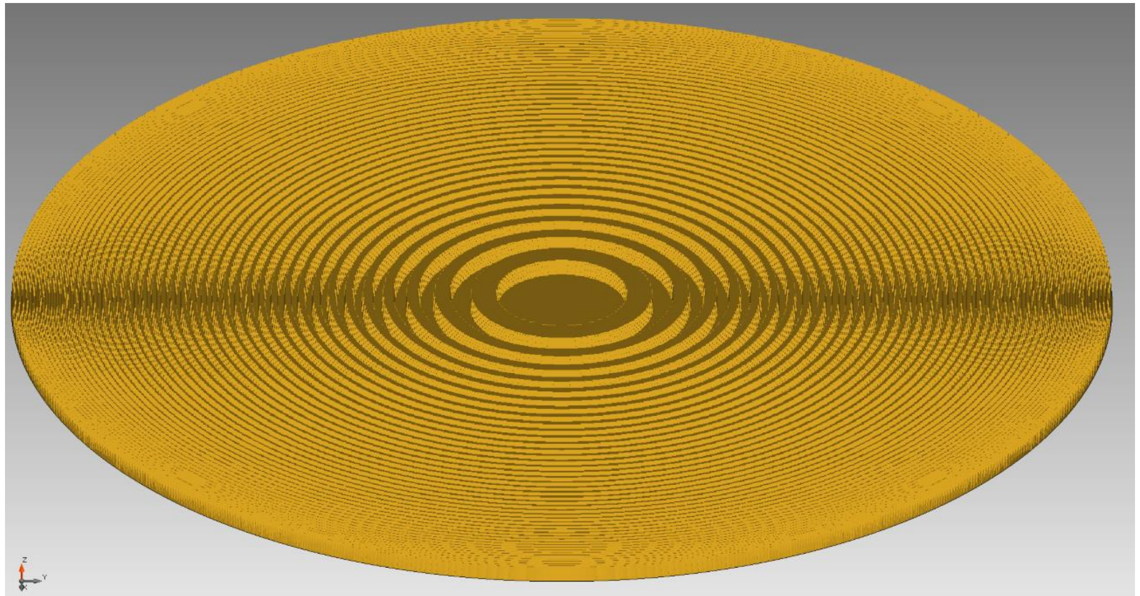
# Design and Analysis of Intraocular Diffractive Lens

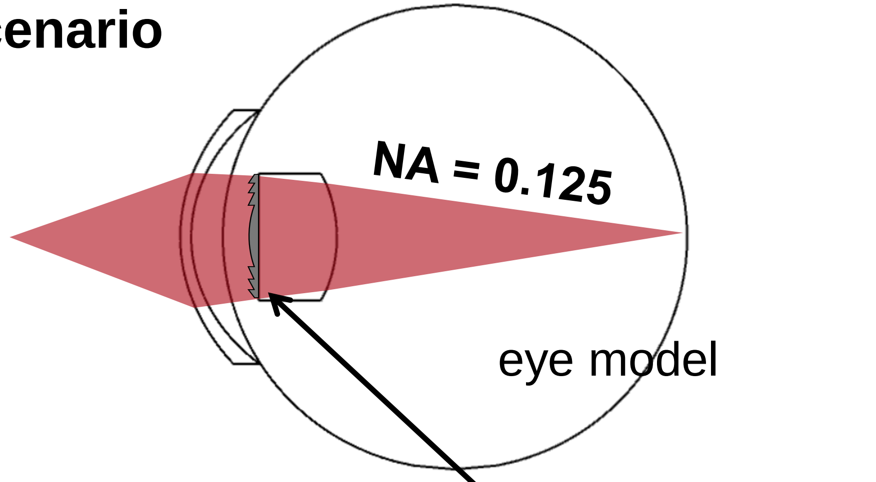
# Abstract



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**

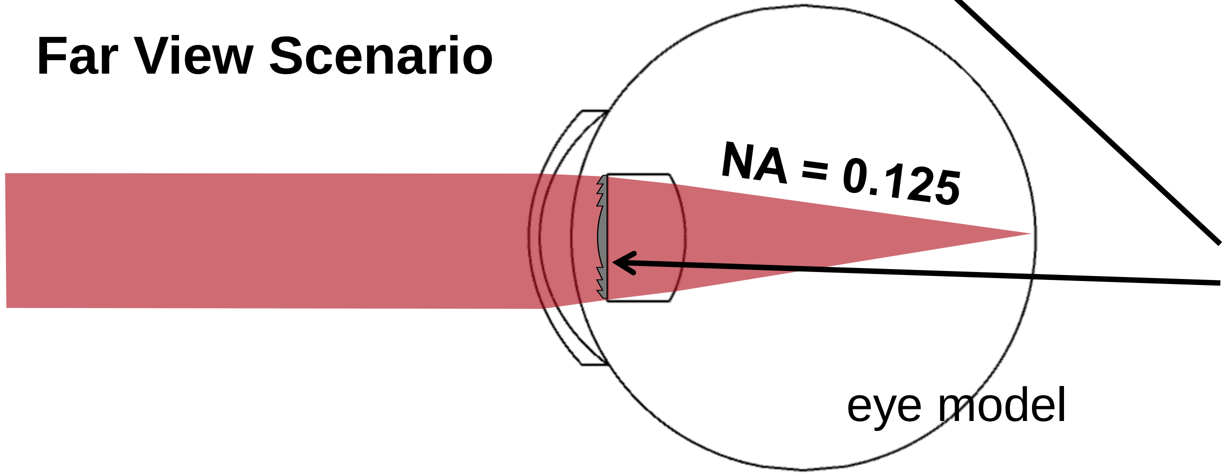


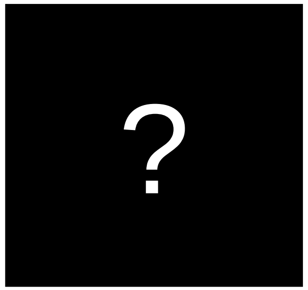

Each configuration of the two intraocular lens requires a certain wavefront phase response function.

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

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

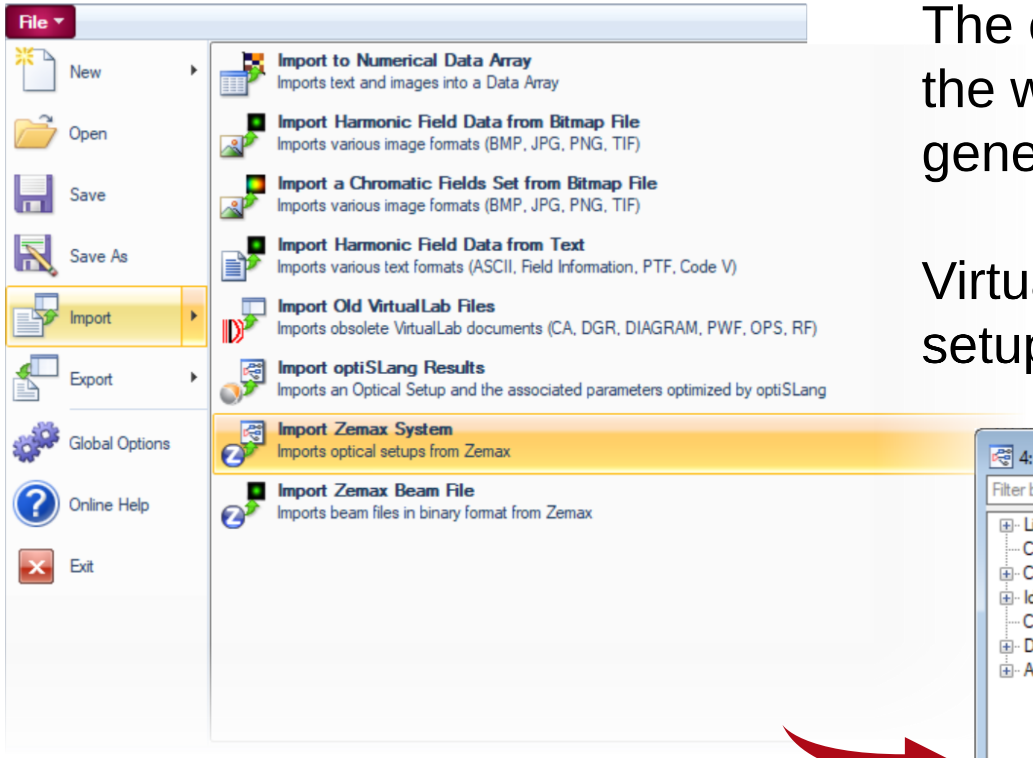
**Far View Scenario**



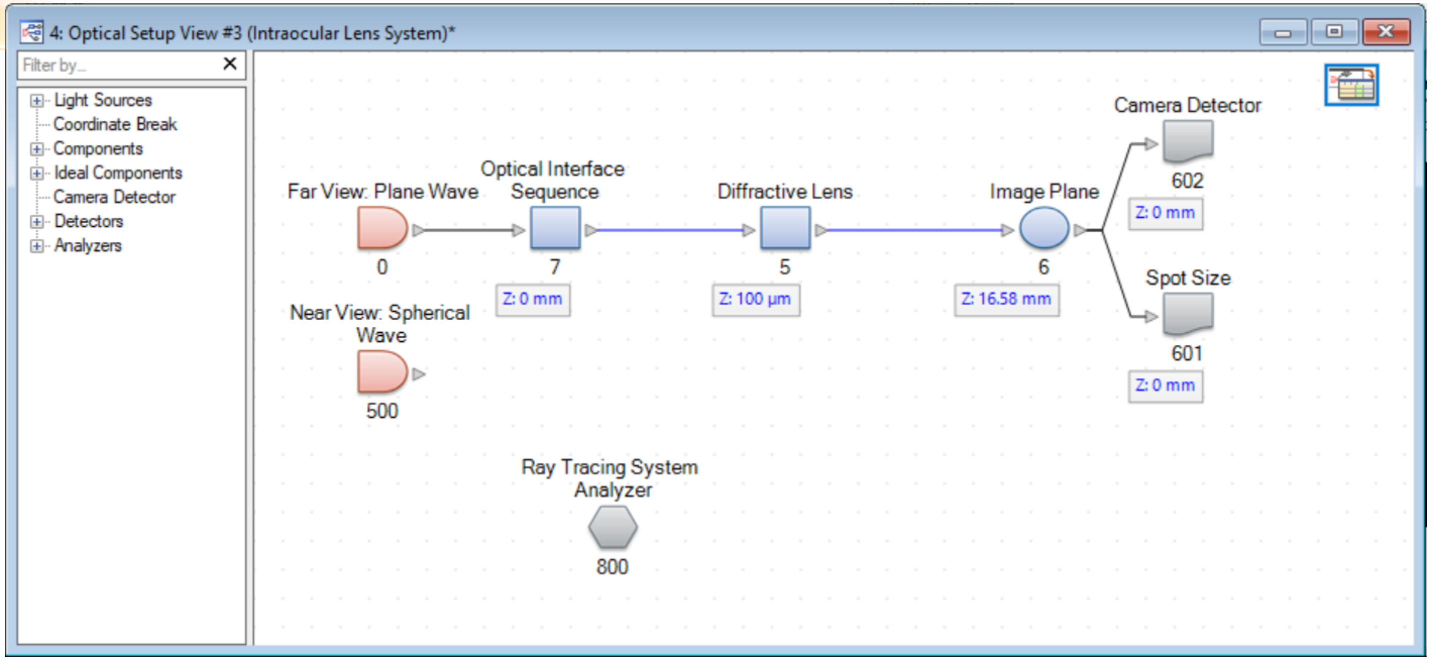

How to design and analyze the diffractive lens with two different wavefront effects for the two configurations?

# Import of Optical System from OpticStudio



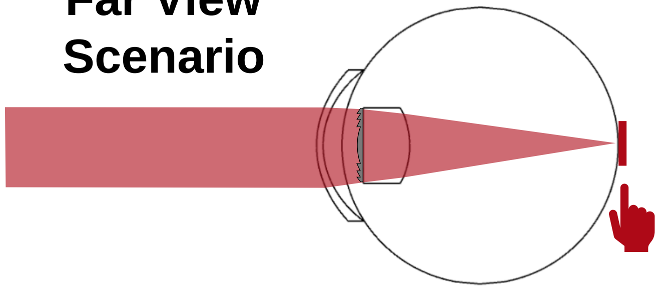

The configuration of the optical setup as well as the design of the wavefront phase response by a Binary 2 surface was generated in Zemax OpticSudio®.

VirtualLab Fusion provides the capability to import the optical setups and merge them in a single optical setup configuration.

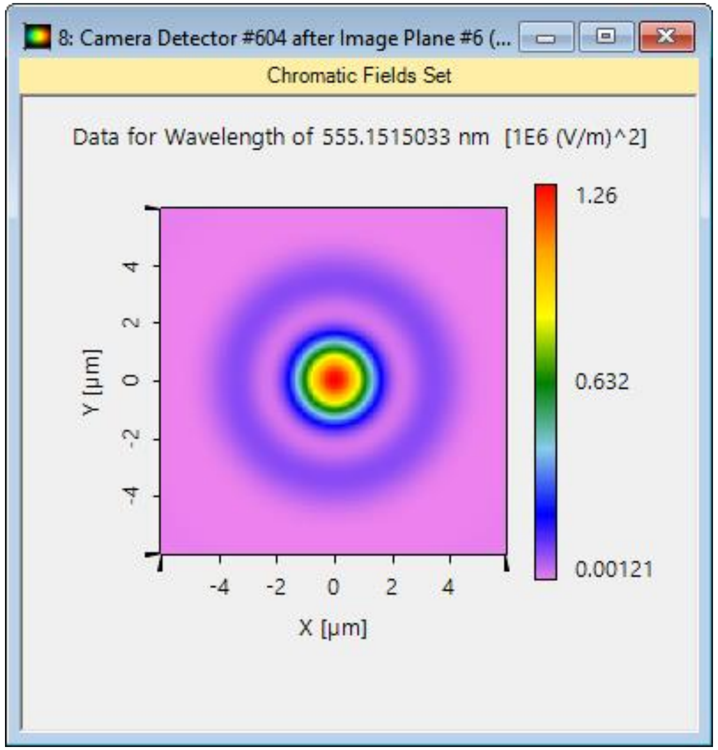


# Far View: Conformity of OpticStudio Import

**Far View Scenario**

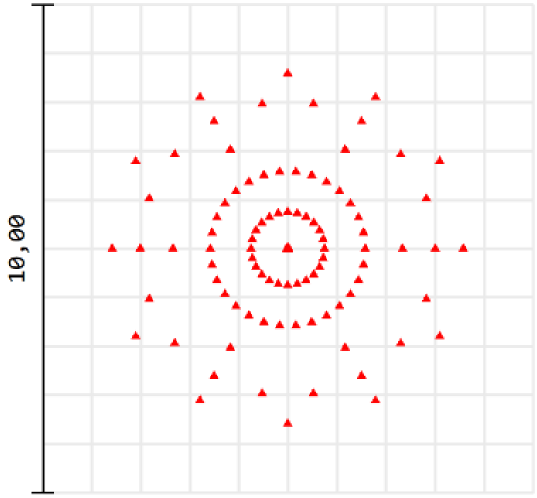


PSF calculation with the wavefront phase response by **VirtualLab Fusion**

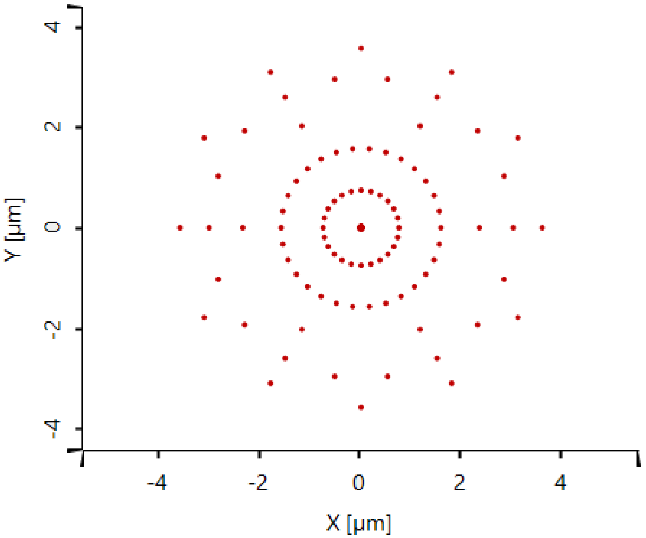



spot diagram of central wavelength (555 nm) calculated by:

**OpticStudio**

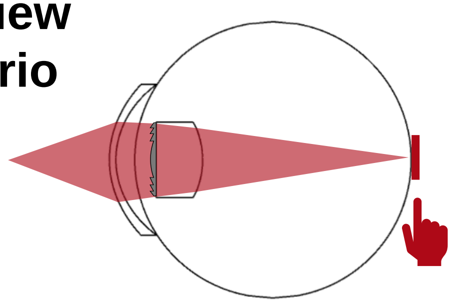



**VirtualLab Fusion**



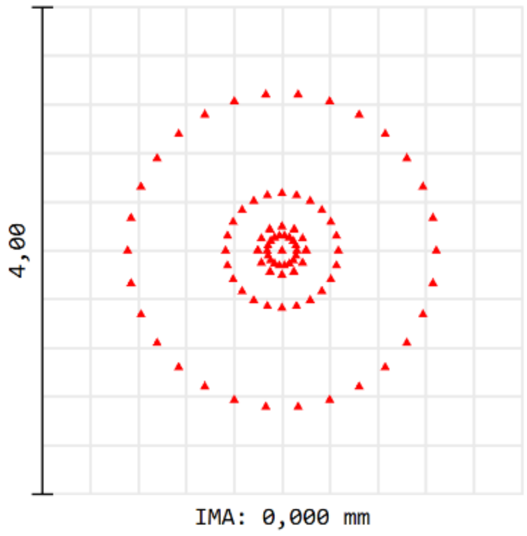
# Near View: Conformity of OpticStudio Import

**Near View Scenario**

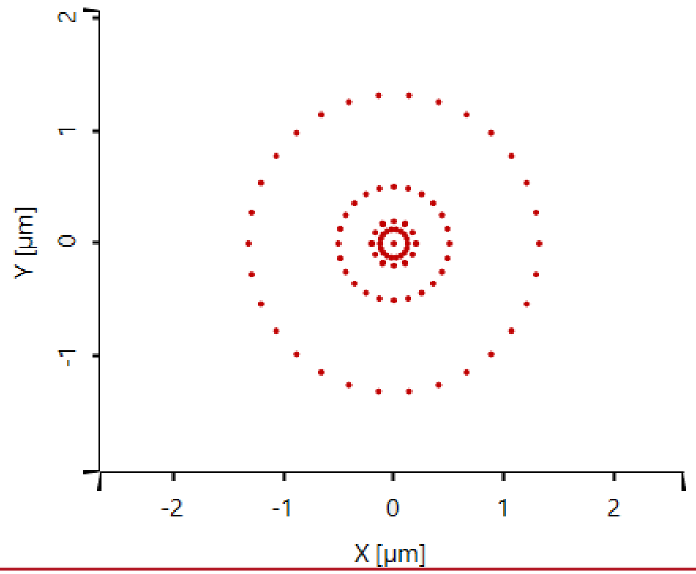


spot diagram of central wavelength (555 nm) calculated by:

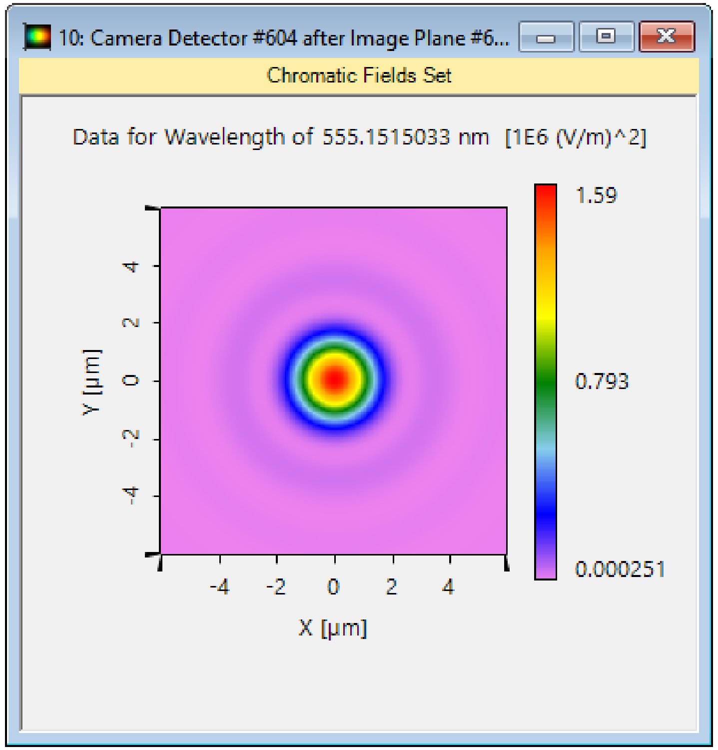
**OpticStudio**




**VirtualLab Fusion**




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



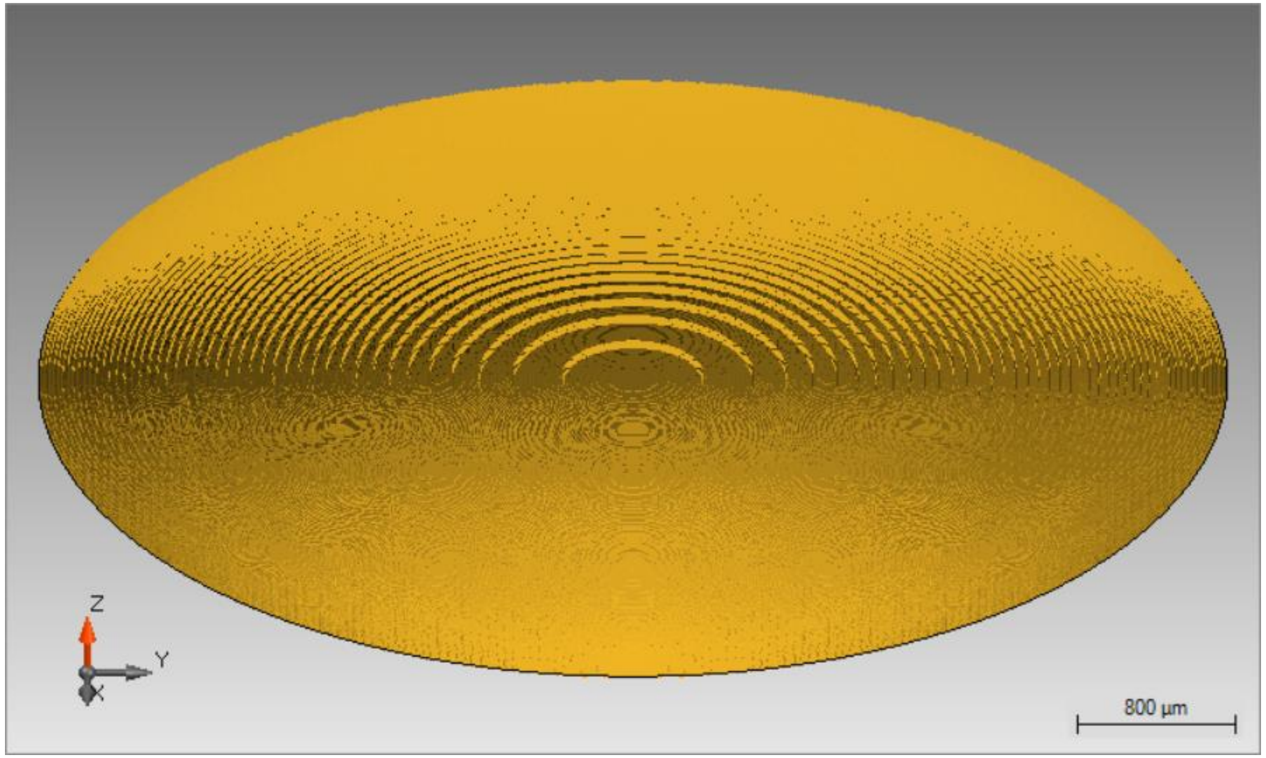
# Structure Design: Diffractive Lens Profile Height

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

$$h^{\mathrm{DOE}}(\rho) = \beta \frac{\lambda}{2\pi \Delta n} \Delta\psi(\rho)^{\mathrm{DOE}}$$

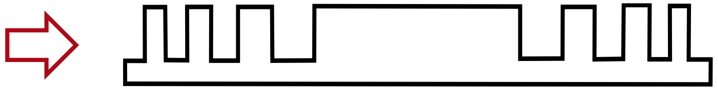
  with a scaling factor $\beta$ to modulate the height and control the efficiency of the diffraction orders.

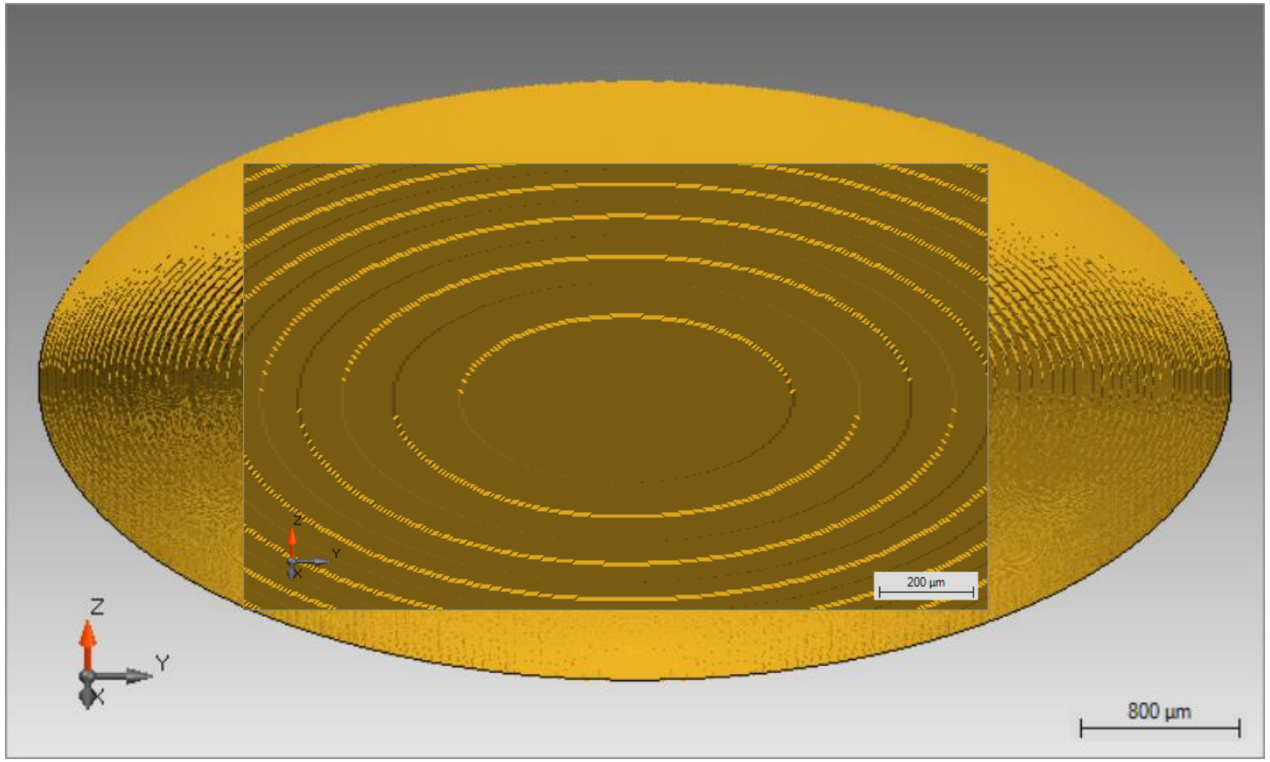
TEA provides directly a very high efficiency for the 1st order



# Structure Design: Diffractive Lens Profile Height

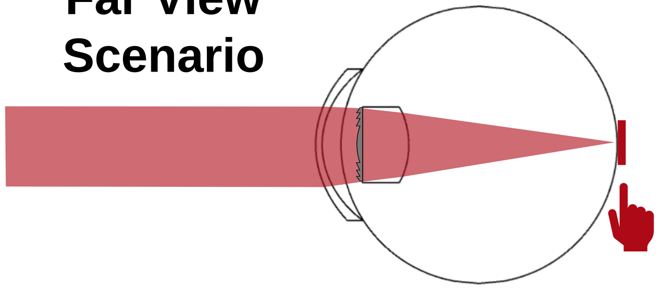
- A quantization of the structure with 2 height levels is chosen because the binary diffractive lens
  - is beneficial for manufacturing (cost, easier to fabricate);
  - gives a better control of the efficiencies especially for the $0^{th}$ and $1^{st}$ order using the height modulation approach.



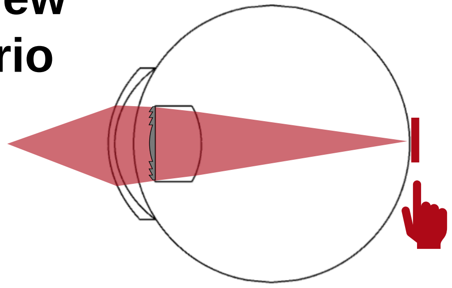


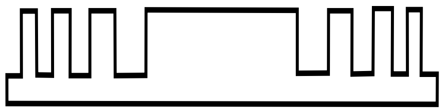
# Structure Design: Height Modulation of 1.00

**Far View Scenario**



**Near View Scenario**

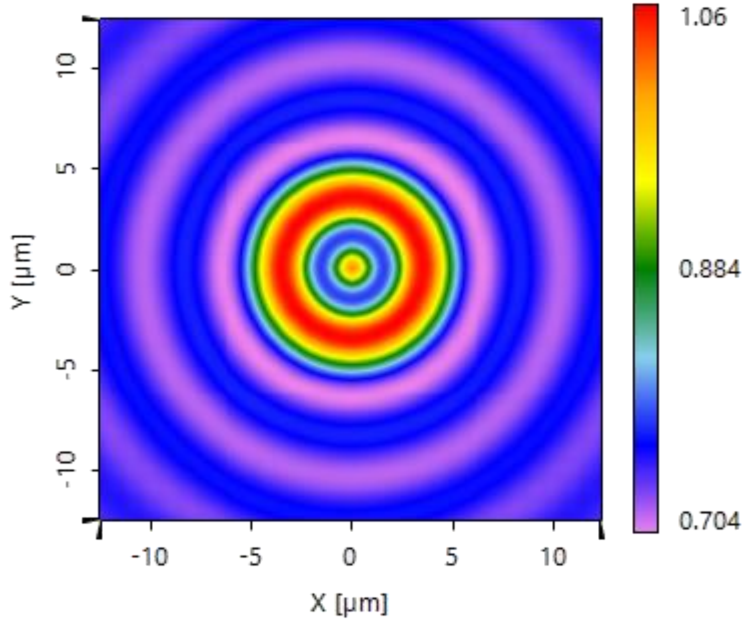




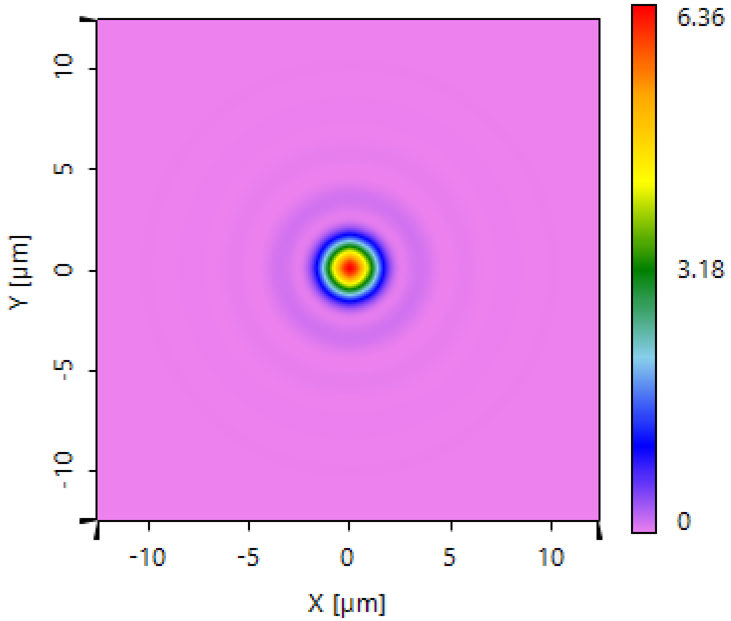
scaling of modulation height by

$\boldsymbol{\beta = 1.00}$

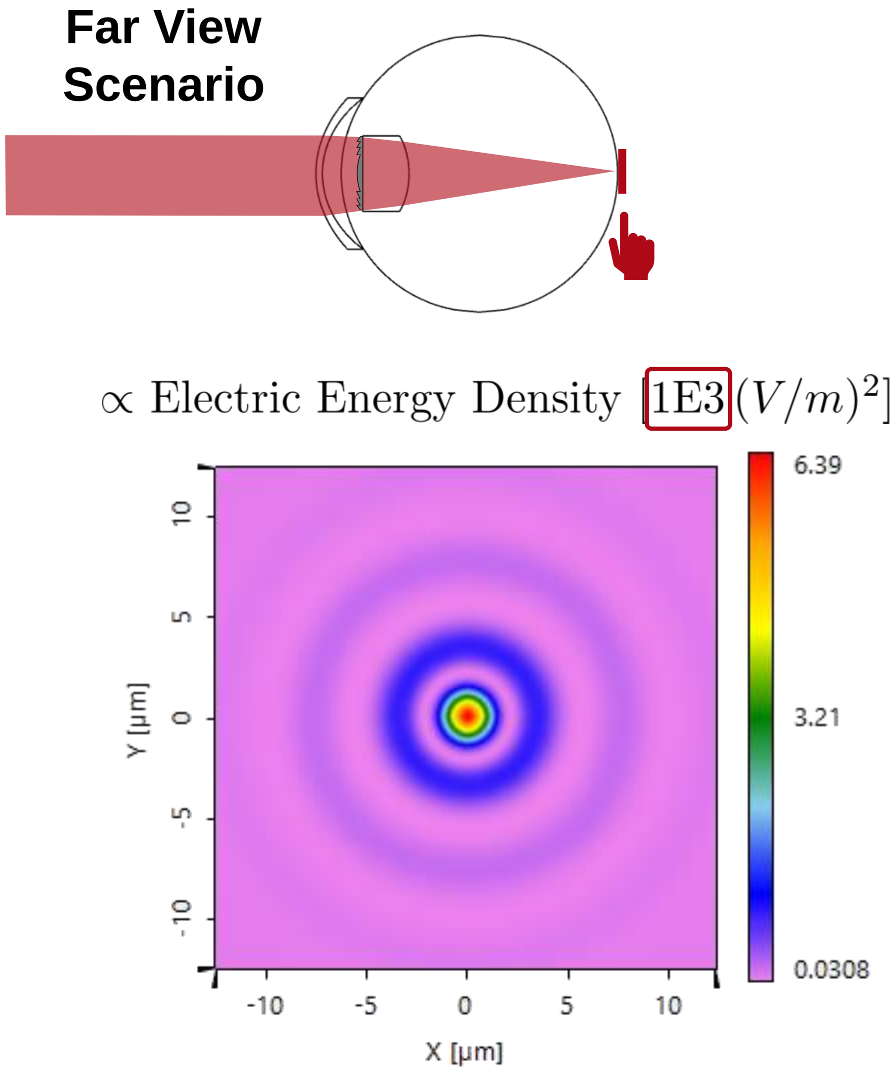
$\propto$ Electric Energy Density $[1E2\,(V/m)^2]$

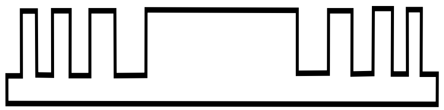



$\propto$ Electric Energy Density $[1E5\,(V/m)^2]$



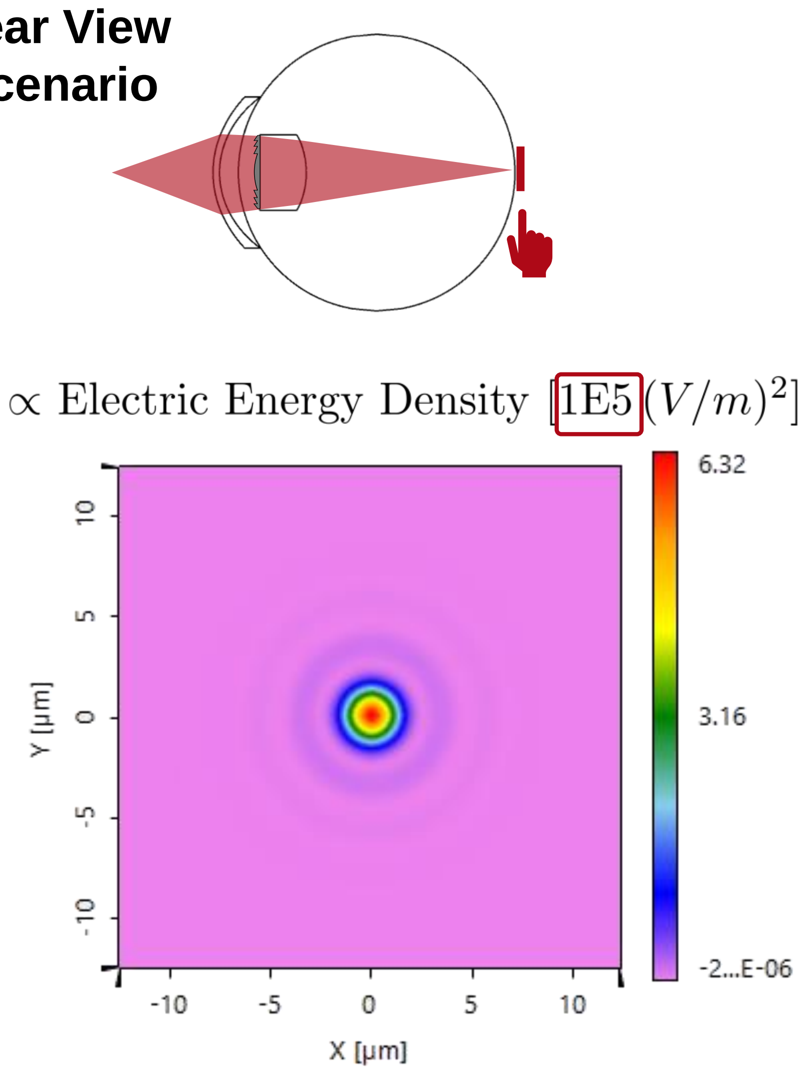
# Structure Design: Height Modulation of 0.95



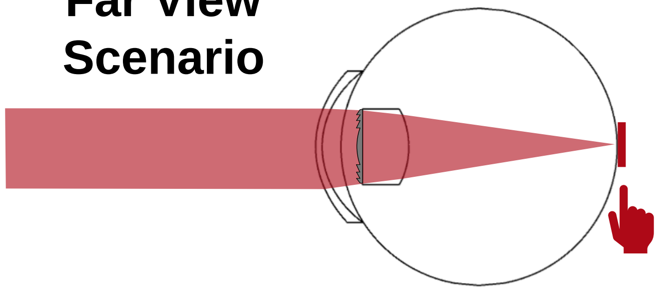
scaling of modulation height by

$\boldsymbol{\beta = 0.95}$

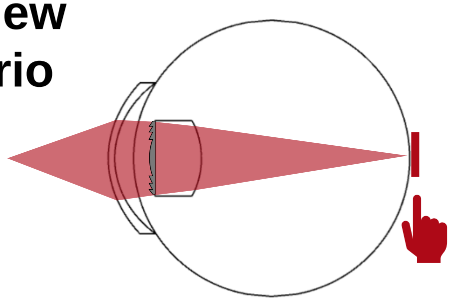


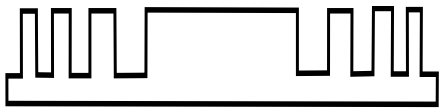
# Structure Design: Height Modulation of 0.90

**Far View Scenario**



**Near View Scenario**

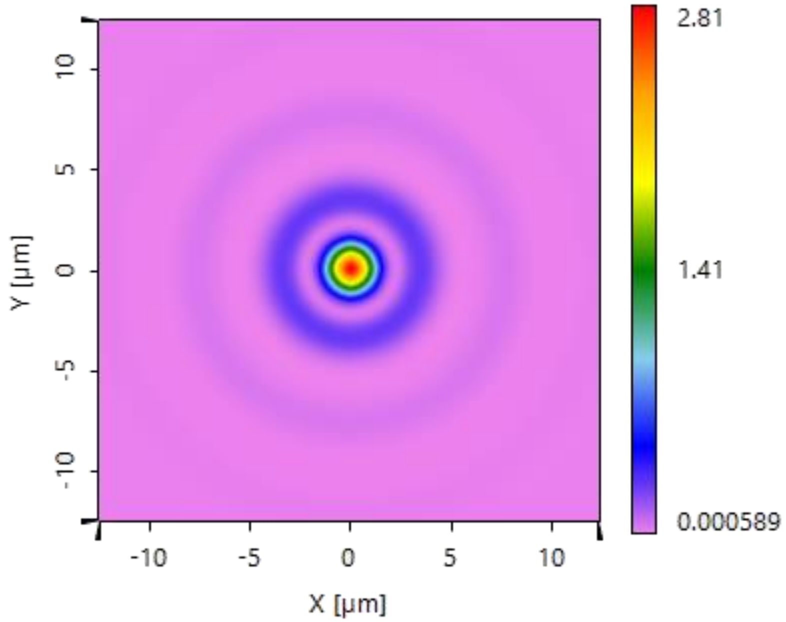




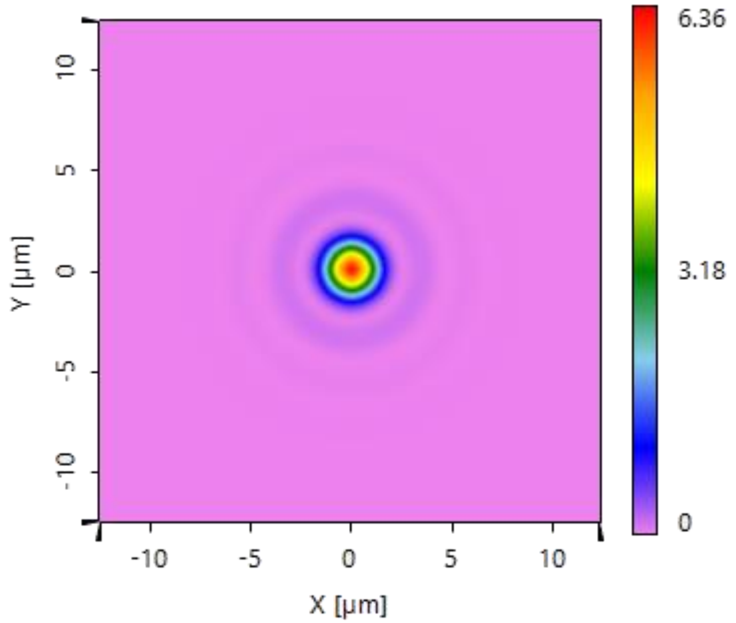
scaling of modulation height by

$\boldsymbol{\beta = 0.90}$

$\propto$ Electric Energy Density [1E4 $(V/m)^2$]

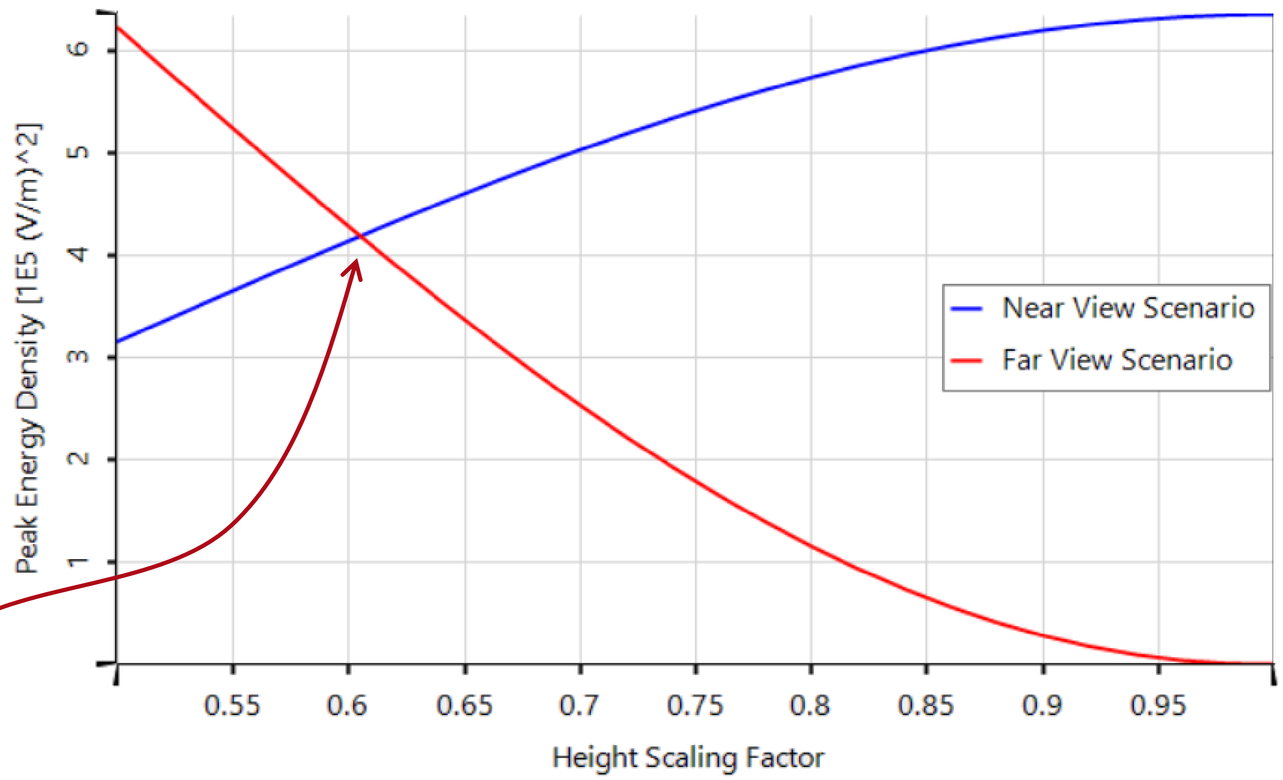



$\propto$ Electric Energy Density [1E5 $(V/m)^2$]



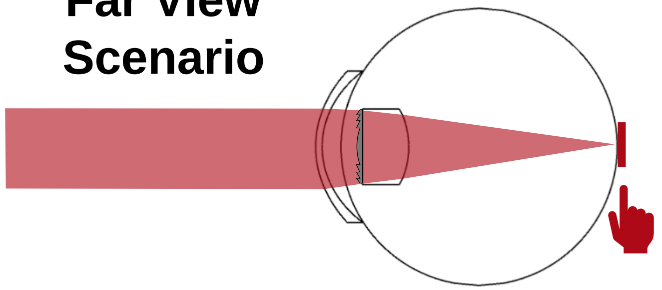
# Structure Design: Find the Optimum Scaling Factor

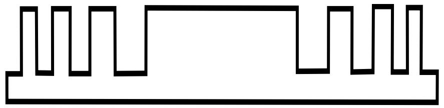
- As a goal, the peak energy density of the foci for both far view and near view scenario shall be the same.
- Therefore, the peak energy density is calculated with respect to the height scaling factor for both scenarios.

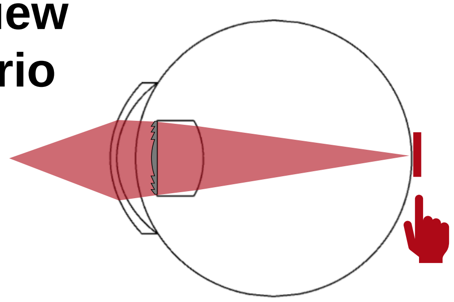


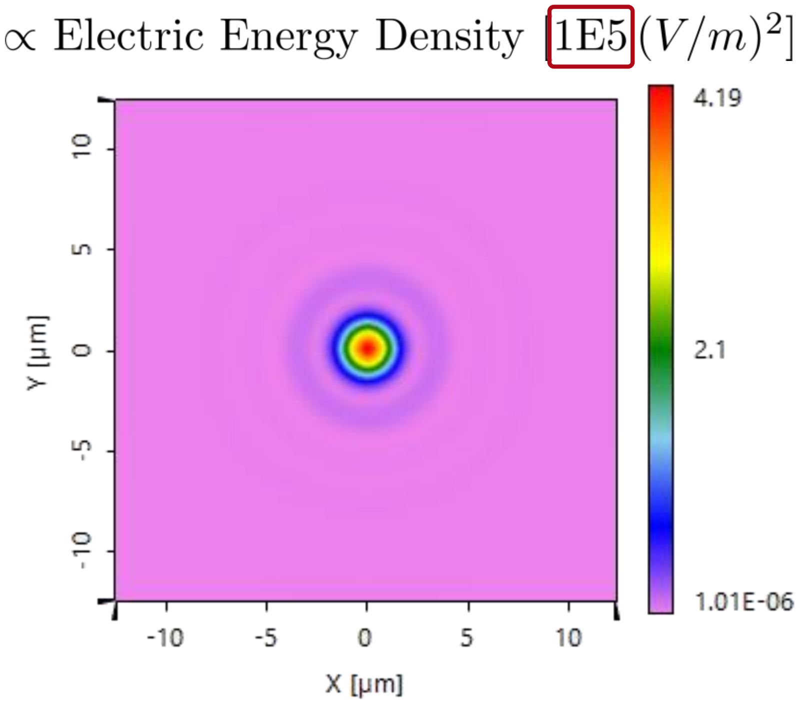

Optimum of the scaling factor for equivalent peak energy density for both foci (near and far view)

# Structure Design: Optimum Height Modulation of 0.605



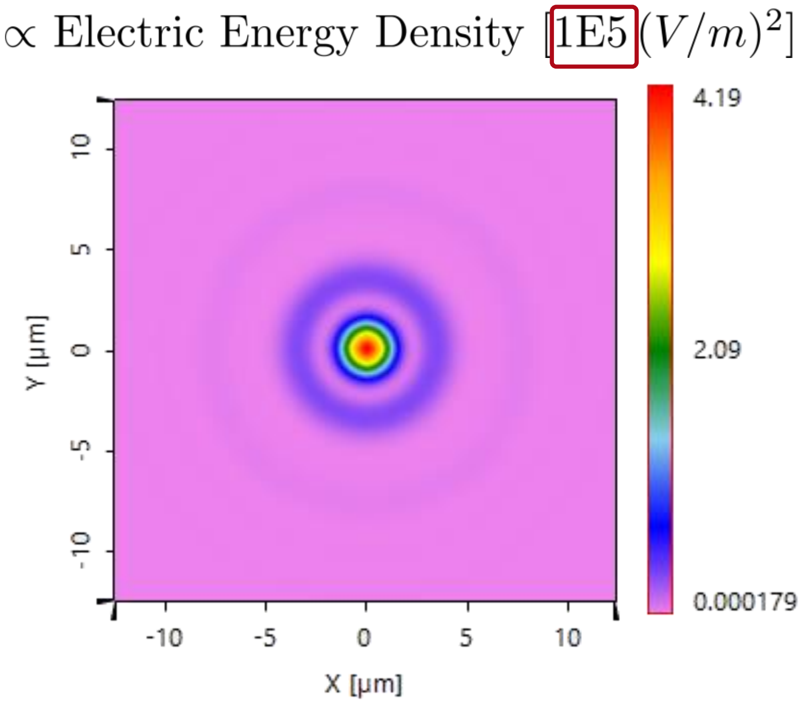






scaling of modulation height by

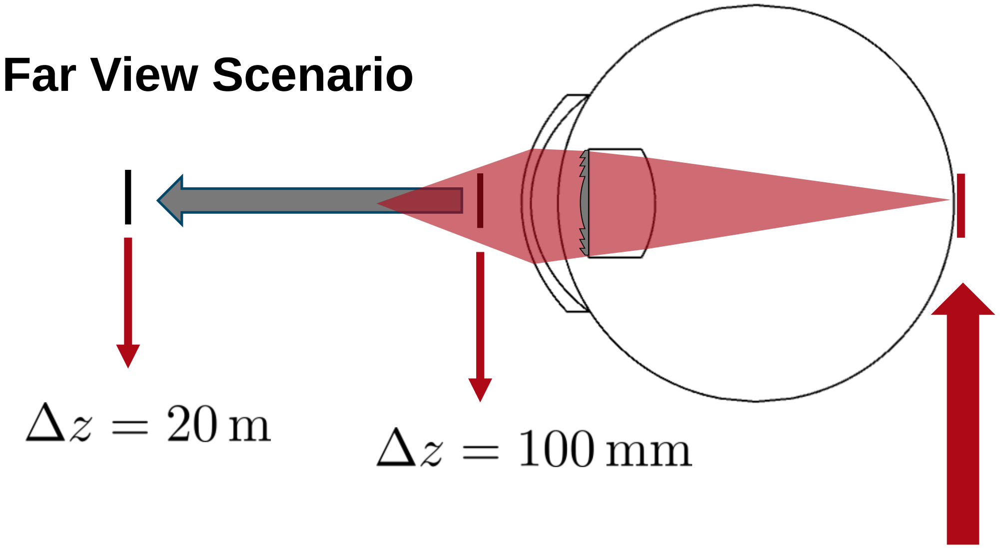
$\beta = 0.605$



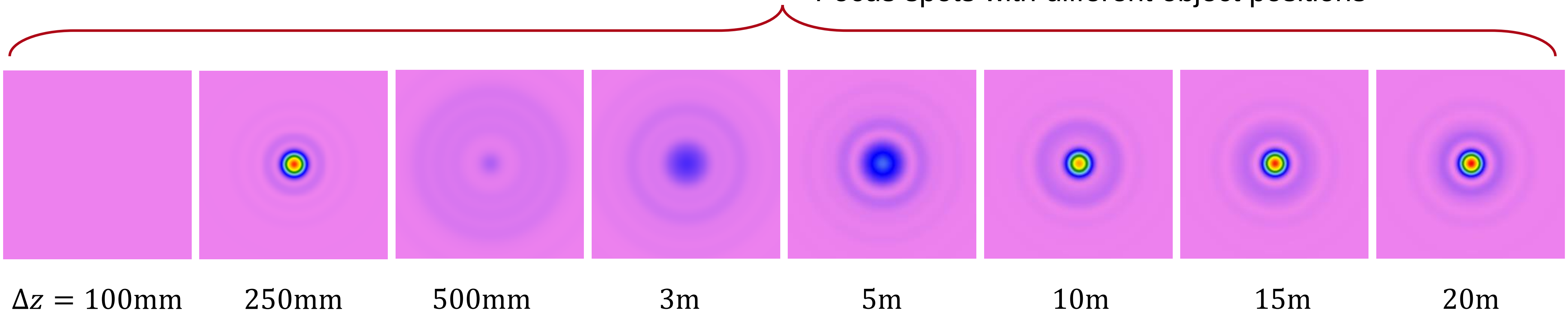

Goal of equivalent maximum energy density for both foci achieved!

# Illustration of Focus Development from Near to Far Region

**Near to Far View Scenario**

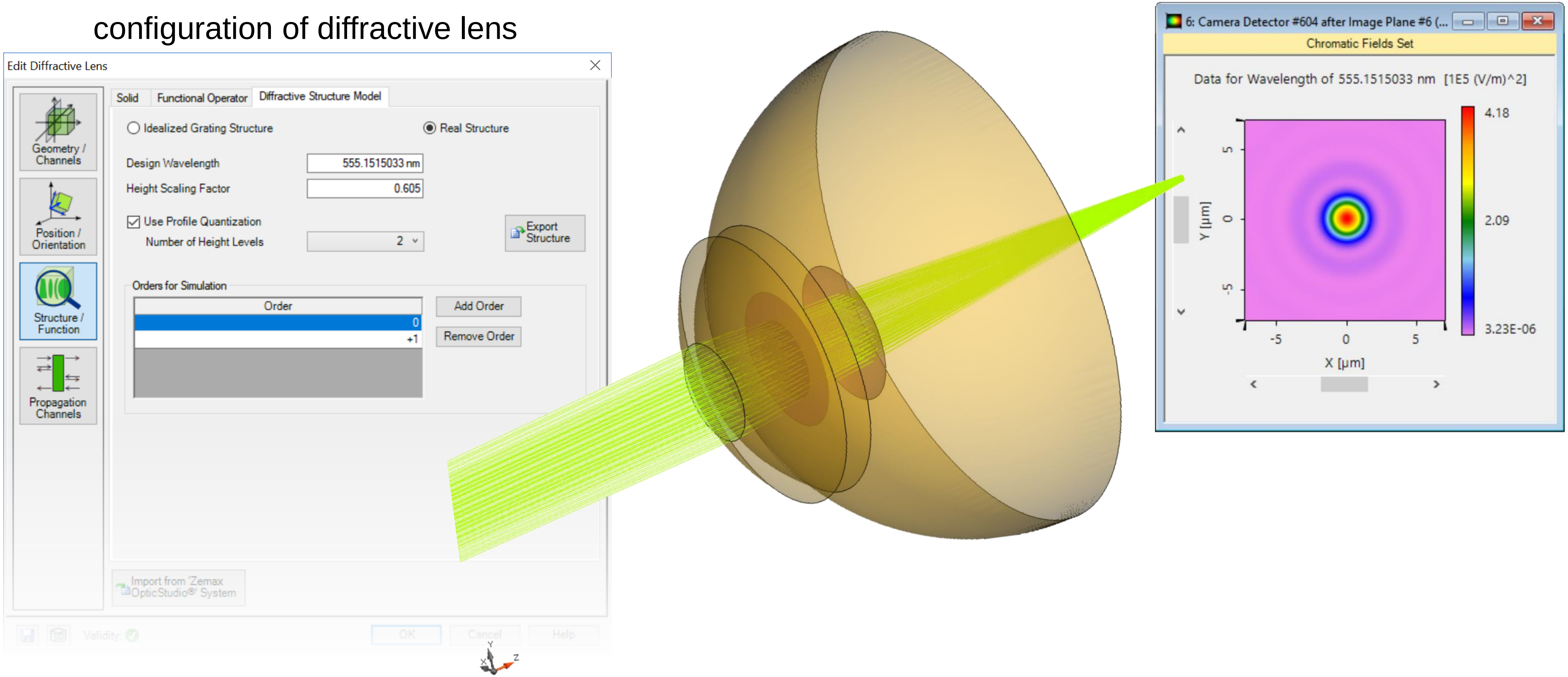



Focus spots with different object positions



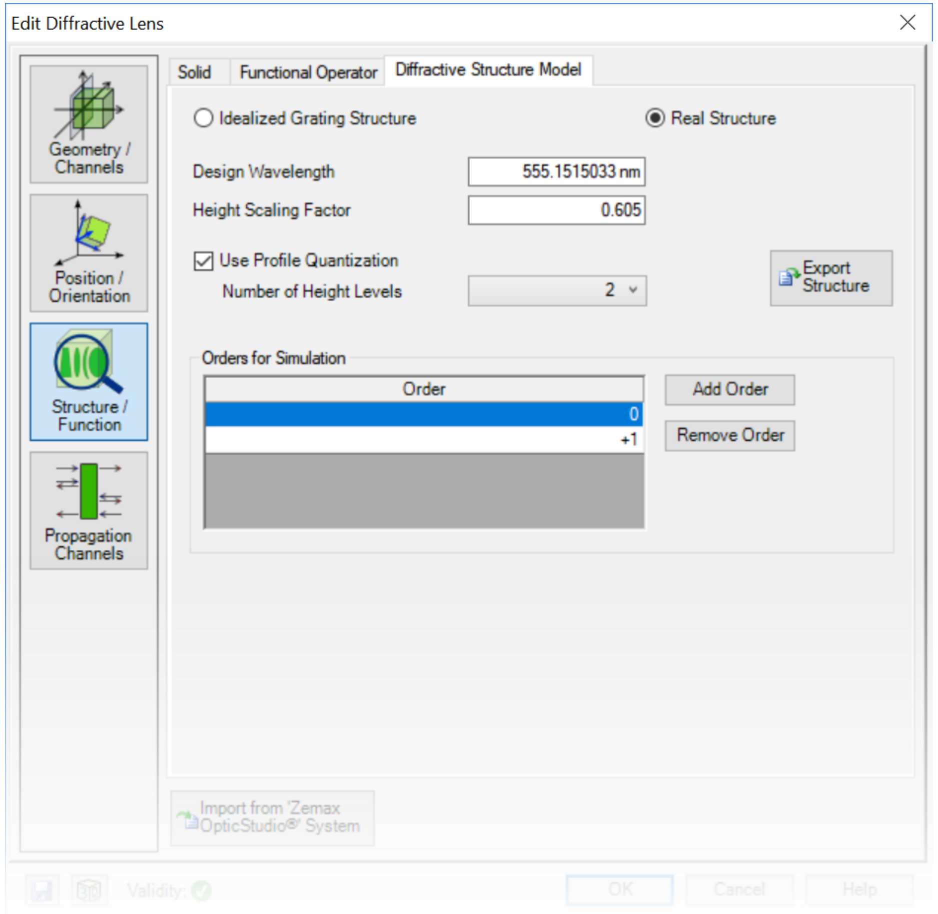
# Peak into VirtualLab Fusion

configuration of diffractive lens

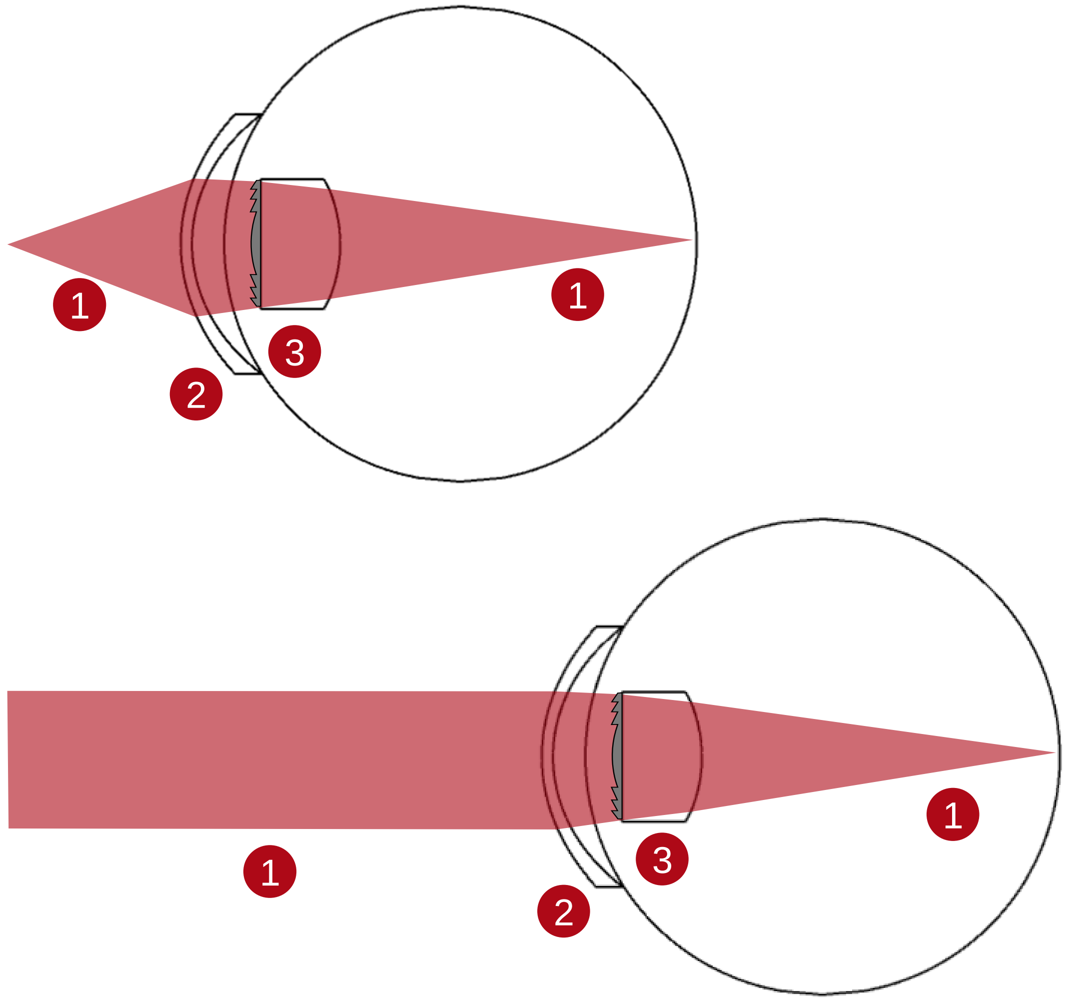


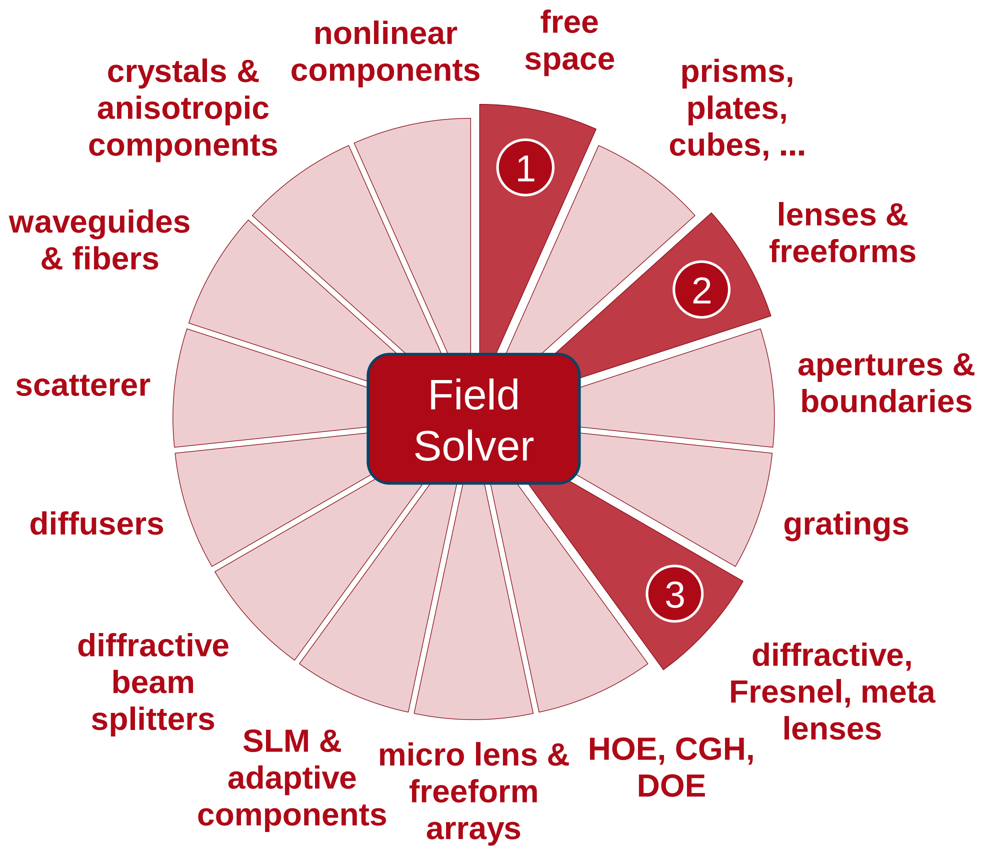
# Workflow in VirtualLab Fusion

- Load different coupling lenses from Zemax files
  - Import Optical Systems from Zemax [Use Case]
- Configuration of Diffractive Lenses
- Configuration of Parameter Run
  - Usage of the Parameter Run Document



# VirtualLab Fusion Technologies



# Document Information

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| VL version used for simulations | VirtualLab Fusion Summer Release 2019 |
| category | Application Use Case |