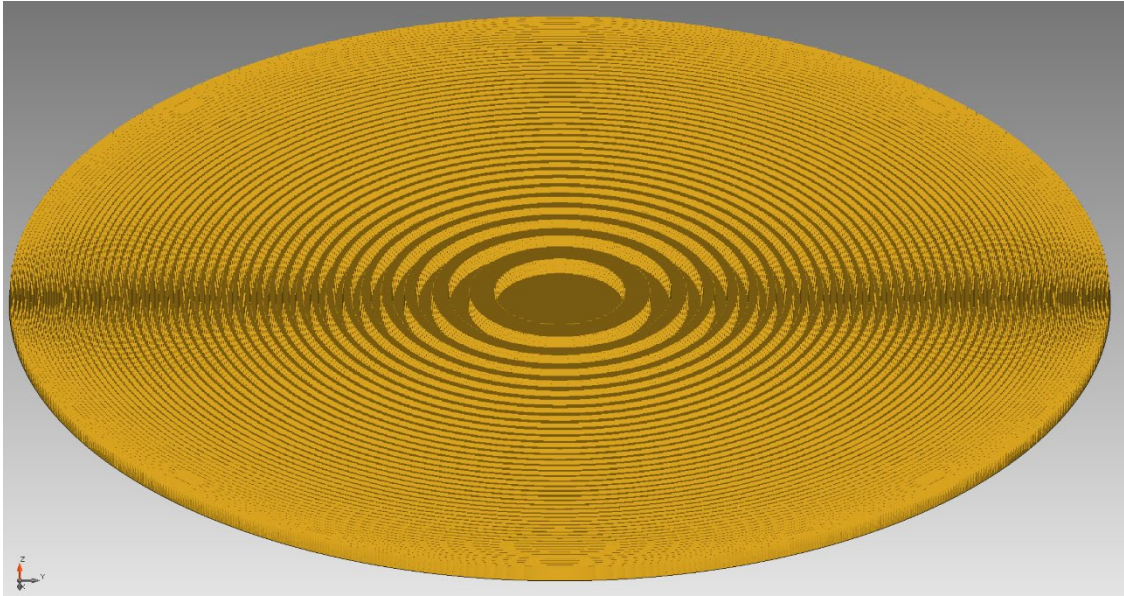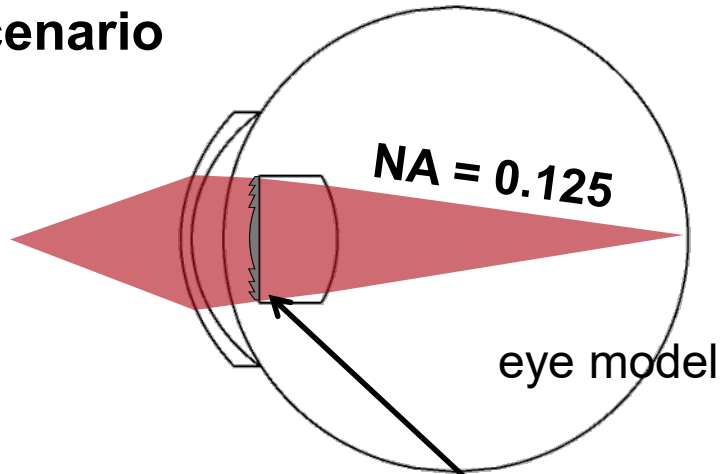# Design and Analysis of Intraocular Diffractive Lens

Abstract

Multifocal intraocular lens implantation is now widely applied for the treatment of cataracts. As one of its advantages, the diffractive intraocular lens provides good far and near vision for the patients. Such lenses are usually designed e.g. using Binary 2 surfaces in Zemax OpticStudio®. In this example, we demonstrate how to import the initial designs into VirtualLab Fusion, and model the lens system with the actual binary structures taken into account. The performance of the diffractive lens is further investigated by varying the height of binary structures.

Design Task for a Diffractive Lens

Near View Scenario

NA = 0.125

eye model
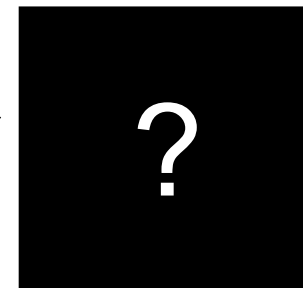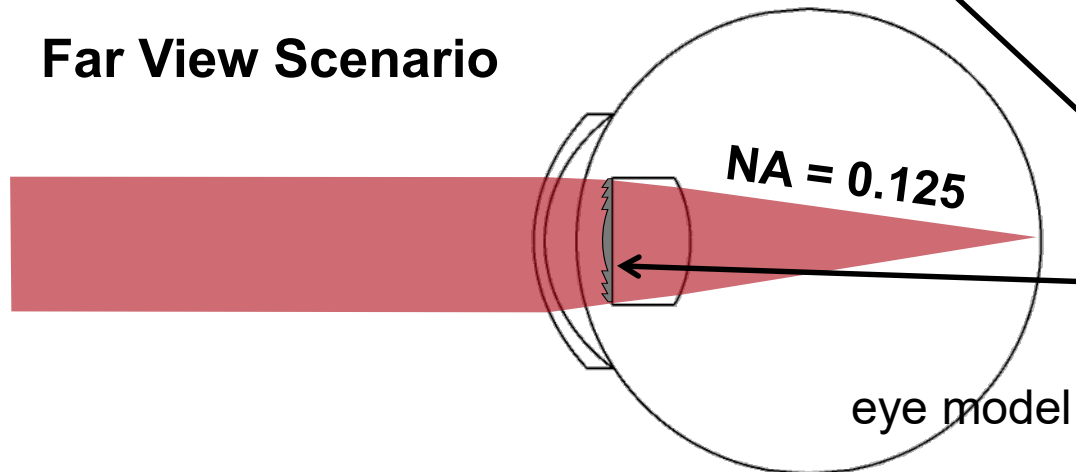
Far View Scenario

NA = 0.125

eye model

Each configuration of the two intraocular lens requires a certain wavefront phase response function.

$$\Delta\psi(\rho) = m\Delta\psi(\rho)$$

Where $m = 0$ for the far view scenario and $m = 1$ for the near view scenario
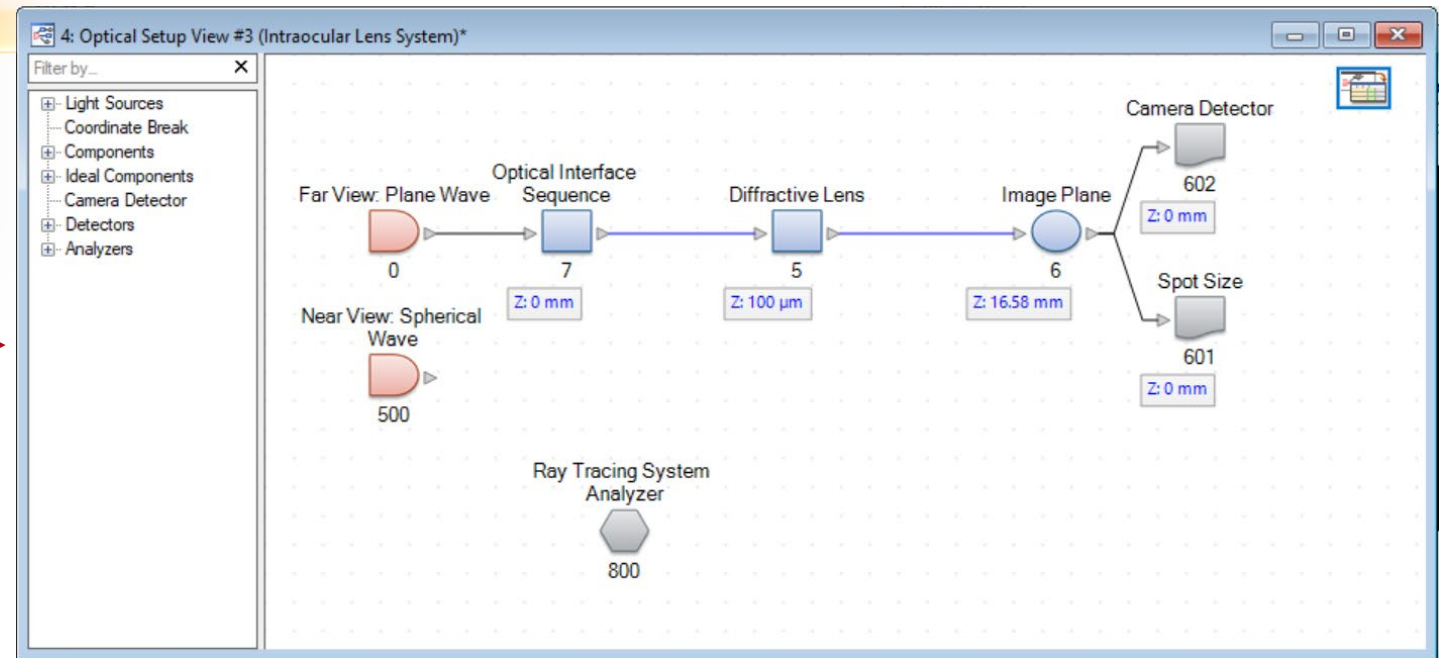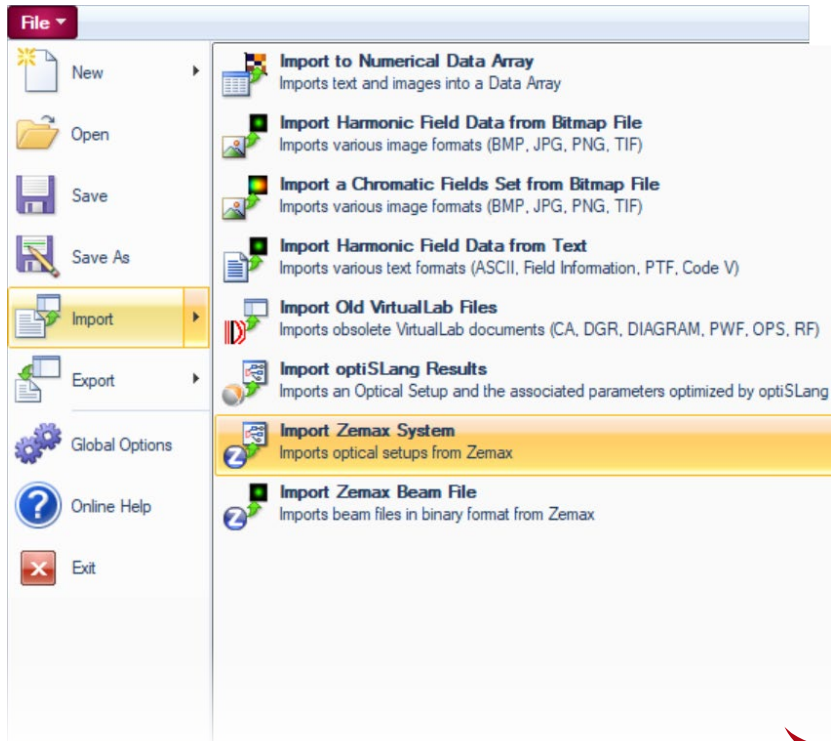
?

How to design and analyze the diffractive lens with two different wavefront effects for the two configurations?
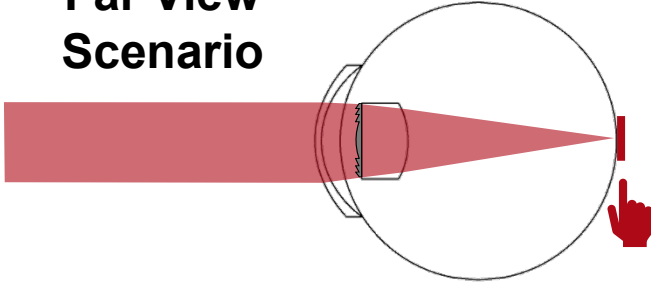
Import of Optical System from OpticStudio

The configuration of the optical setup as well as the design of the wavefront phase response by a Binary 2 surface was generated in Zemax OpticSudio®.

VirtualLab Fusion provides the capability to import the optical setups and merge them in a single optical setup configuration.
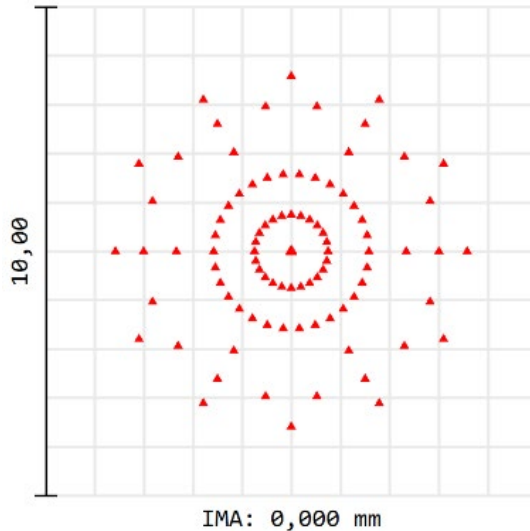
Far View: Conformity of OpticStudio Import
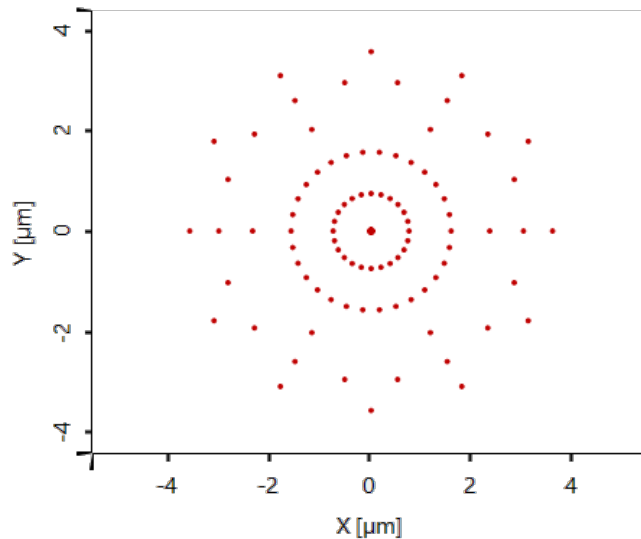
Far View Scenario

PSF calculation with the wavefront phase response by **VirtualLab Fusion**

spot diagram of central wavelength (555nm) calculated by:

OpticStudio

IMA: 0,000 mm

10,00

VirtualLab Fusion

Near View: Conformity of OpticStudio Import

Near View Scenario
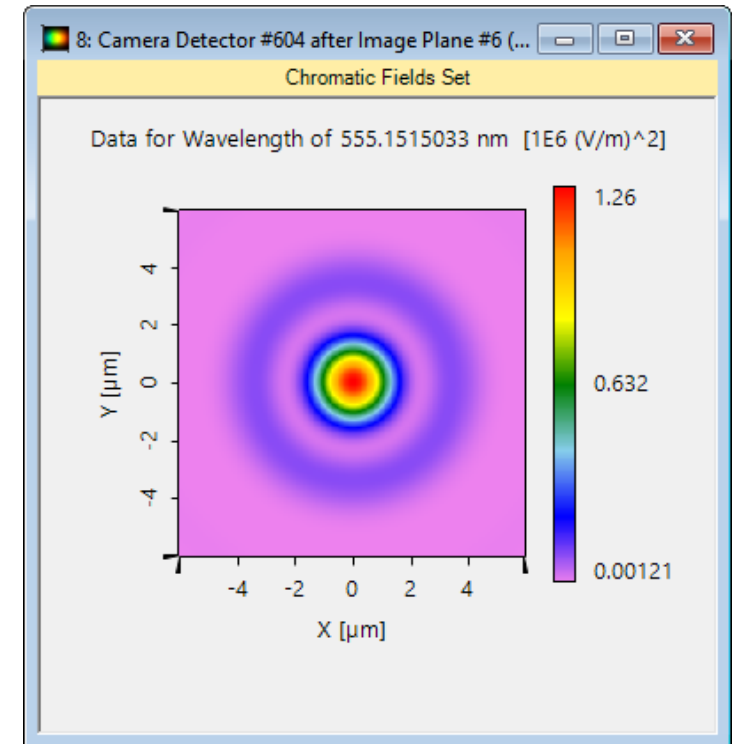
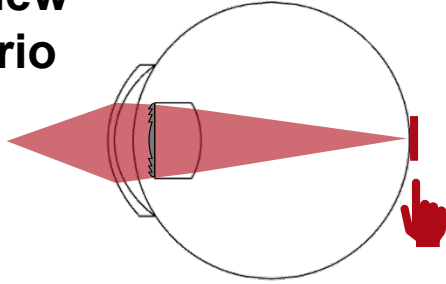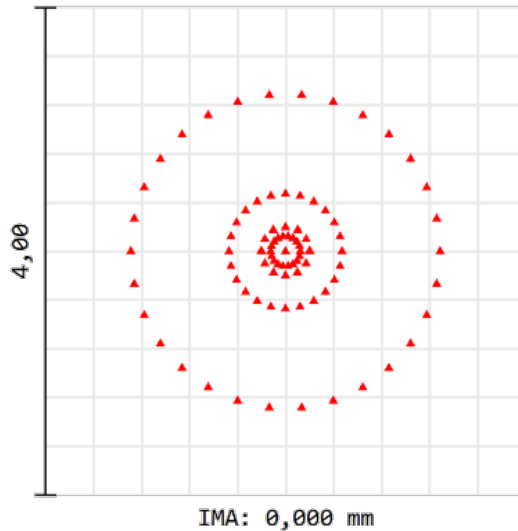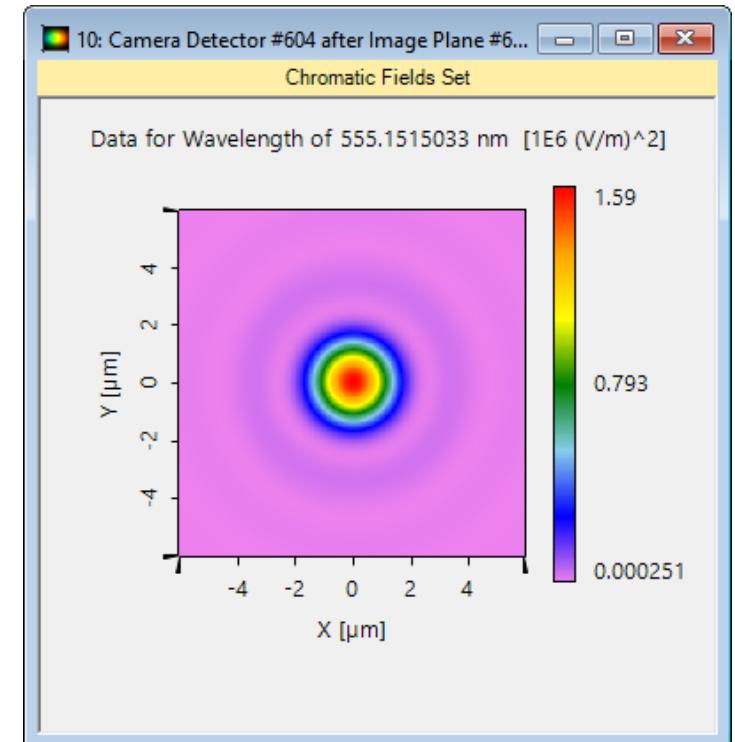spot diagram of central wavelength (555 nm) calculated by:

OpticStudio

4,00

IMA: 0,000 mm

VirtualLab Fusion

PSF calculation with the wavefront surface response by **VirtualLab Fusion**

10: Camera Detector #604 after Image Plane #6...

Chromatic Fields Set

Data for Wavelength of 555.1515033 nm [1E6 (V/m)^2]
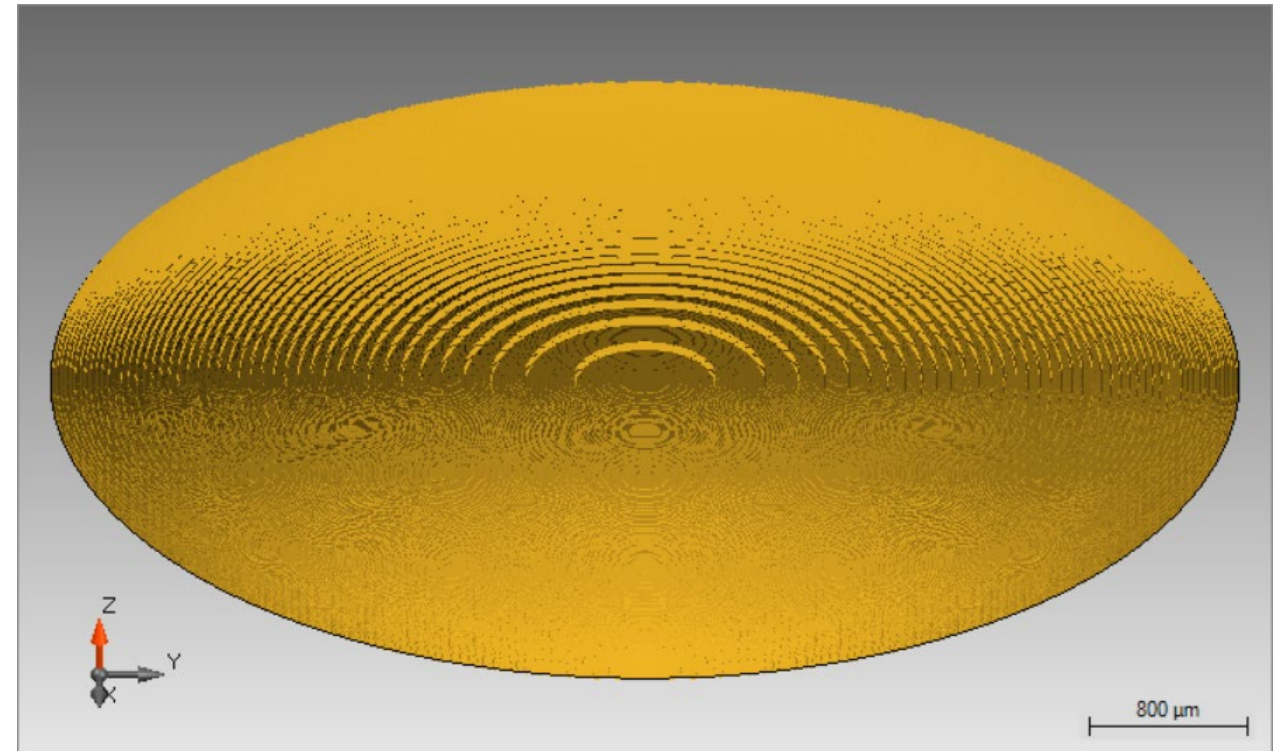
1.59

0.793

0.000251

Structure Design: Diffractive Lens Profile Height

- The structure profile of the diffractive lens is calculated by Thin Element Approximation (TEA) according to the wavefront phase response:

$$h^{\mathrm{DOE}}(\rho) = \beta \frac{\lambda}{2\pi \Delta n} \Delta \psi(\rho)^{\mathrm{DOE}}$$
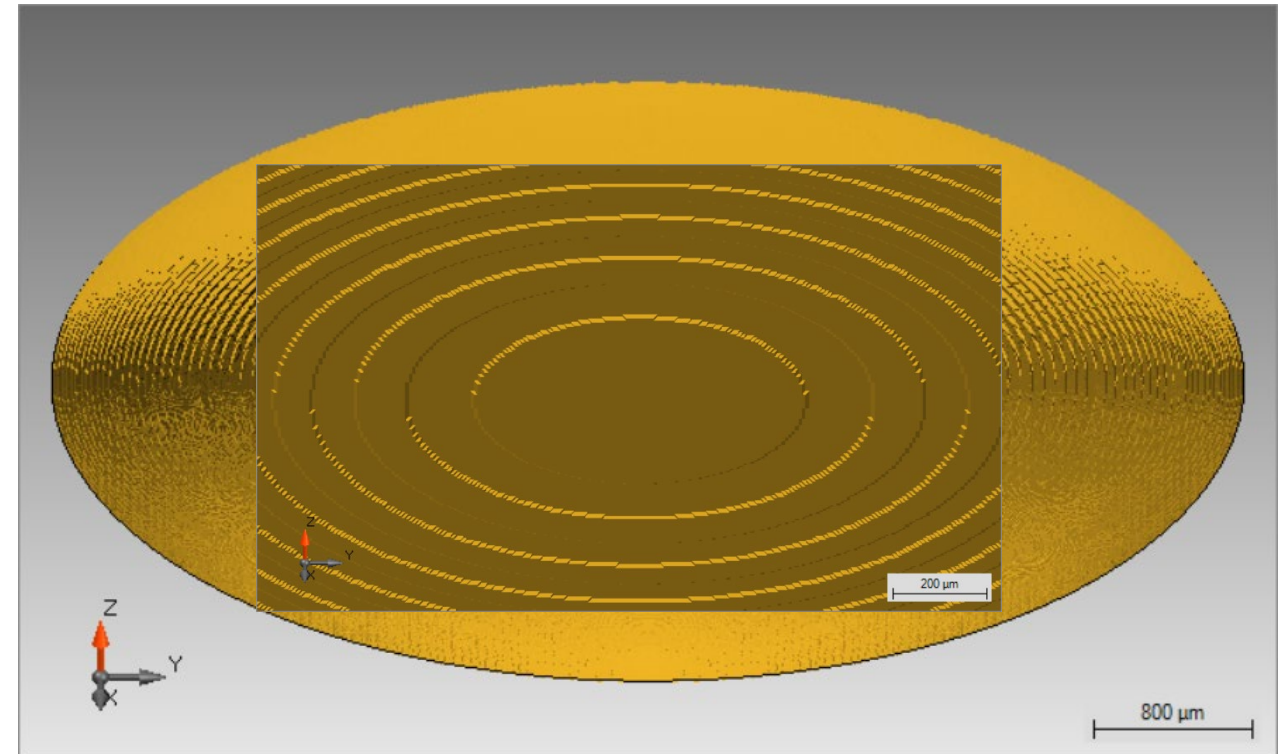
with a scaling factor β to modulate the height and control the efficiency of the diffraction orders.

TEA provides directly a very high efficiency for the 1st order
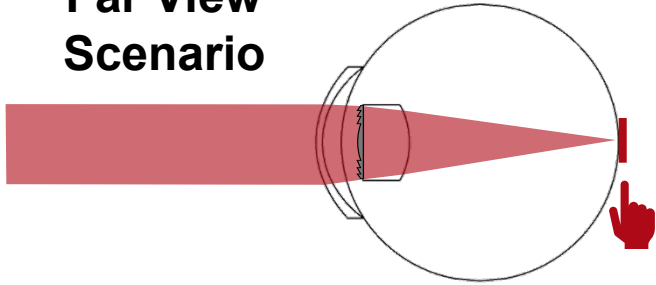

800 µm

Structure Design: Diffractive Lens Profile Height

- A quantization of the structure with 2 height levels is chosen because the binary diffractive lens

    - is beneficial for manufacturing (cost, easier to fabricate);

    - gives a better control of the efficiencies especially for the 0th and 1st order using the height modulation approach.
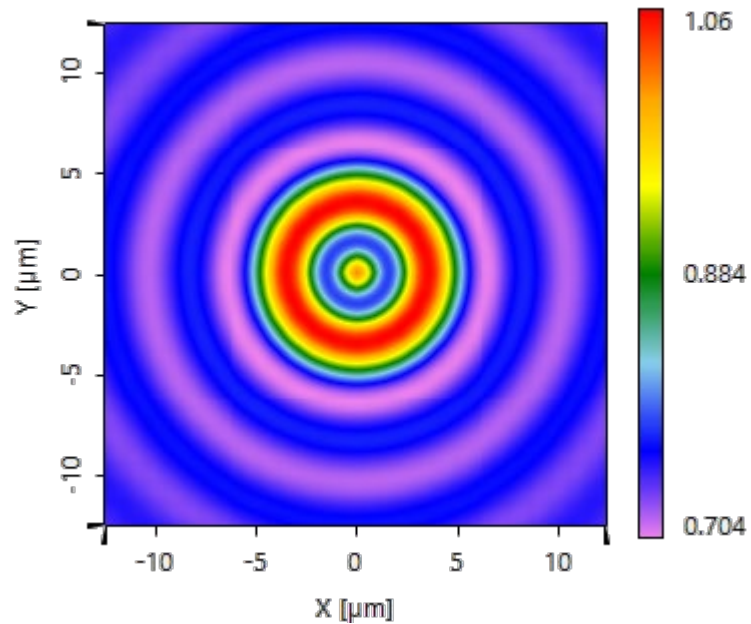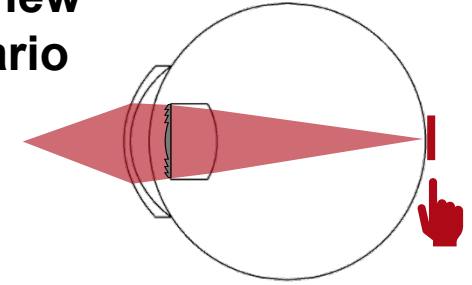
Structure Design: Height Modulation of 1.00

Far View Scenario

Near View Scenario
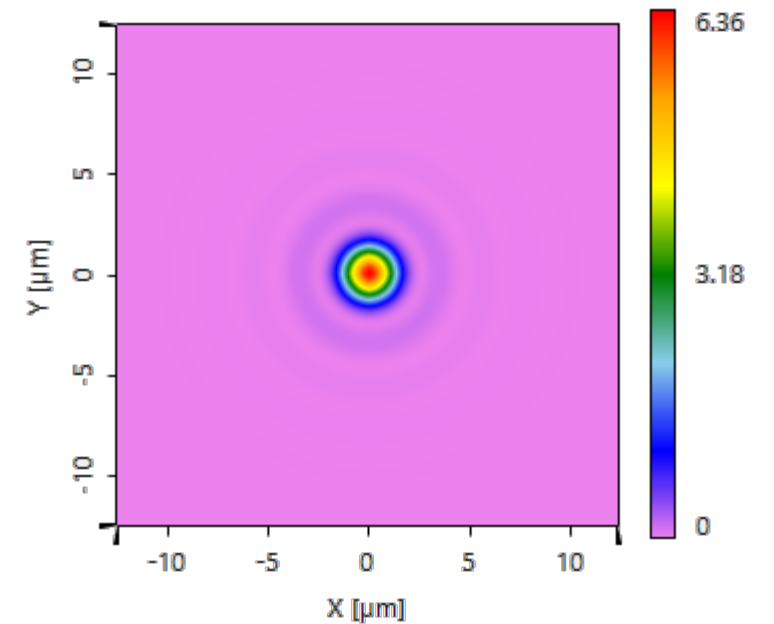
$\propto$ Electric Energy Density [1E2 $(V/m)^2$]

scaling of modulation height by
$\boldsymbol{\beta = 1.00}$

$\propto$ Electric Energy Density [1E5 $(V/m)^2$]

Structure Design: Height Modulation of 0.95

Far View Scenario

Near View Scenario

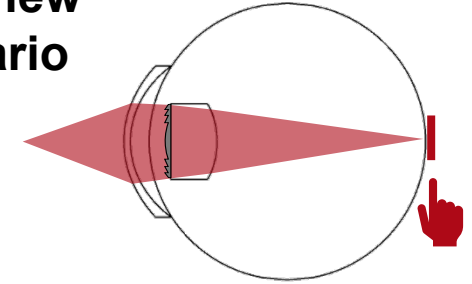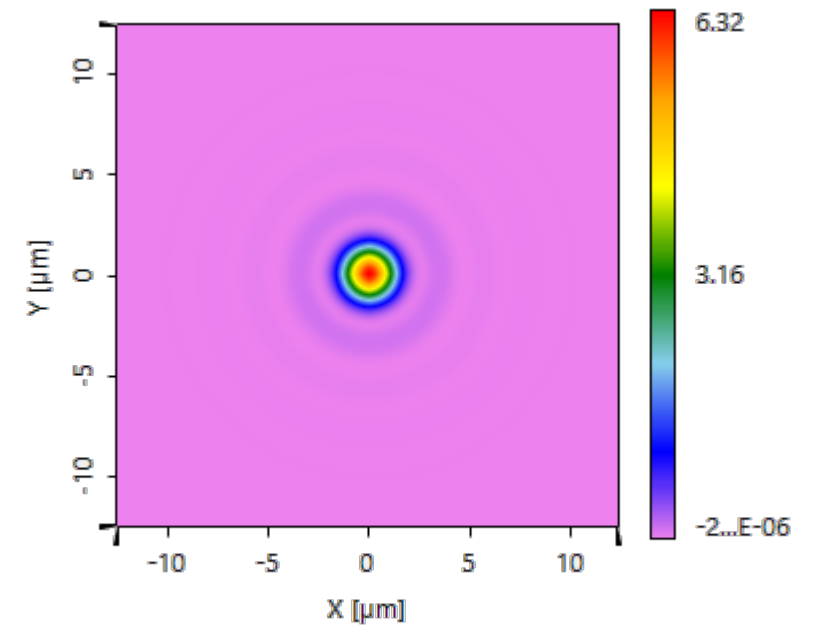$\propto$ Electric Energy Density $[\boxed{1E3}(V/m)^2]$

scaling of modulation height by
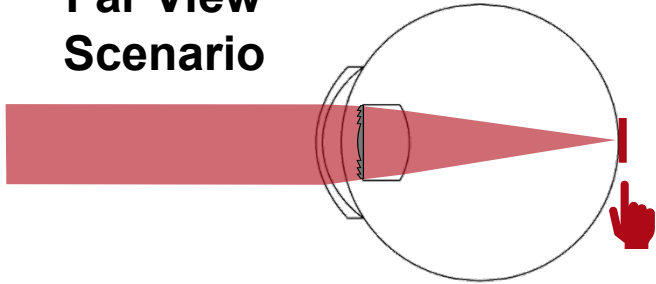$$\beta = 0.95$$
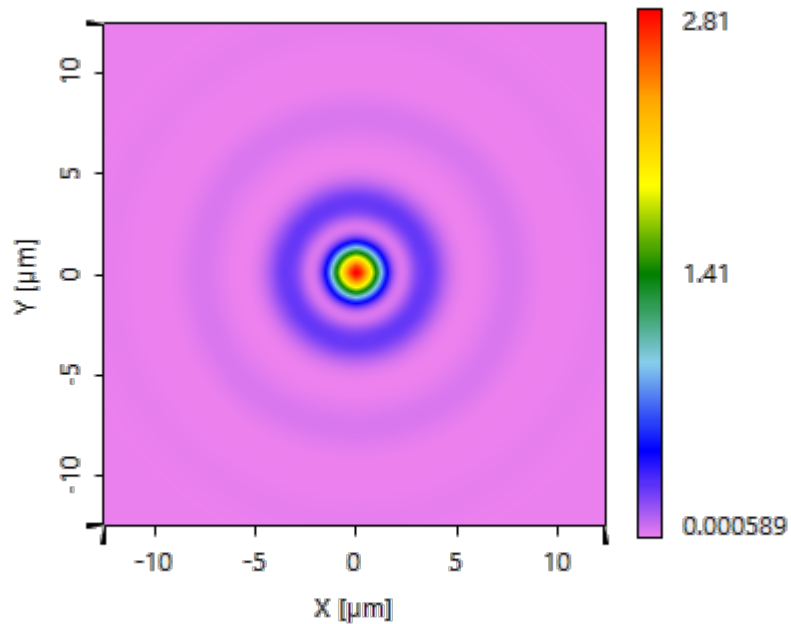
$\propto$ Electric Energy Density $[\boxed{1E5}(V/m)^2]$

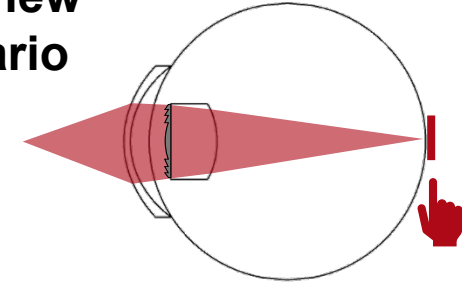# Structure Design: Height Modulation of 0.90

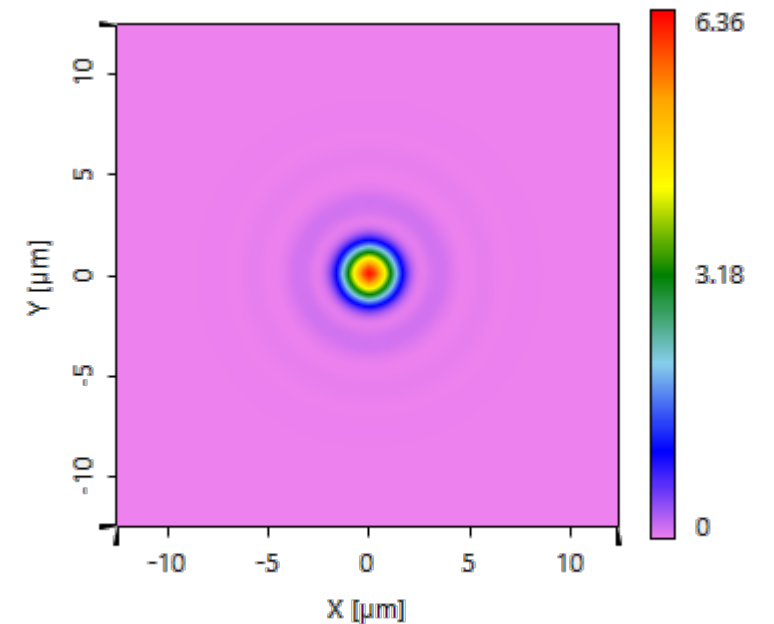**Far View Scenario**

$\propto$ Electric Energy Density $[\boxed{1\mathrm{E}4}(V/m)^2]$

scaling of modulation height by

$\boldsymbol{\beta = 0.90}$

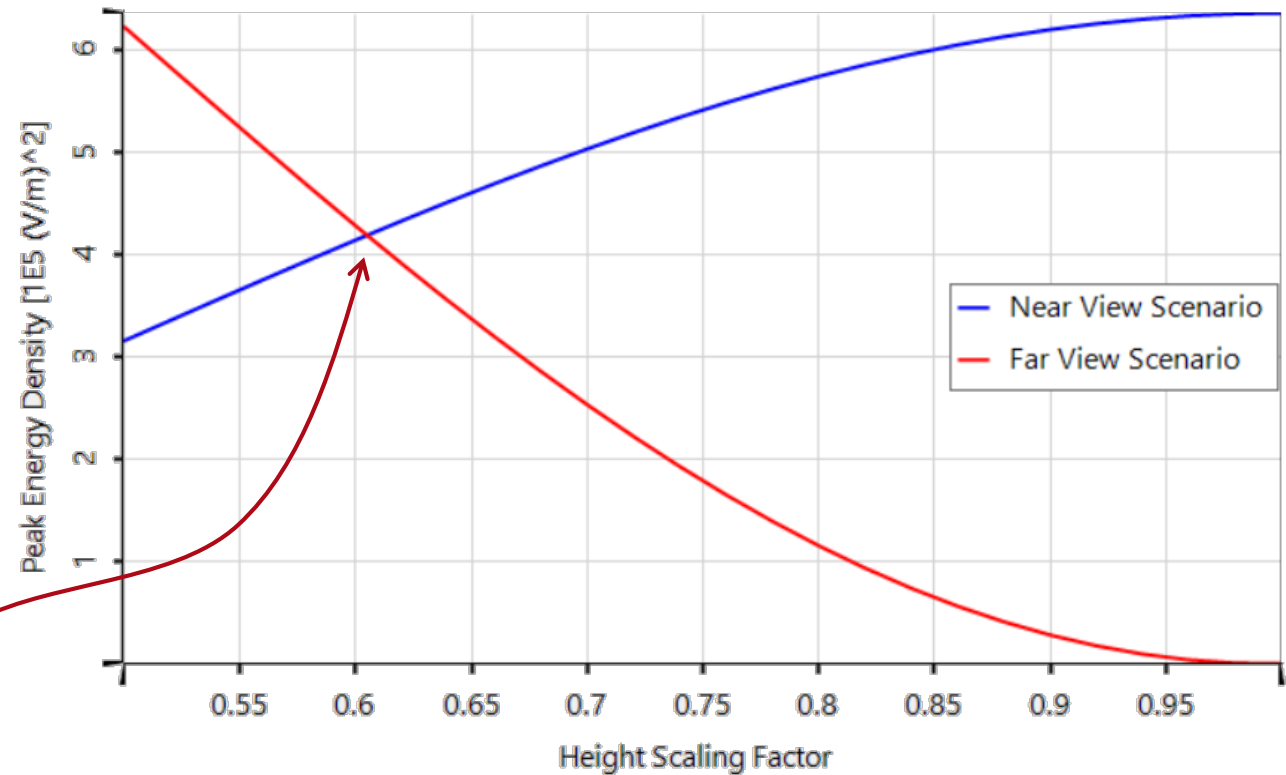**Near View Scenario**

$\propto$ Electric Energy Density $[\boxed{1\mathrm{E}5}(V/m)^2]$

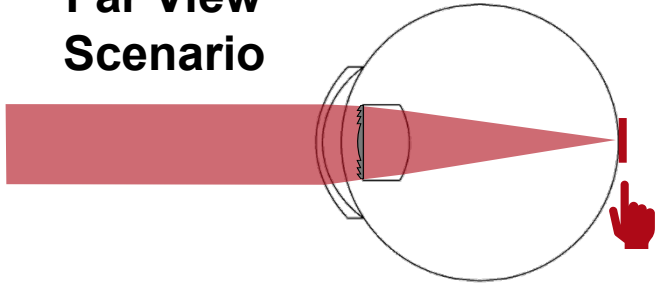# Structure Design: Find the Optimum Scaling Factor

- As a goal, the peak energy density of the foci for both far view and near view scenario shall be the same.
- Therefore, the peak energy density is calculated with respect to the height scaling factor for both scenarios.

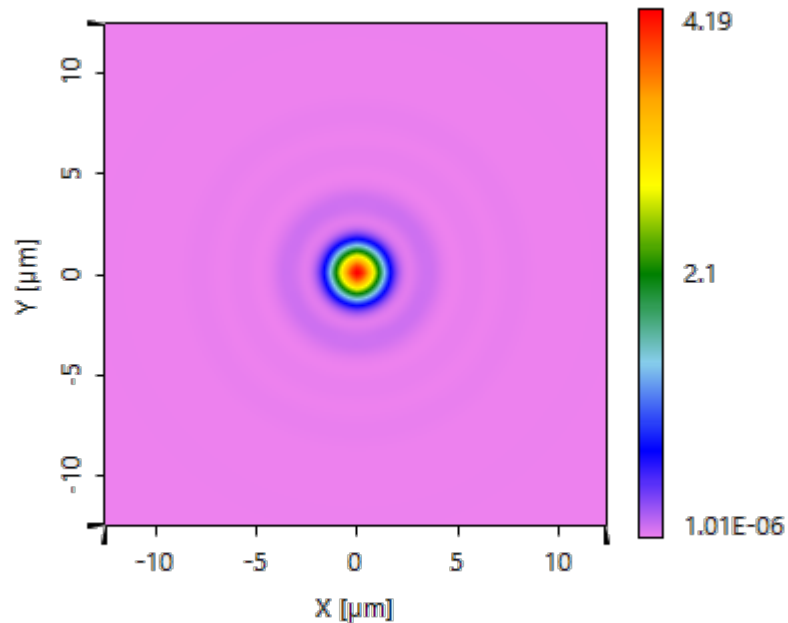Optimum of the scaling factor for equivalent peak energy density for both foci (near and far view)

Structure Design: Optimum Height Modulation of 0.605

Far View Scenario

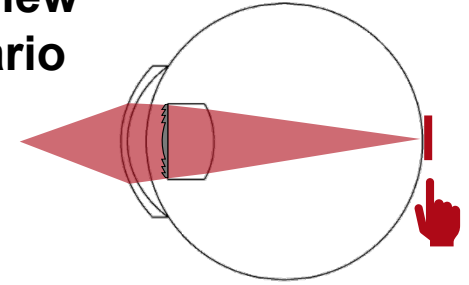$\propto$ Electric Energy Density $[$ 1E5 $(V/m)^2]$

scaling of modulation height by

$\boldsymbol{\beta = 0.605}$

Goal of equivalent maximum energy density for both foci achieved!

Near View Scenario

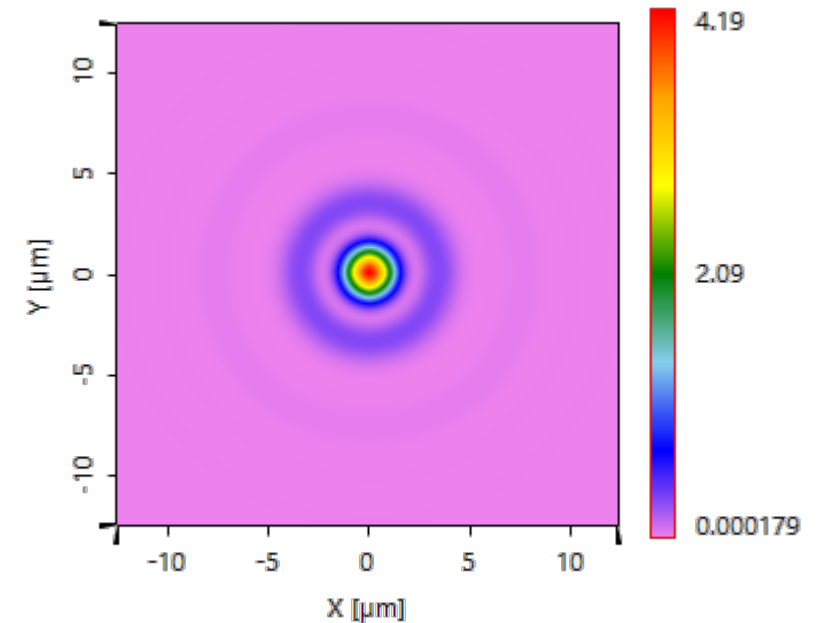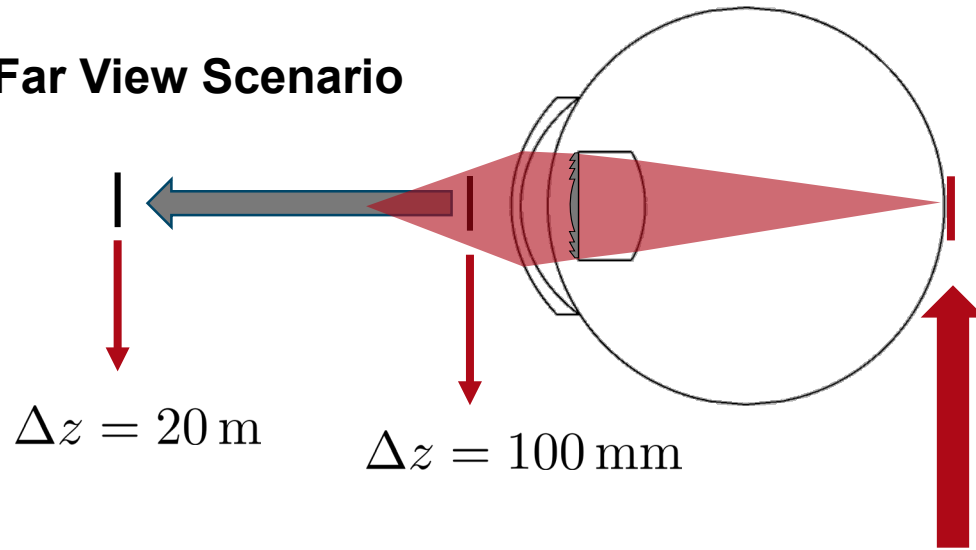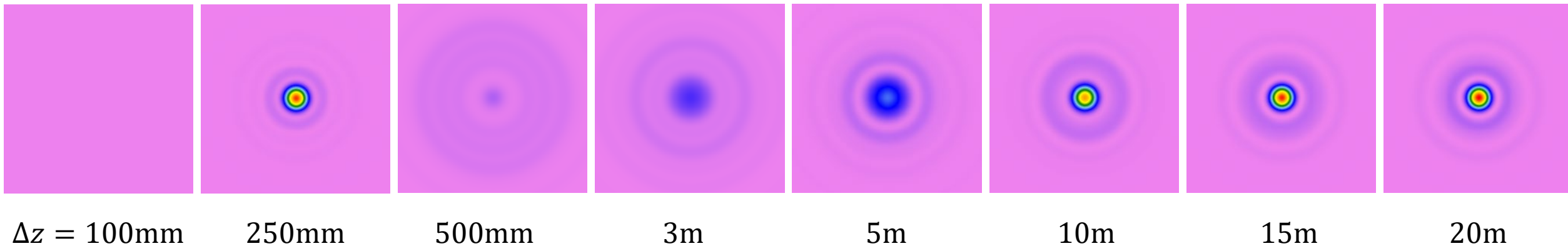$\propto$ Electric Energy Density $[$ 1E5 $(V/m)^2]$

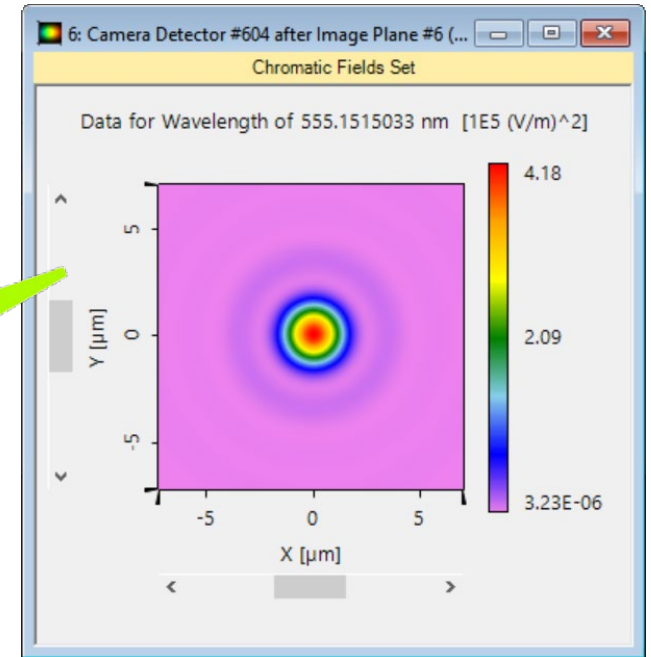# Illustration of Focus Development from Near to Far Region
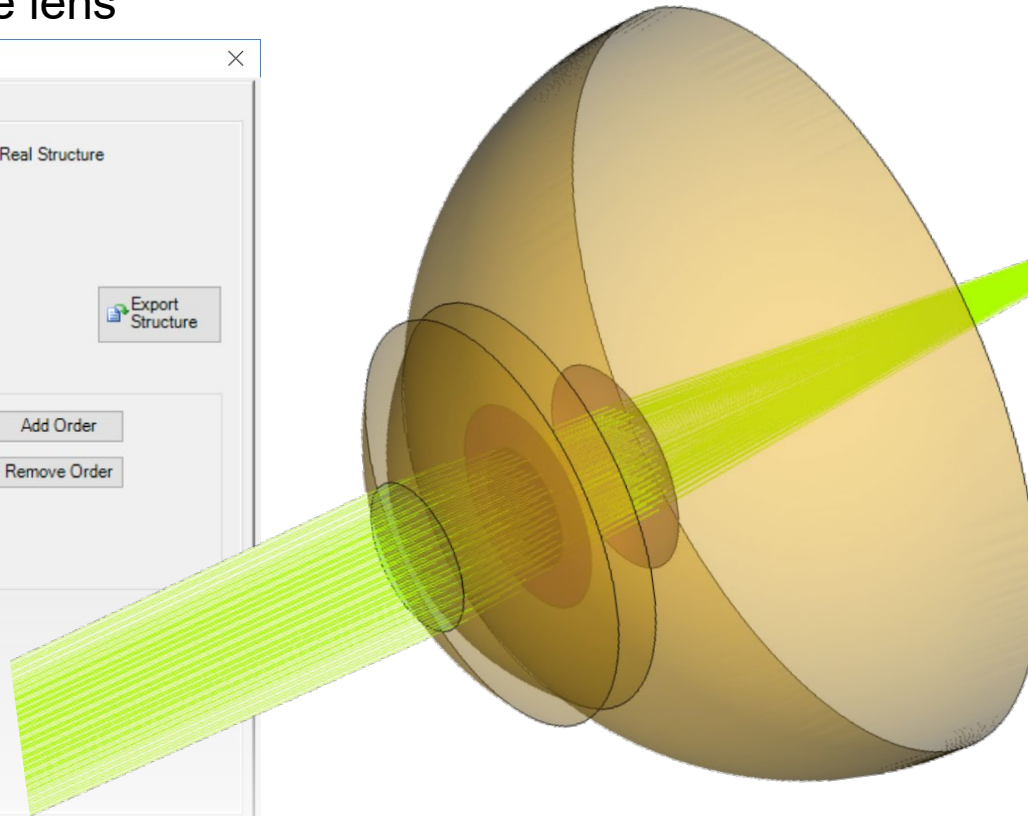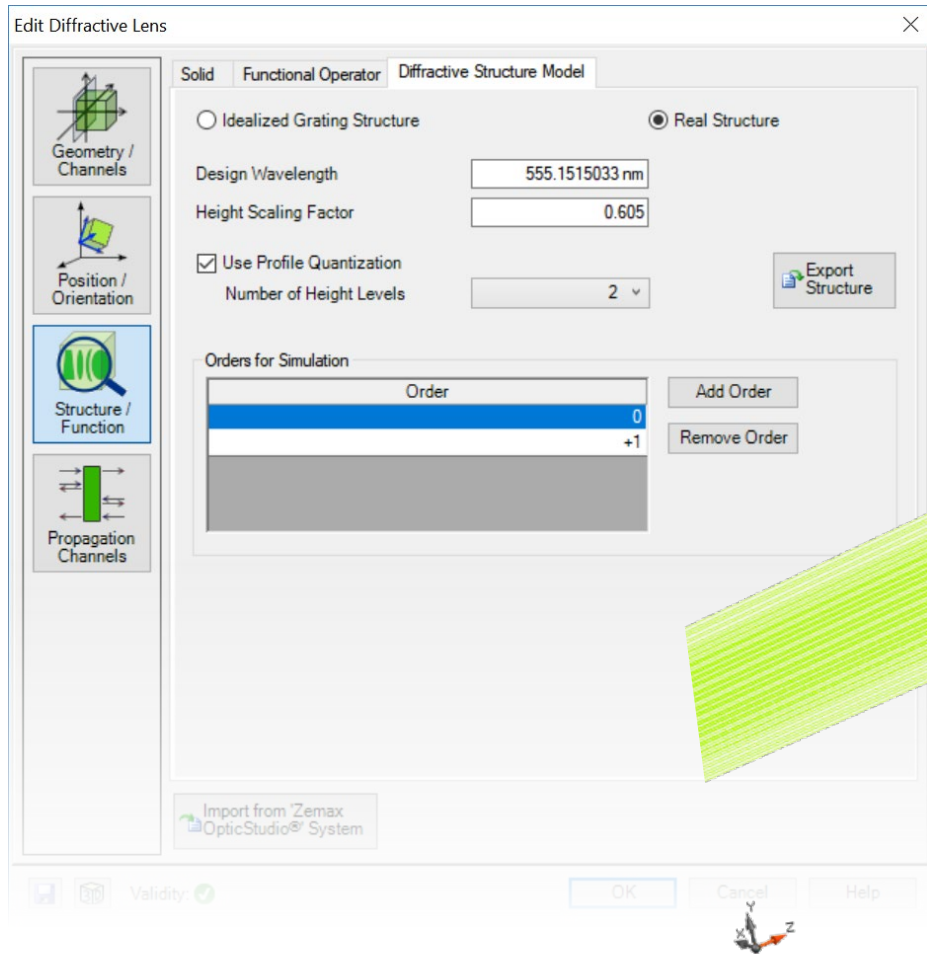
Near to Far View Scenario

$\Delta z = 20\,\text{m}$

$\Delta z = 100\,\text{mm}$

Focus spots with different object positions

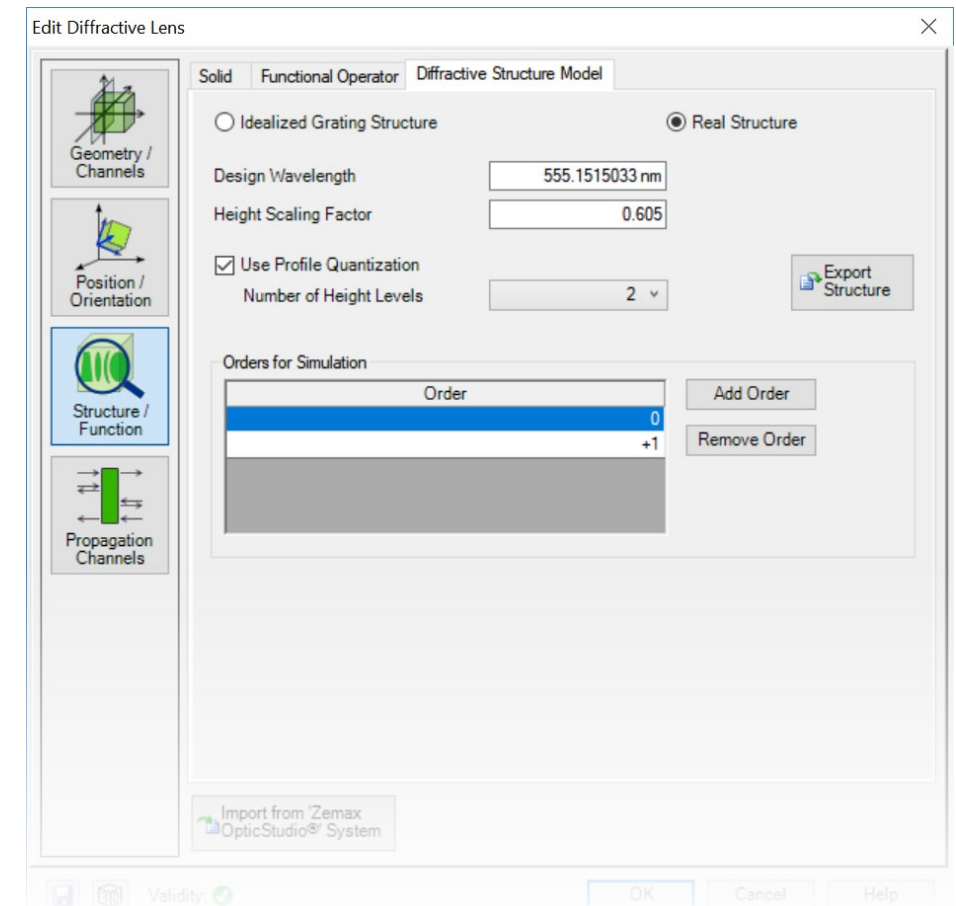| $\Delta z = 100$mm | 250mm | 500mm | 3m | 5m | 10m | 15m | 20m |

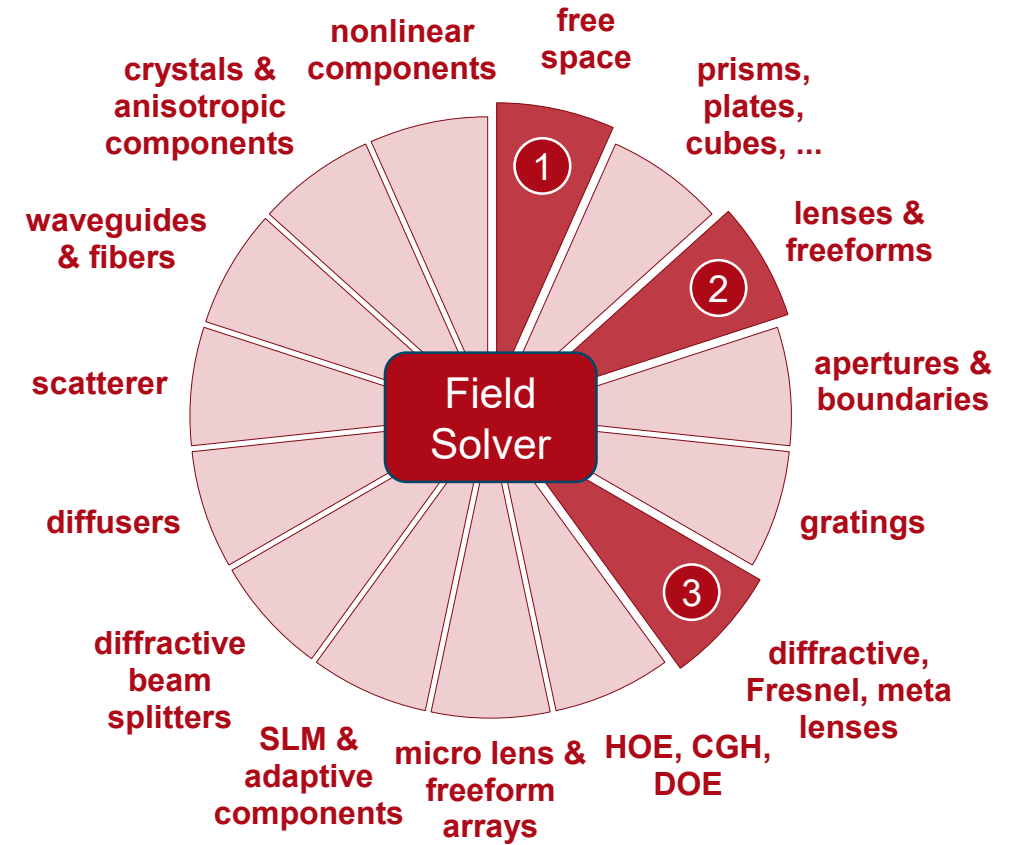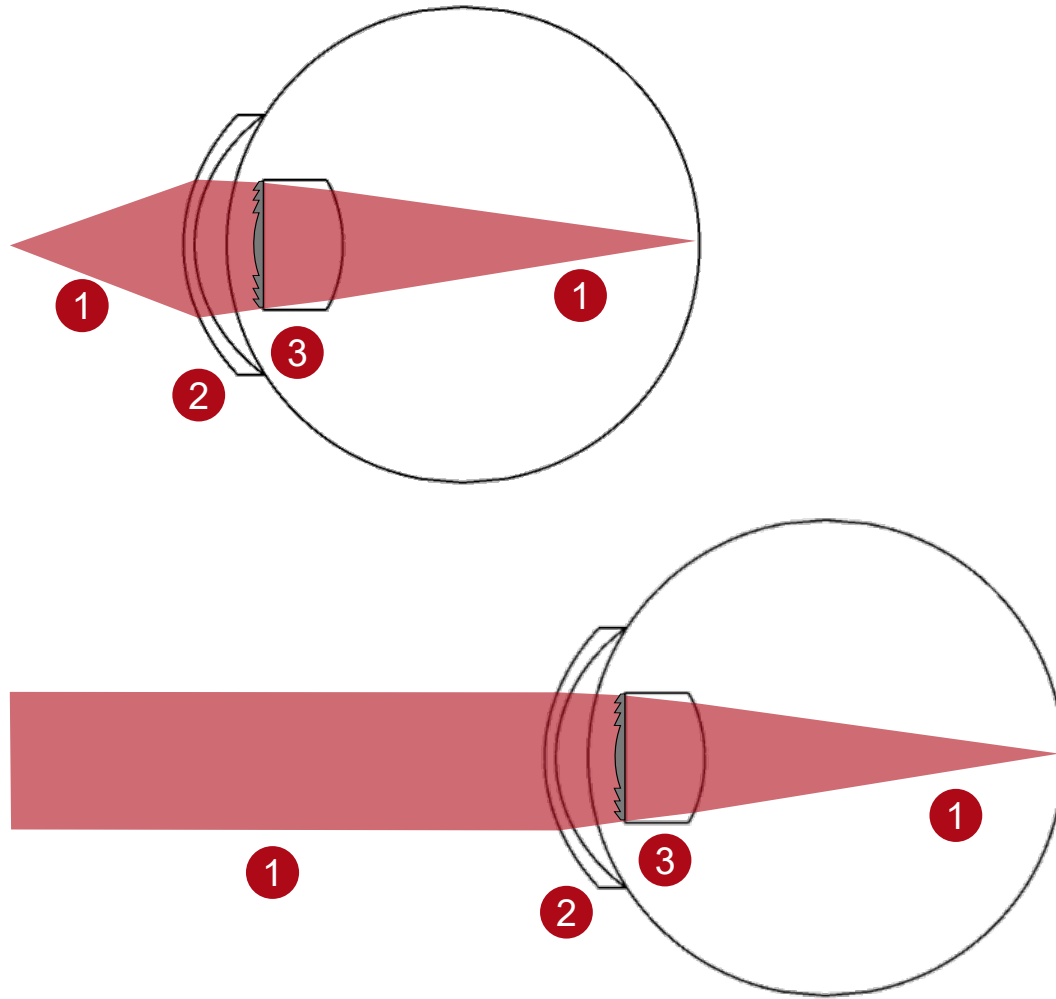configuration of diffractive lens

Workflow in VirtualLab Fusion

- Import lens systems from Zemax OpticStudio®
  - Import Optical Systems from Zemax [Use Case]
- Configuration of Diffractive Lenses

- Configuration of Parameter Run
  - Usage of the Parameter Run Document [Use Case]

VirtualLab Fusion Technologies

Document Information

title	Design and Analysis of Intraocular Diffractive Lens
document code	DFL.0001
version	1.0
toolbox(es)	Starter Toolbox, Diffractive Optics Toolbox, Grating Toolbox
VL version used for simulations	VirtualLab Fusion Summer Release 2019 (7.6.0.116)
category	Application Use Case
further reading	- Modeling of a Hybrid Eyepiece with Diffractive Lens Surface for Chromatic Aberration Correction - Import Optical Systems from Zemax OpticStudio®