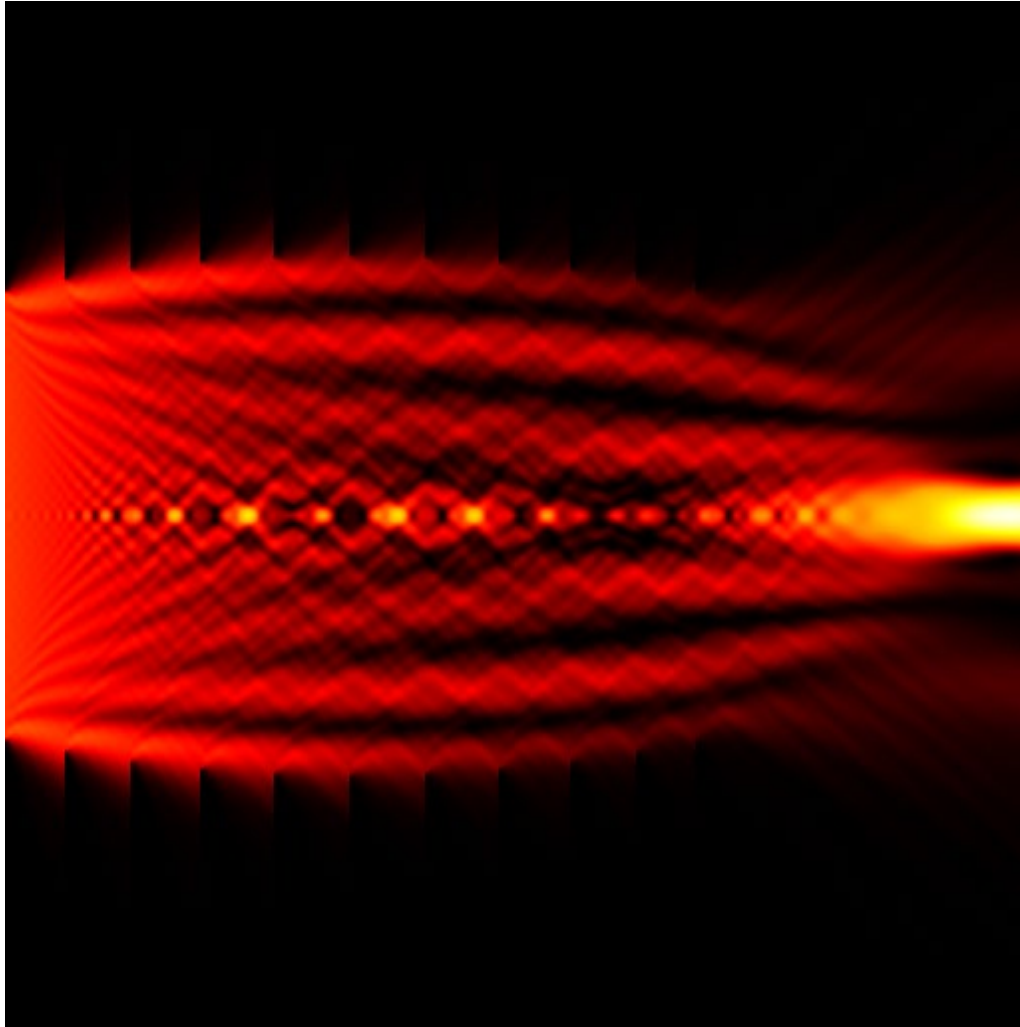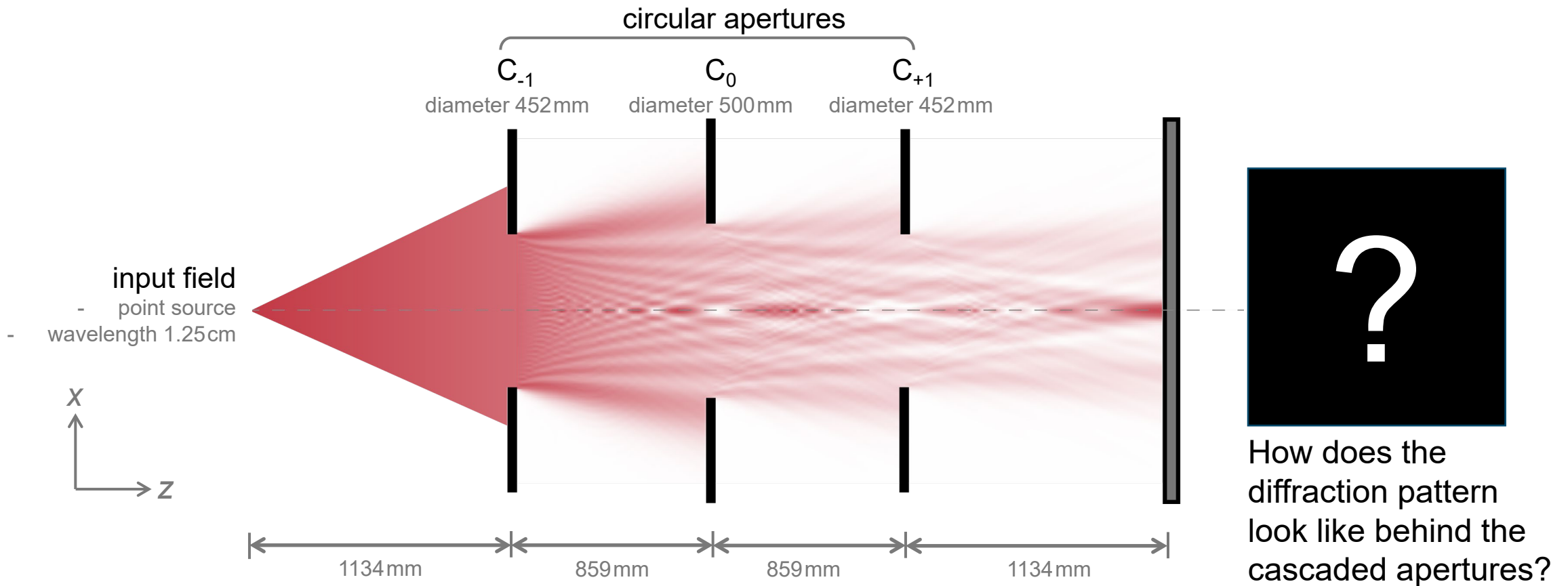# Focusing Electromagnetic Fields with Cascaded Circular Apertures
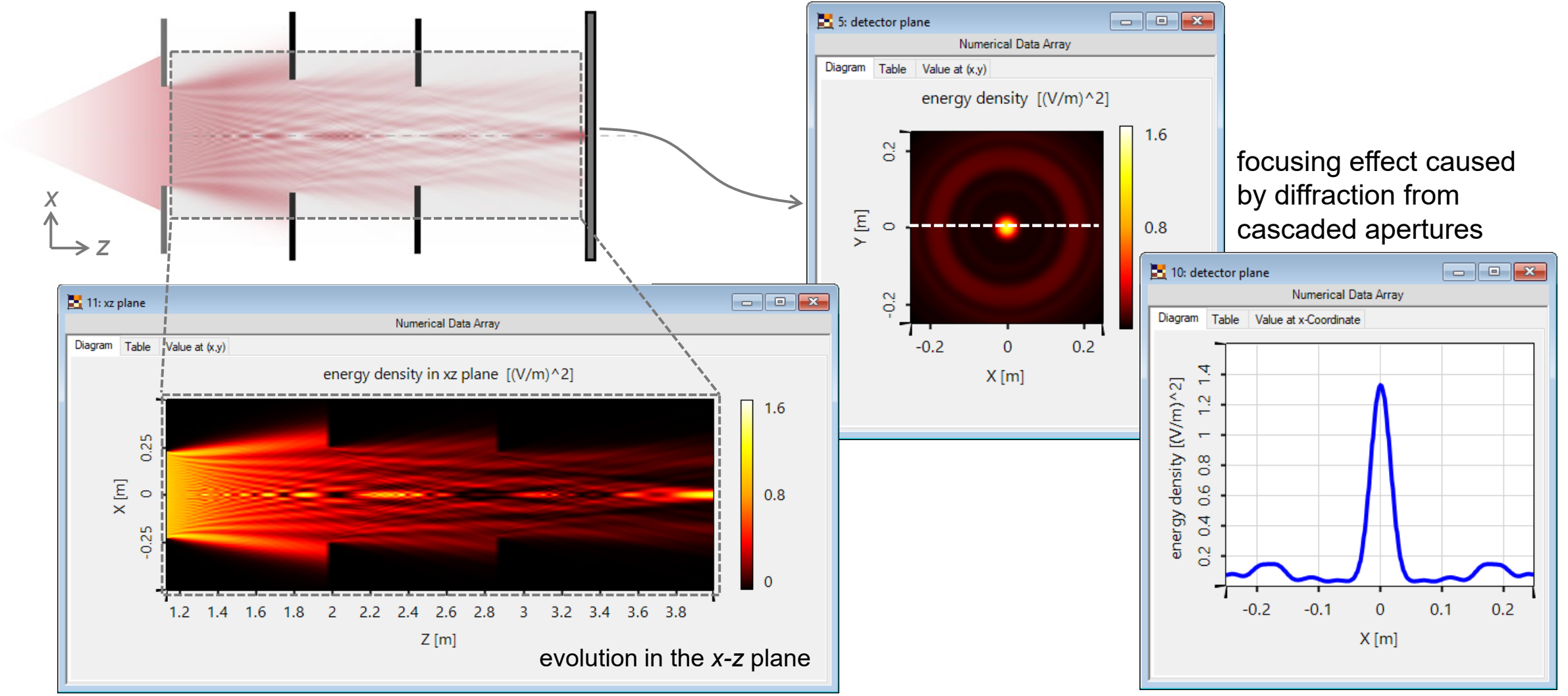
# Abstract

Diffraction from apertures – often understood as a detrimental effect that makes the beam size larger – can be used to focus light in proper configurations. Following the theory of M. De, *et al.*, Appl. Opt. 7, 483-488 (1968), and J. W. Y. Lit, *et al.*, J. Opt. Soc. Am. 59, 559-567 (1969), we demonstrate such effects in VirtualLab Fusion with its flexible Fourier transform settings. In the following two examples, we show the field along z axis, analyze it on the focal plane, and compare it with the reference.

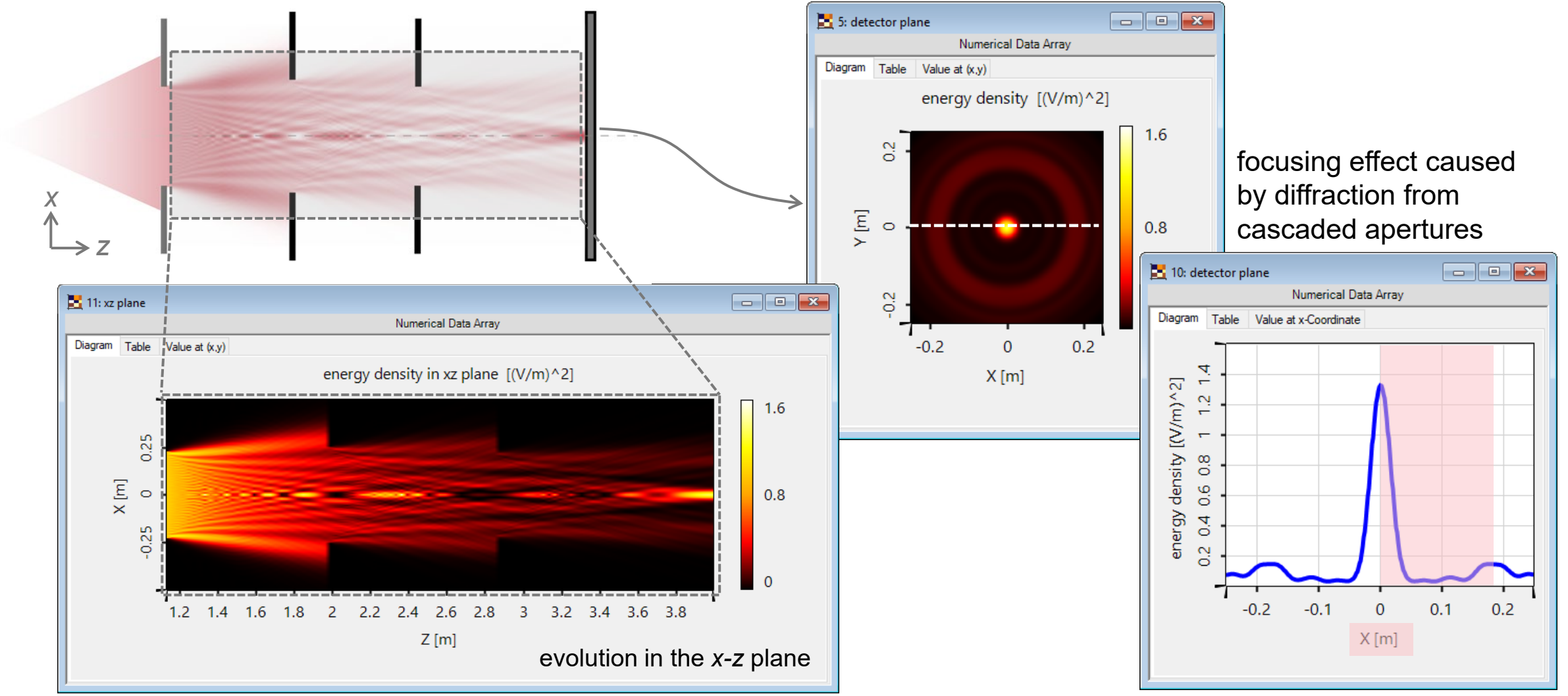# Modeling Task – Three Cascaded Circular Apertures



circular apertures

$C_{-1}$
diameter 452 mm

$C_0$
diameter 500 mm

$C_{+1}$
diameter 452 mm

input field
- point source
- wavelength 1.25 cm

$x$
$z$

1134 mm    859 mm    859 mm    1134 mm

How does the diffraction pattern look like behind the cascaded apertures?

system configuration, including aperture sizes and distances, based on M. De, *et al.*, Appl. Opt. 7, 483-488 (1968), and J. W. Y. Lit, *et al.*, J. Opt. Soc. Am. 59, 559-567 (1969)
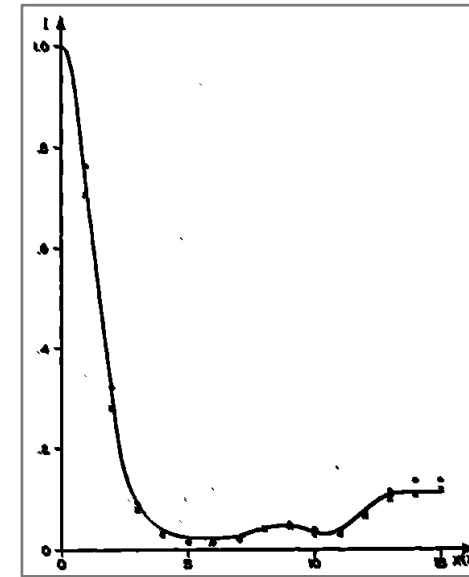
# Diffraction from Three Cascaded Circular Apertures



focusing effect caused by diffraction from cascaded apertures

evolution in the *x-z* plane

# Diffraction from Three Cascaded Circular Apertures



energy density [(V/m)^2]

focusing effect caused by diffraction from cascaded apertures

energy density in xz plane [(V/m)^2]

evolution in the *x-z* plane

energy density [(V/m)^2]

# Diffraction from Three Cascaded Circular Apertures

Fig. 4 from J. W. Y. Lit, *et al.*,
J. Opt. Soc. Am. 59, 559-567 (1969)

energy density in xz plane [(V/m)^2]

evolution in the *x-z* plane
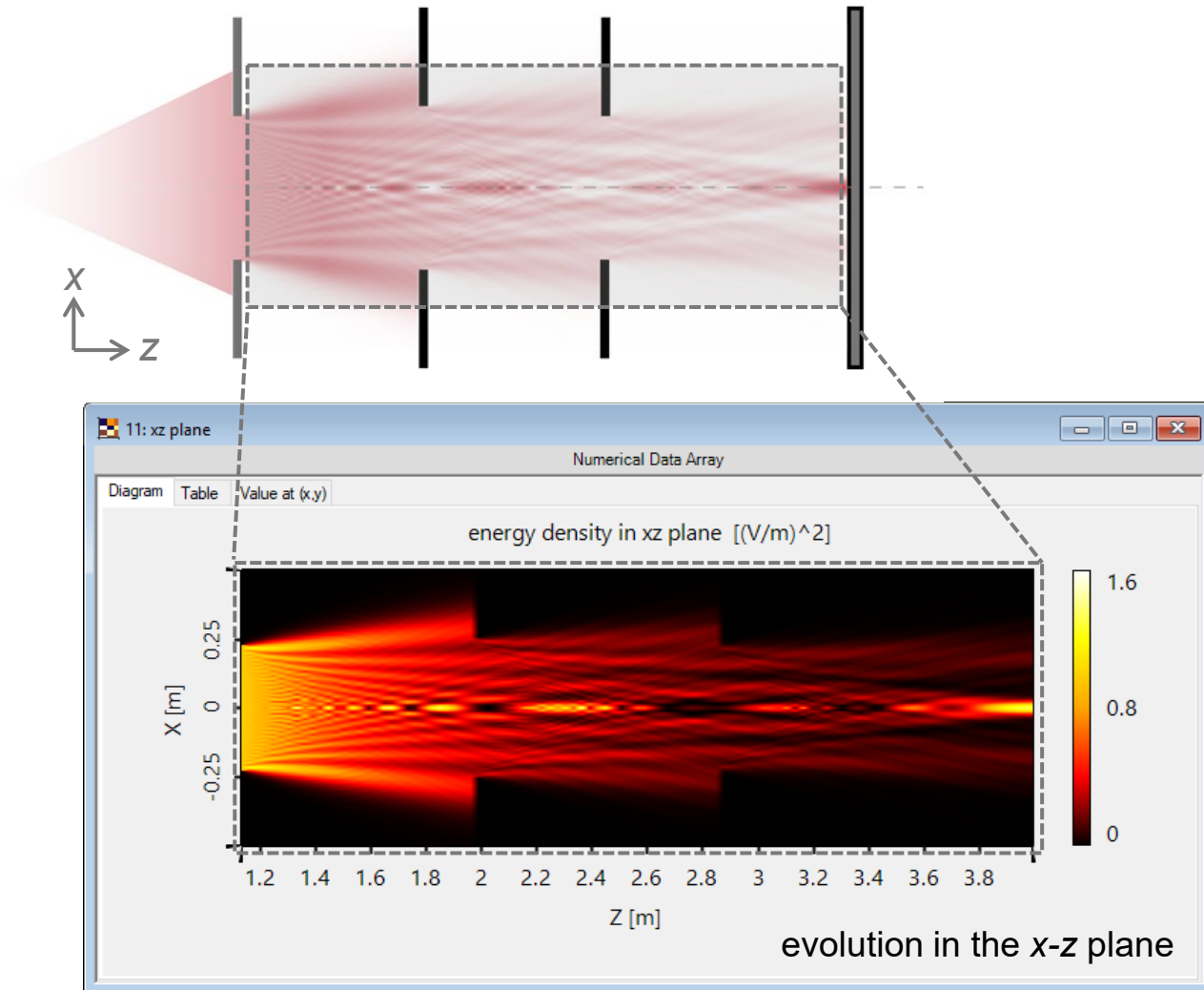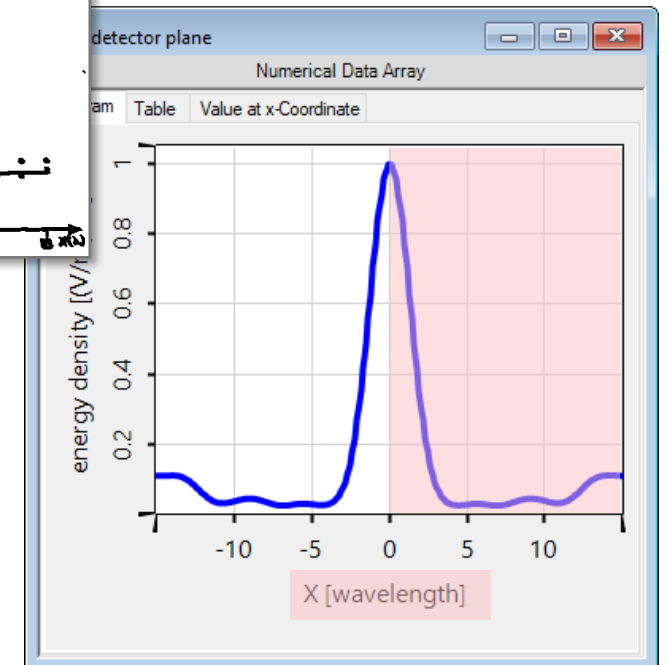
# Modeling Task – Eleven Cascaded Circular Apertures

$C_{-5}$ ⋯ $C_{-3}$ ⋯ $C_0$ ⋯ $C_{+3}$ ⋯ $C_{+5}$

input field
- point source
- wavelength 1.25 cm

$x$

$z$

$d_{-5}$ ⋯ $d_{-2}$ ⋯ $d_{+1}$ ⋯ $d_{+3}$

975 mm

975 mm

?

How does the pattern look like after eleven cascade apertures?
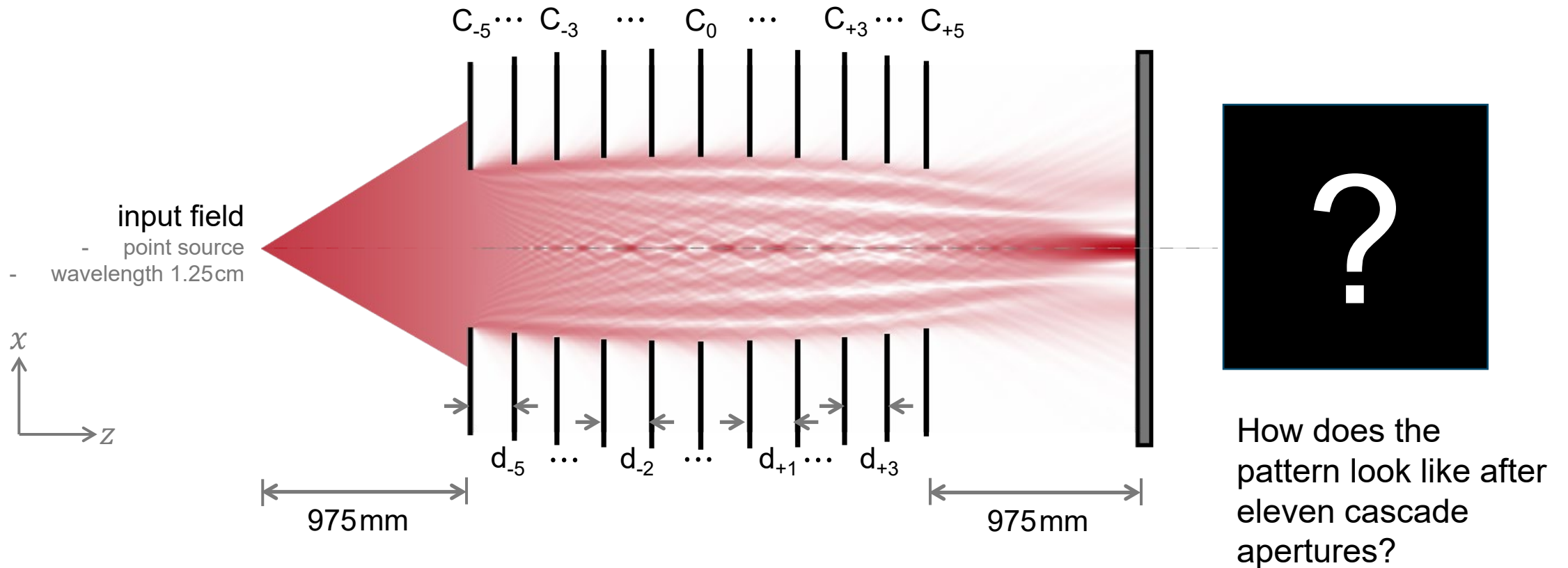
# Aperture Sizes and Locations

| aperture index | diameter | distance between neighbour apertures | |
|:---:|:---:|:---:|:---:|
| $C_{-5}$ | 431 mm | $d_{-5}$ | 176 mm |
| $C_{-4}$ | 454 mm | $d_{-4}$ | 193 mm |
| $C_{-3}$ | 473 mm | $d_{-3}$ | 207 mm |
| $C_{-2}$ | 488 mm | $d_{-2}$ | 217 mm |
| $C_{-1}$ | 497 mm | $d_{-1}$ | 222 mm |
| $C_{0}$ | 500 mm | $d_{0}$ | 222 mm |
| $C_{+1}$ | 497 mm | $d_{+1}$ | 217 mm |
| $C_{+2}$ | 488 mm | $d_{+2}$ | 207 mm |
| $C_{+3}$ | 473 mm | $d_{+3}$ | 193 mm |
| $C_{+4}$ | 454 mm | $d_{+4}$ | 176 mm |
| $C_{+5}$ | 431 mm | | |

based on De *et al*. Appl. Opt. 7, 483-488 (1968)

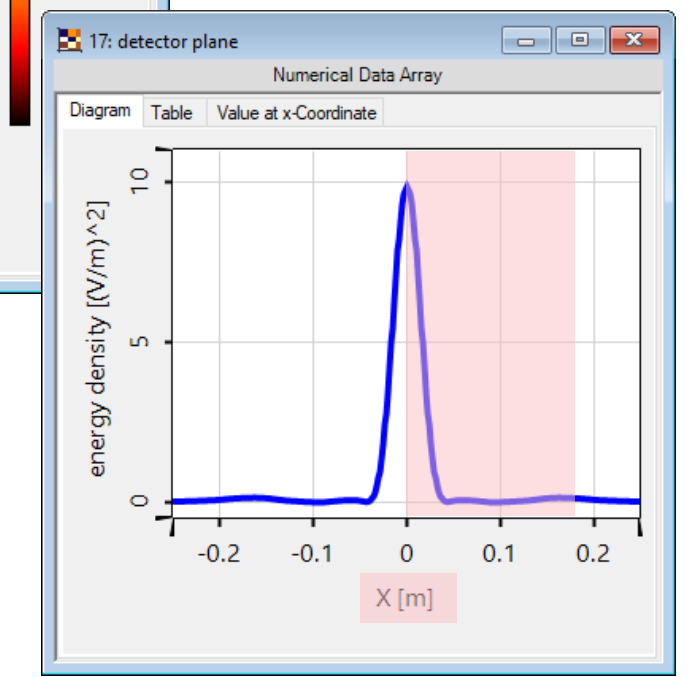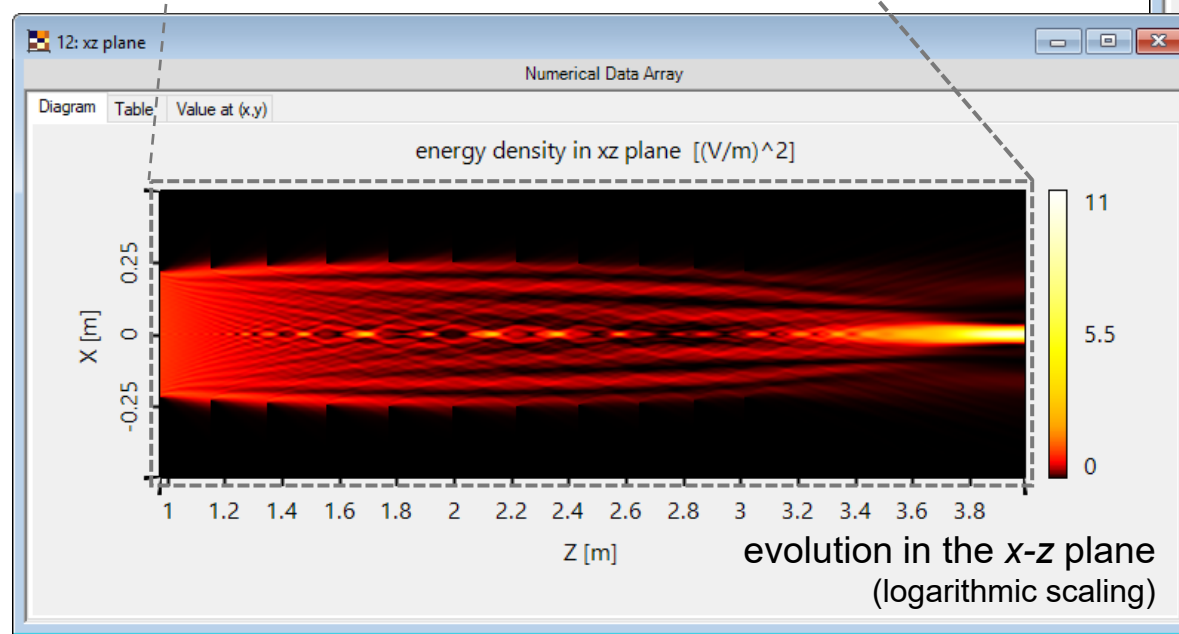# Results Energy Density in Detector and *xz* Plane
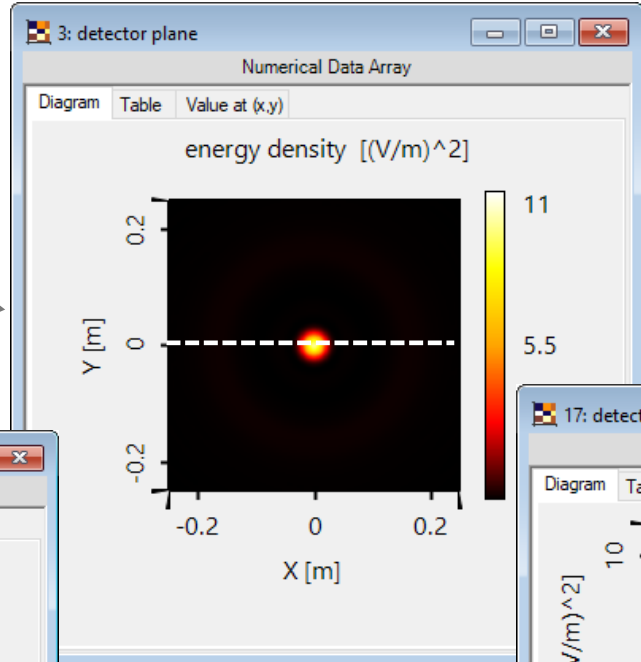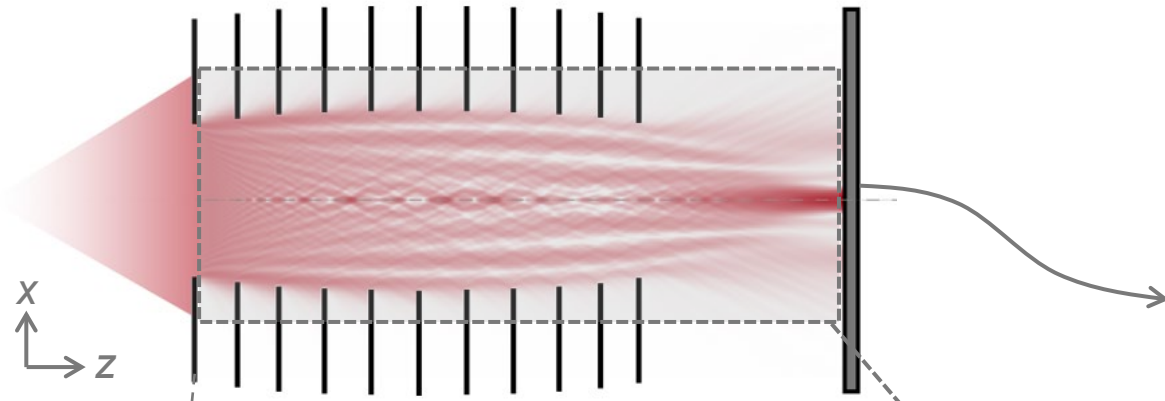


focusing effect caused by diffraction from cascaded apertures
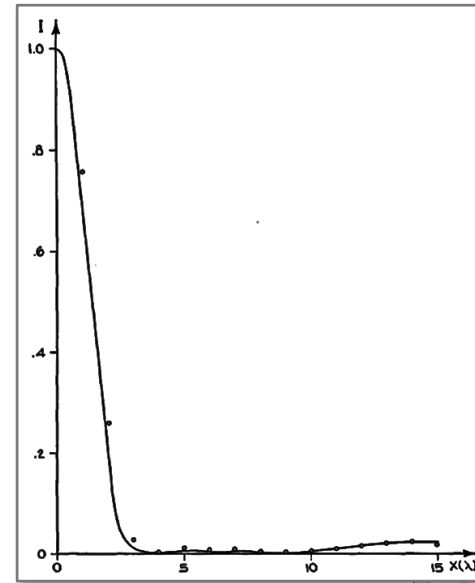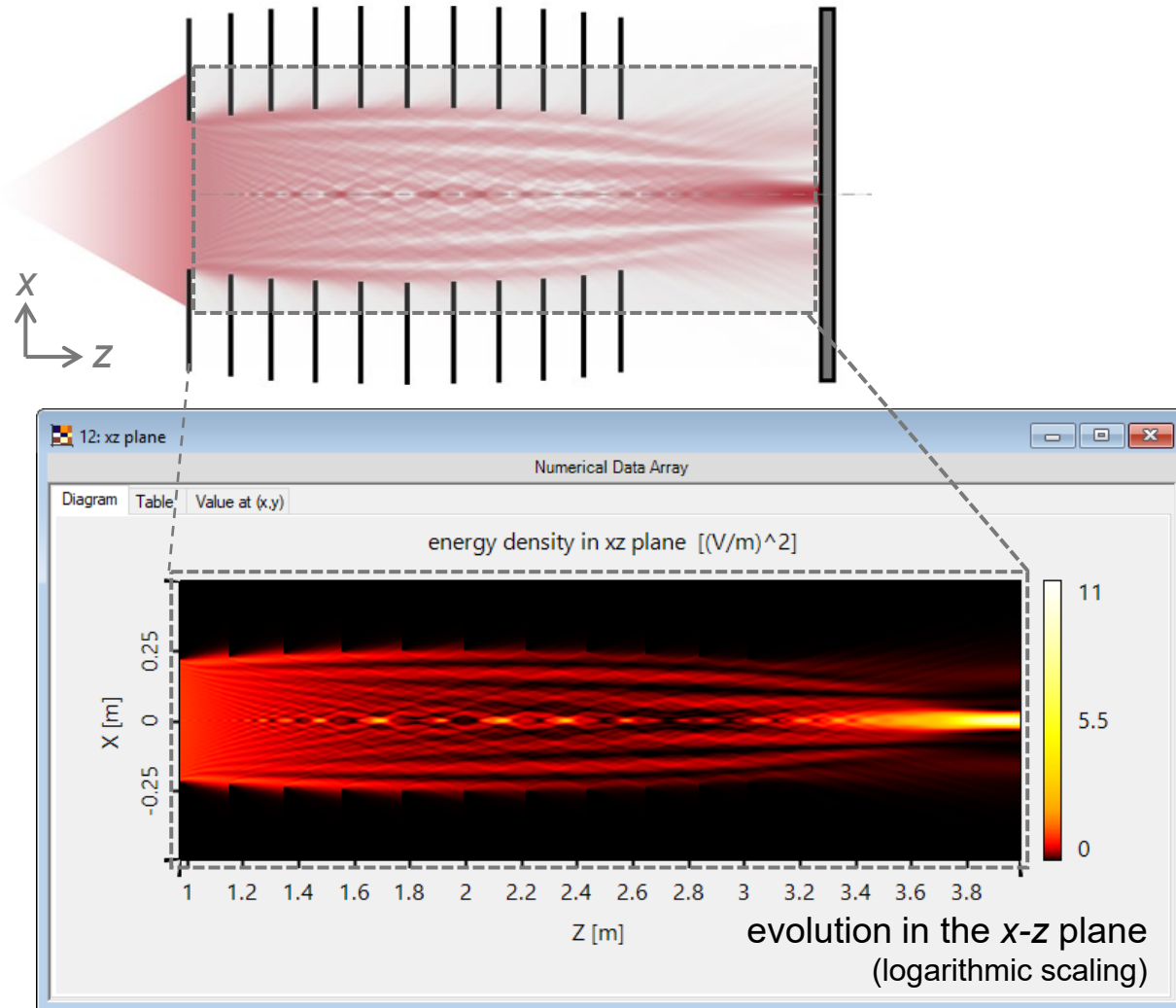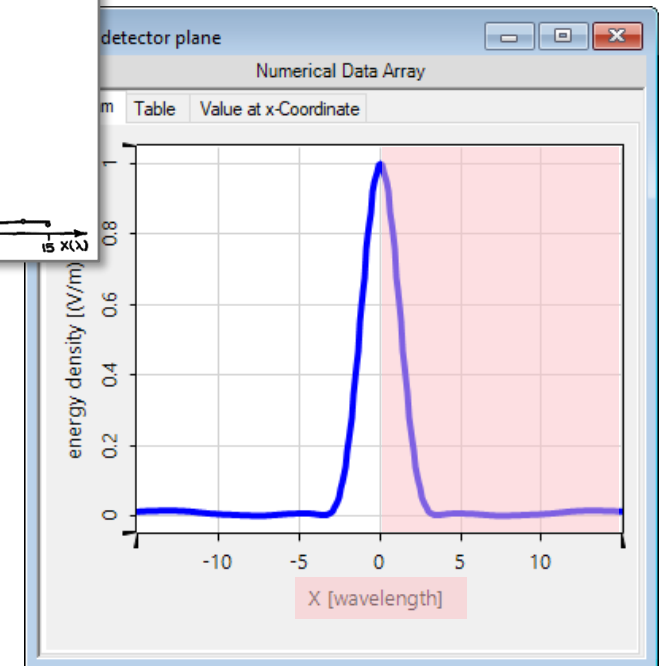
evolution in the *x-z* plane (logarithmic scaling)

# Results Energy Density in Detector and *xz* Plane



focusing effect caused by diffraction from cascaded apertures

evolution in the *x-z* plane
(logarithmic scaling)

# Results Energy Density in Detector and *xz* Plane

x
z

Fig. 5 from J. W. Y. Lit, *et al.*,
J. Opt. Soc. Am. 59, 559-567 (1969)

**12: xz plane** — Numerical Data Array

Diagram | Table | Value at (x,y)

energy density in xz plane [(V/m)^2]

X [m]

Z [m]

evolution in the *x-z* plane
(logarithmic scaling)

detector plane — Numerical Data Array

m | Table | Value at x-Coordinate

energy density [(V/m)]

X [wavelength]
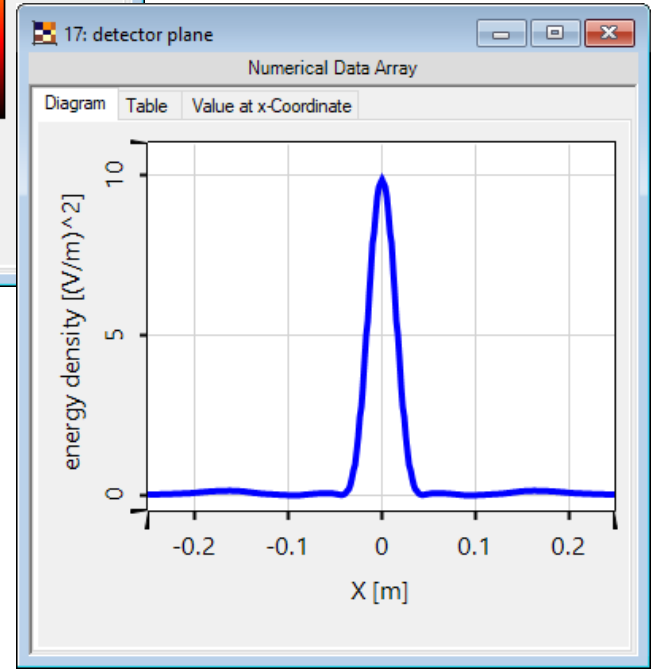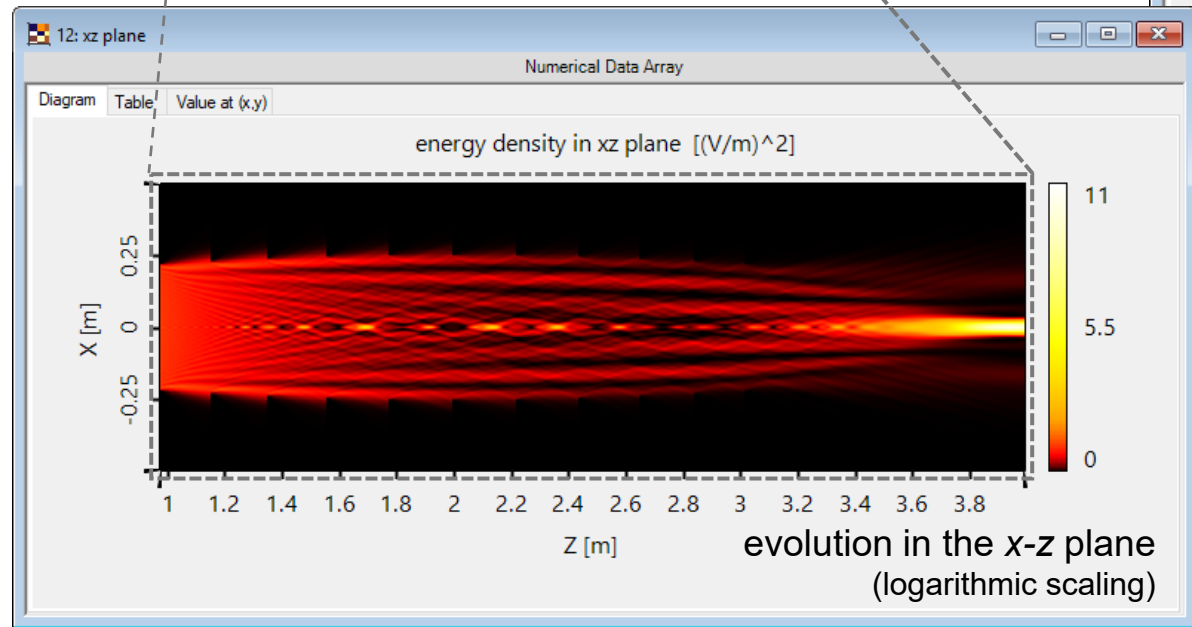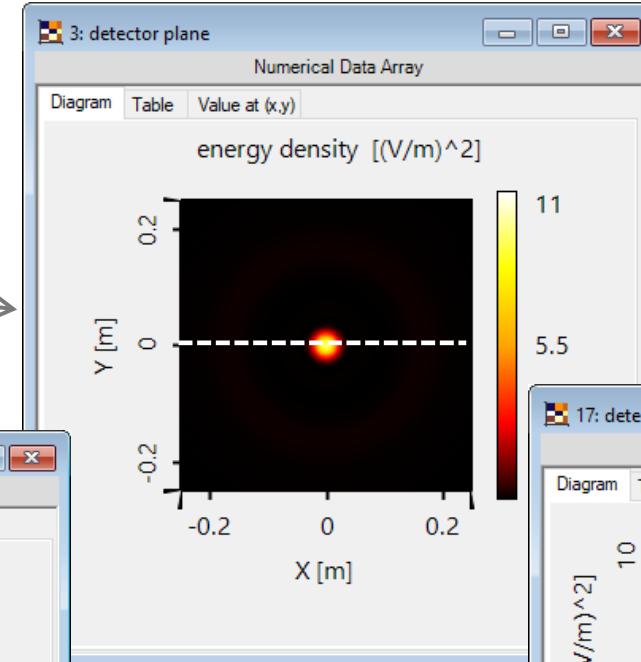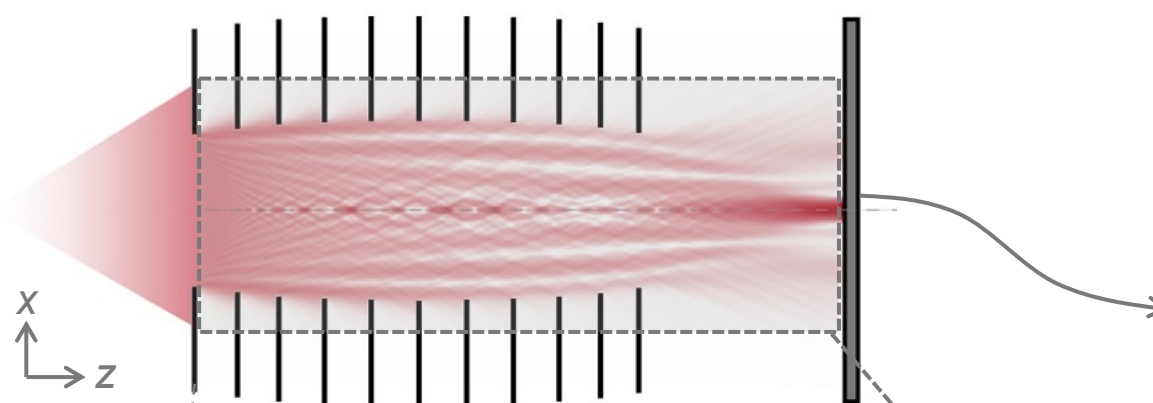
# Peek into VirtualLab Fusion

Parameter Overview for fast accessing system parameters



flexible Fourier transform settings
for diffraction consideration

# Workflow in VirtualLab Fusion

- Set the Fourier transforms properly

- Select proper detector for field visualization
  - Usage of Cameral Detector [Use Case]

- Use Parameter Run to scan along z axis
  - Usage of Parameter Run [Use Case]
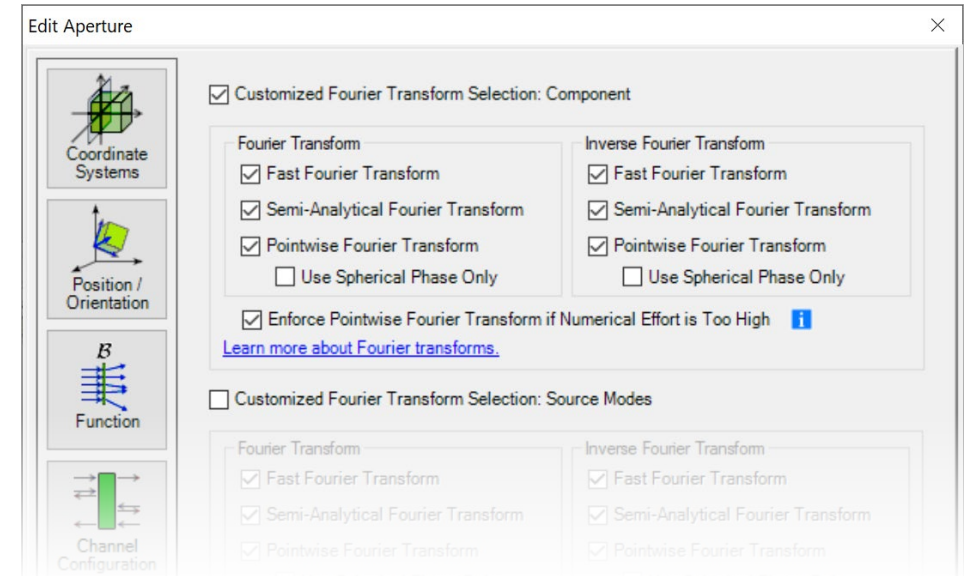
# VirtualLab Fusion Technologies
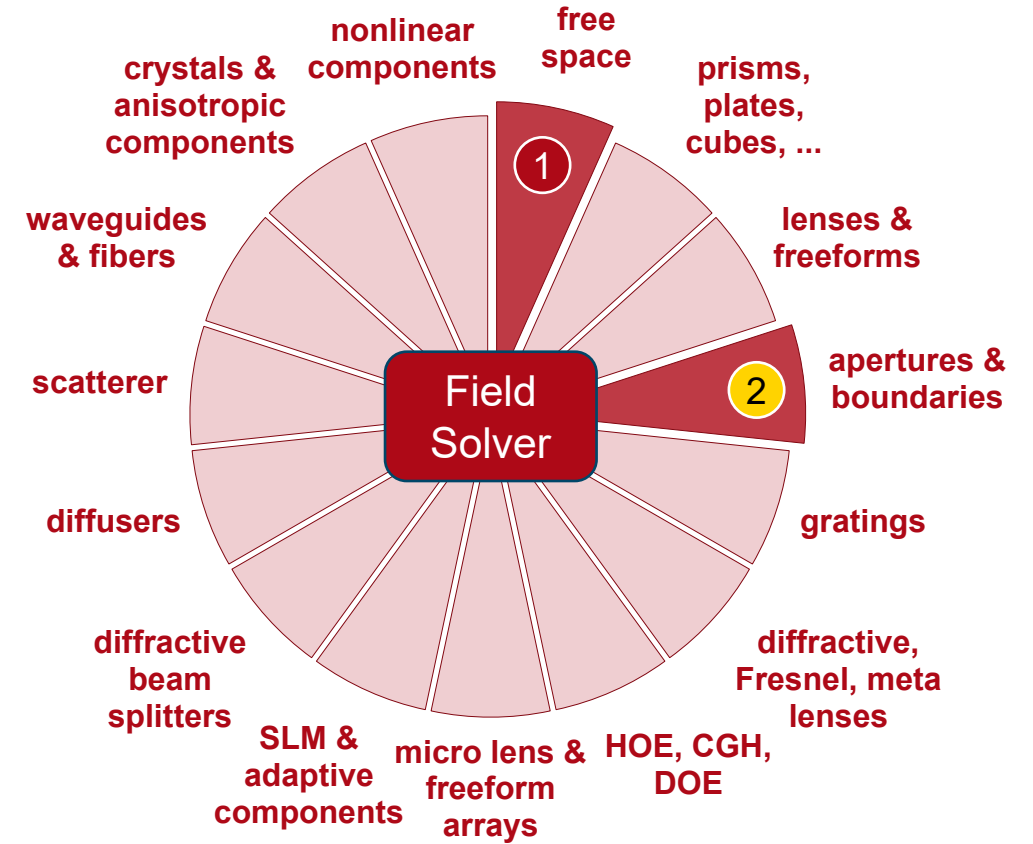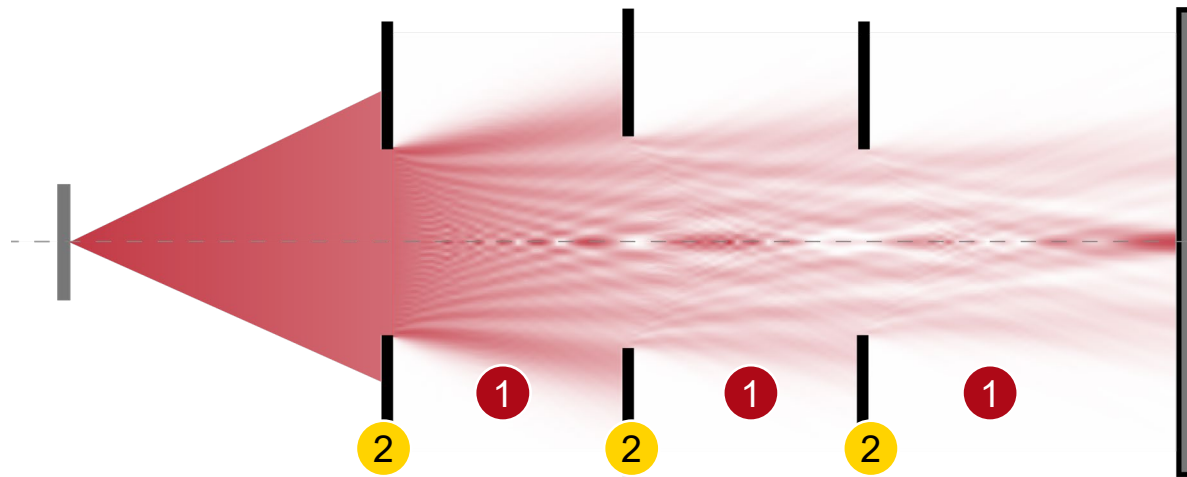
# Document Information

| | |
|---|---|
| title | Focusing Electromagnetic Fields with Cascaded Circular Apertures |
| document code | MISC.0081 |
| version | 1.0 |
| edition | VirtualLab Fusion Basic |
| software version | 2020.1 (Build 1.202) |
| category | Application Use Case |
| further reading | - Pinhole Modeling in a Low-Fresnel-Number System<br>- Diffraction Patterns behind Different Apertures |