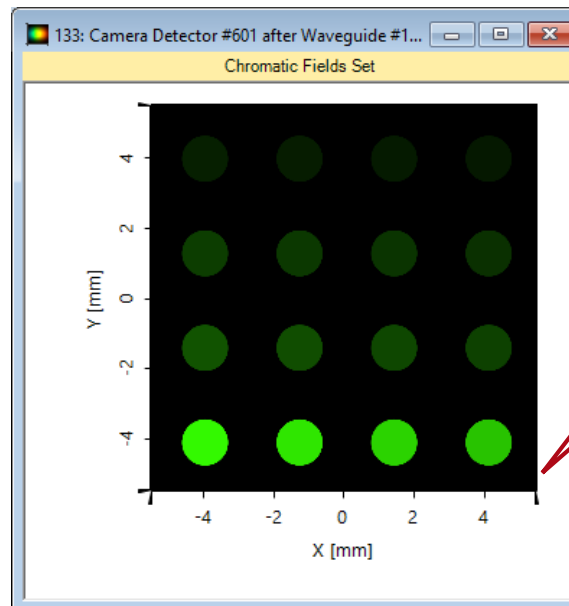
## Highlights

- non-sequential ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or real grating surfaces

ray tracing spot diagram

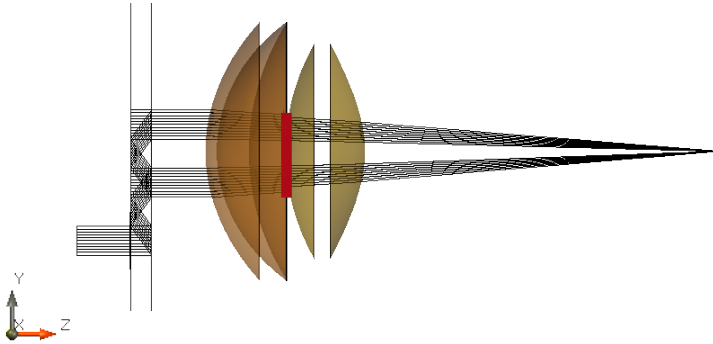


intensity  
(real color view)



**simulation time  
~15s (rigorous  
grating simulation  
included!)**

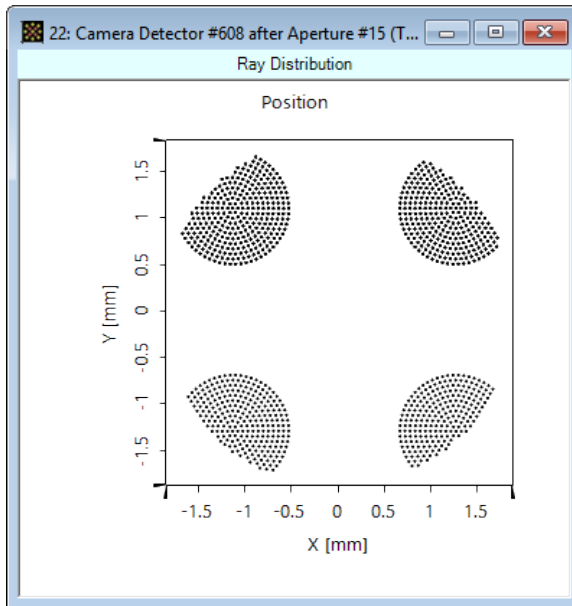
# Result: Spots & Intensity at Pupil



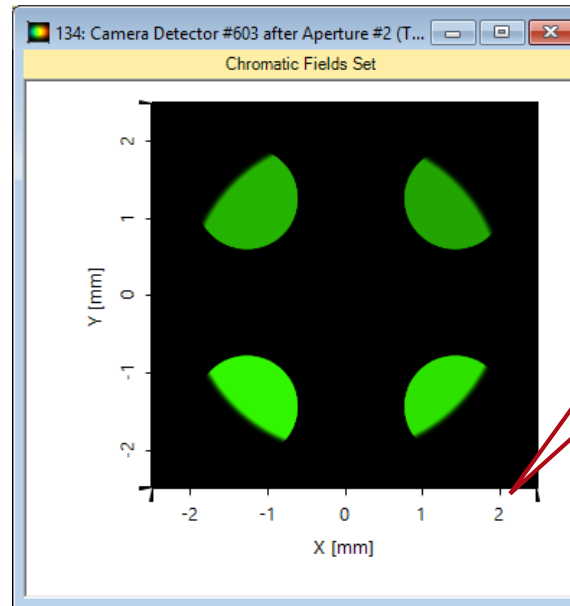
## Highlights

- non-sequential ray and field tracing analysis of waveguide optics
- definition of arbitrary in- and outcoupling regions at the waveguide containing ideal or real grating surfaces

ray tracing spot diagram

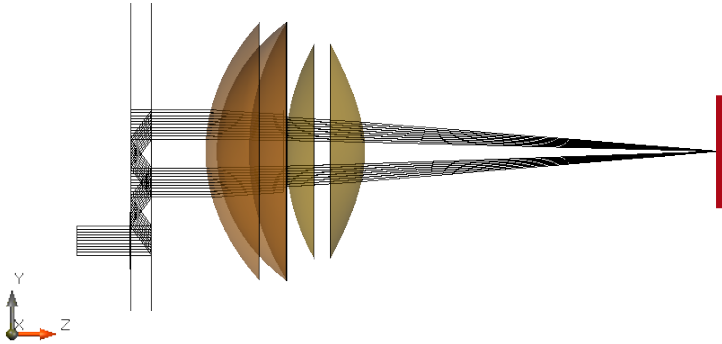


intensity  
(real color view)



simulation time  
~17s (rigorous  
grating simulation  
included!)

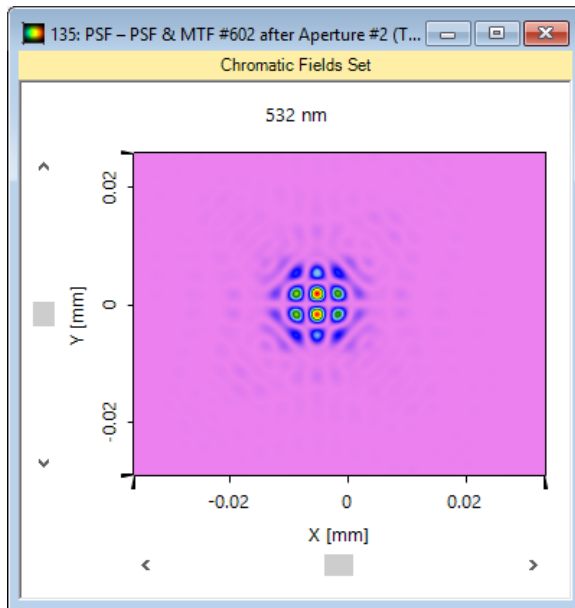
# Result: PSF at Retina



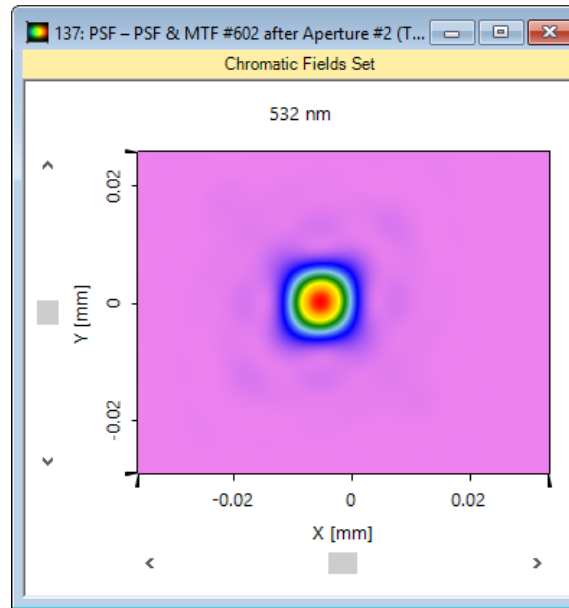
## Highlights

- non-sequential ray and field tracing analysis of waveguide optics including **coherence**, polarization and energy effects
- calculation of **PSF** and MTF of arbitrary shaped and illuminated apertures

PSF coherent

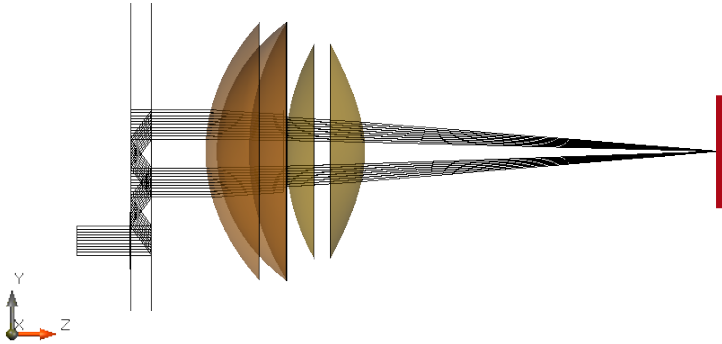


PSF incoherent





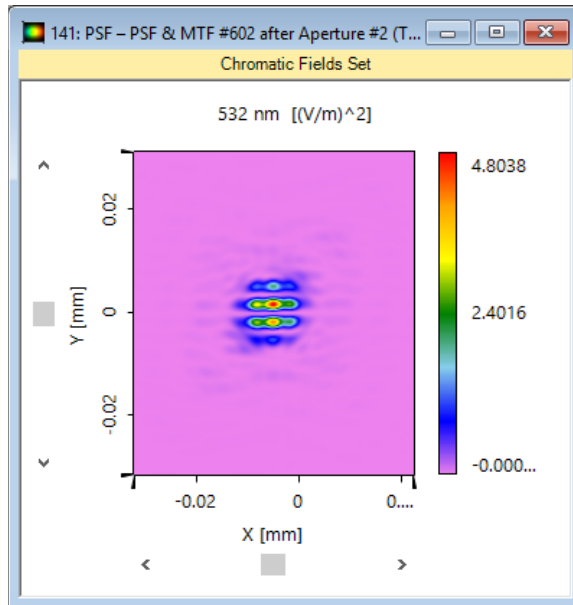
# Result: PSF at Retina



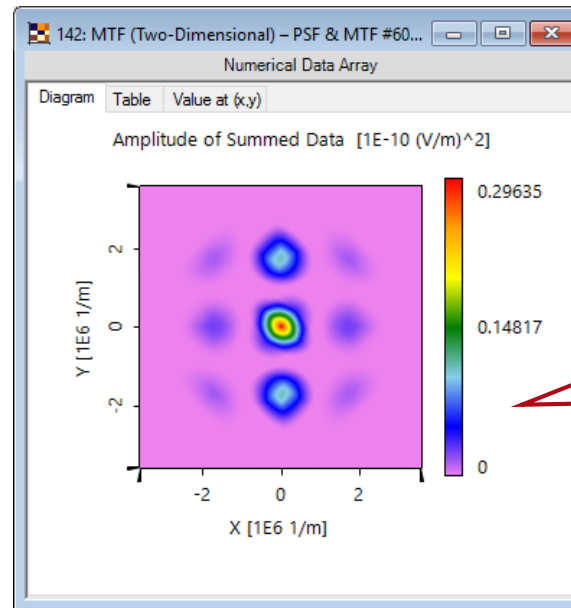
## Highlights

- non-sequential ray and field tracing analysis of waveguide optics including coherence, polarization and energy effects
- calculation of PSF and MTF of arbitrary shaped and illuminated apertures

PSF coherent

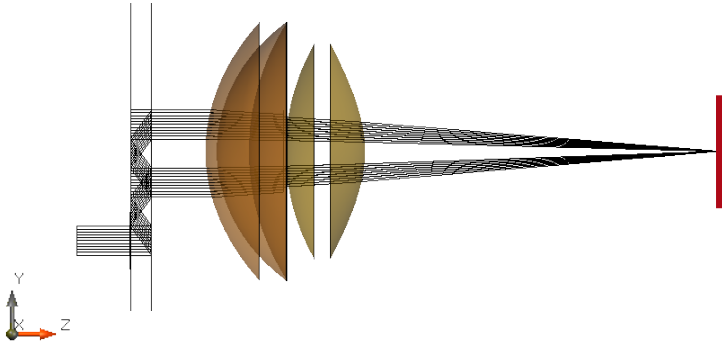


MTF coherent



changing  
polarization to  
linear in y-  
direction (90°)

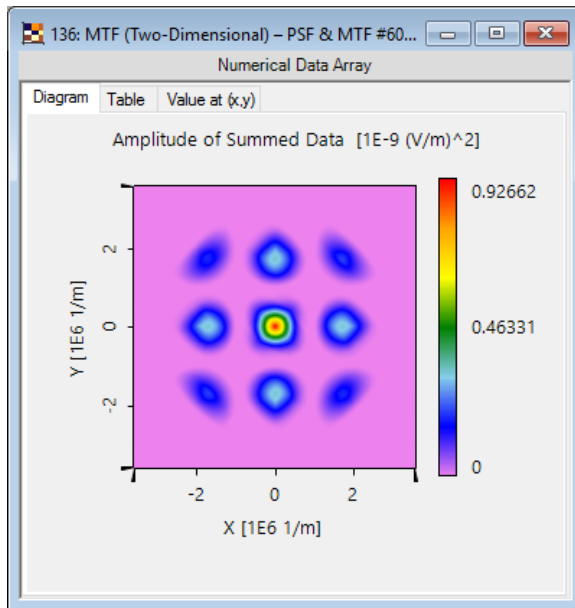
# Result: MTF at Retina



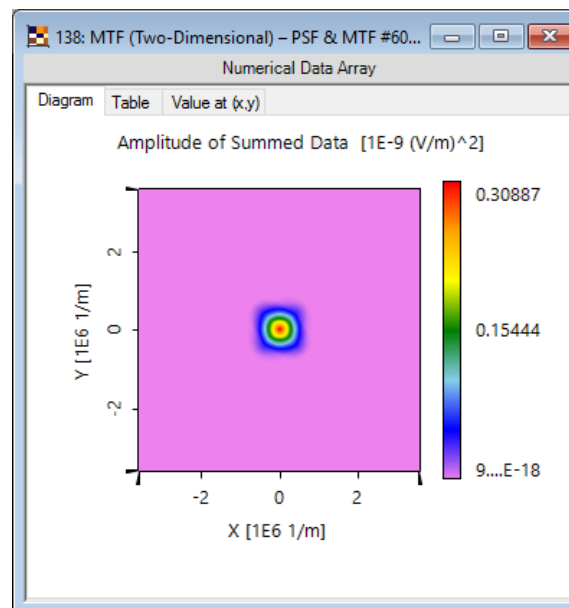
## Highlights

- non-sequential ray and field tracing analysis of waveguide optics including **coherence**, polarization and energy effects
- calculation of PSF and **MTF** of arbitrary shaped and illuminated apertures

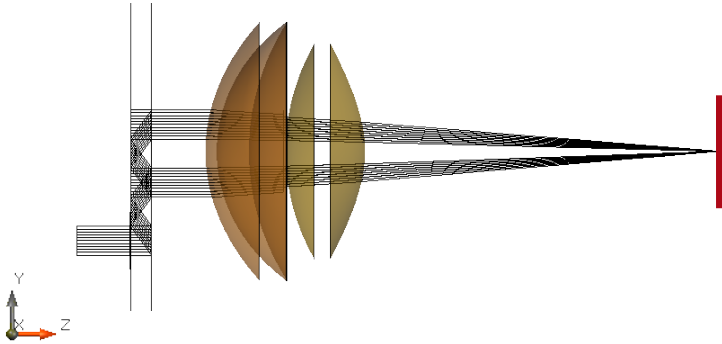
MTF coherent



MTF incoherent

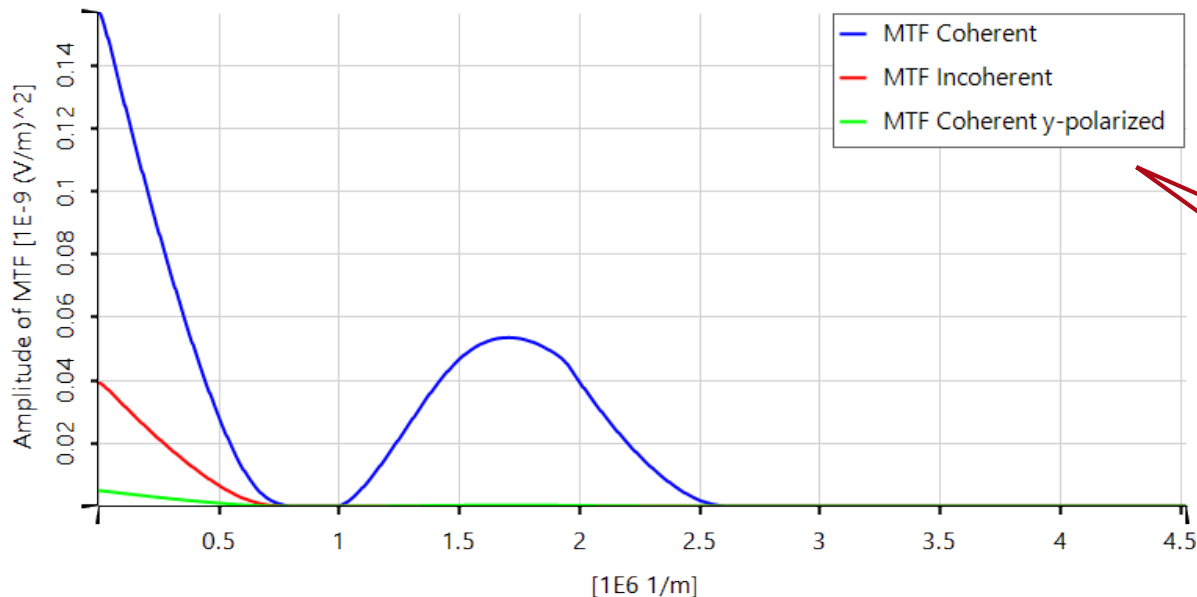


# Result: MTF at Retina



## Highlights

- non-sequential ray and field tracing analysis of waveguide optics including coherence, polarization and energy effects
- calculation of PSF and MTF of arbitrary shaped and illuminated apertures



**MTF strongly dependent on coherence and polarization effects**

# Document & Technical Info

---

code	NED.0007
version of document	1.0
title	Simulation of Waveguide System containing a Complex 2D Exit Pupil Expansion
category	Virtual and Mixed Reality > Near-Eye-Displays
created by	Roberto Knoth (LightTrans)
used VL version	7.0.0.29

---

---

## Specifications of PC Used for Simulation

Processor	i7-49010MQ (4 CPU cores)
RAM	32GB
Operating System	Windows 10