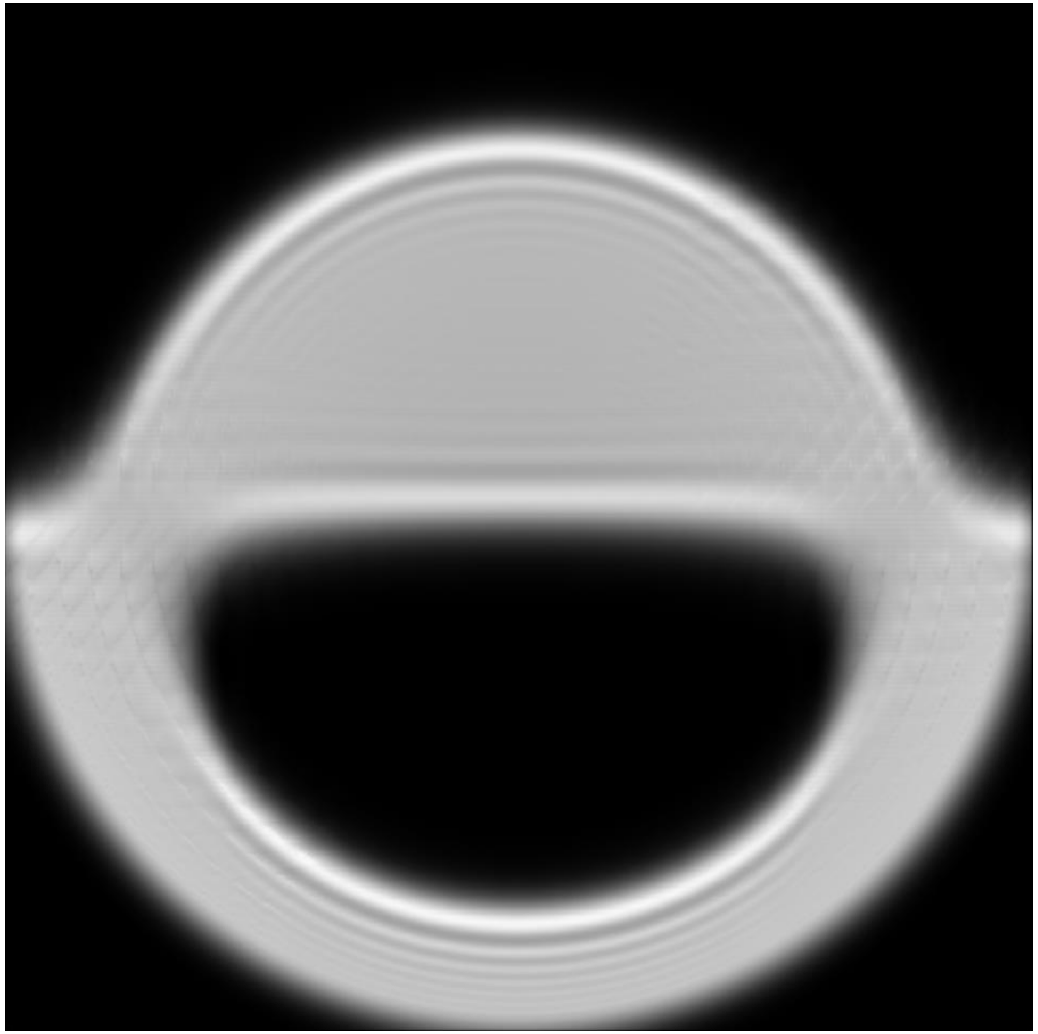
Modeling of Foucault Knife-Edge Test

Abstract

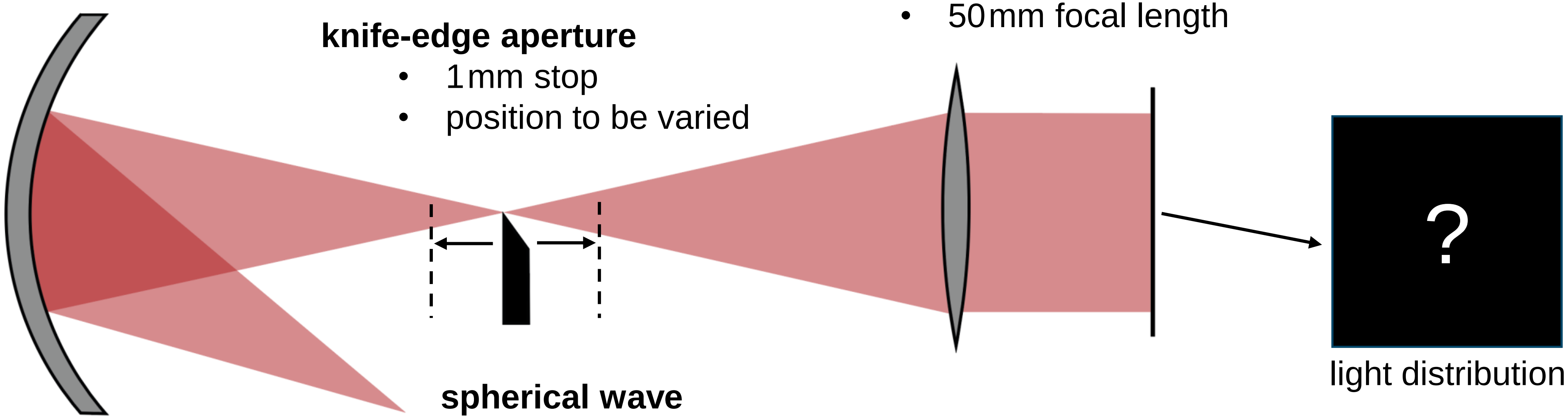


Since 1858 the Foucault knife-edge test has been a simple and inexpensive method to determine the properties of a concave shaped mirror. As the name suggests, in this test, a knife's edge (e.g. a razor blade) is held in the path of the beam, close to the expected focal point, to obscure half of the beam. The transmitted field is then again collimated before evaluation. The resulting pattern provides an indication of the shape of the mirror used. Furthermore, if the position of the knife-edge is varied along the optical axis, the resulting light pattern at the detector plane will also change. This behavior enables the user to precisely determine the position of the focal point of the curved mirror.

Modeling Task

idealized collimation
- 50 mm focal length

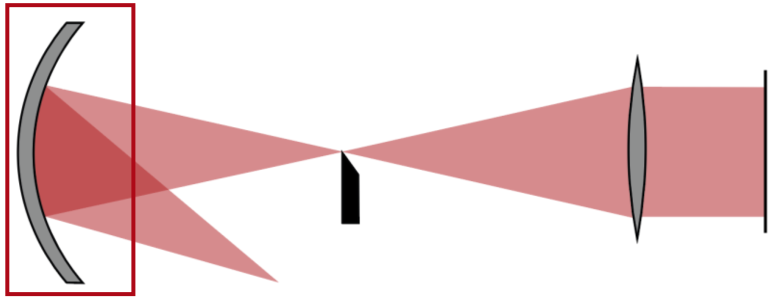
knife-edge aperture
- 1 mm stop
- position to be varied

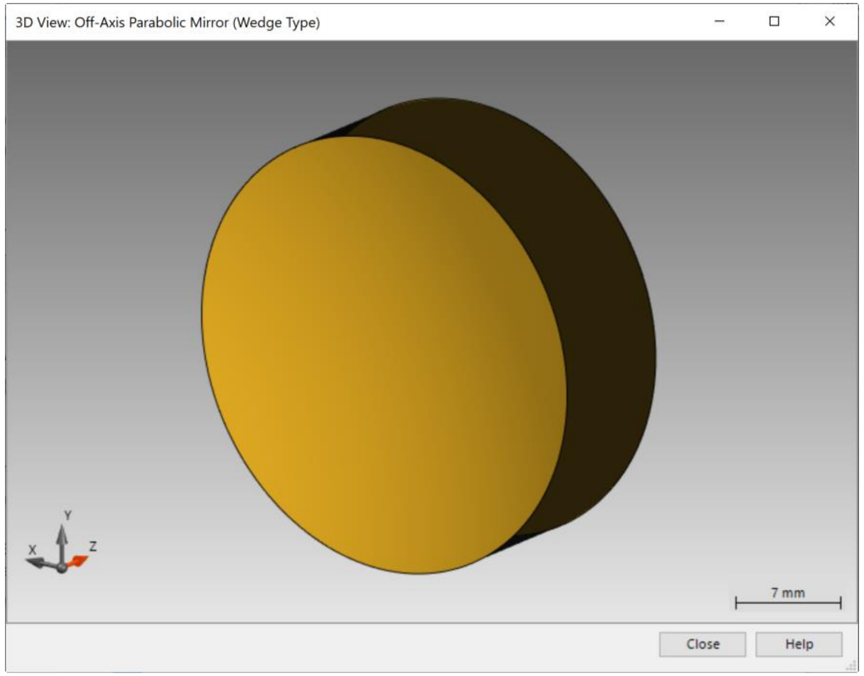


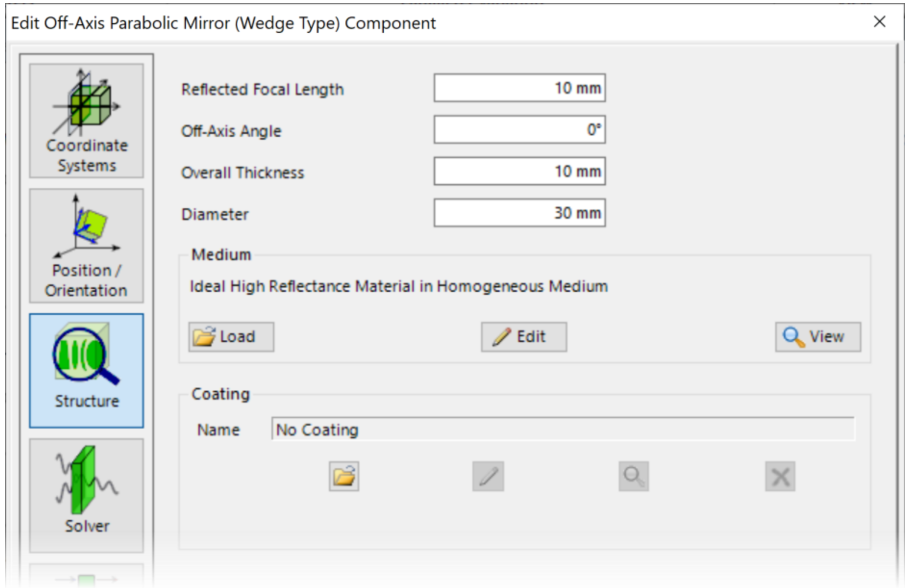
spherical wave
- 532 nm central wavelength
- 20 mm × 20 mm diameter
- 50 mm distance to point source

concave mirror
- 20 mm × 20 mm diameter
- ideal reflecting material
- two shapes:
  a) parabolic mirror: 25 mm back focal length
  b) spherical mirror: 50 mm focal length

System Building Blocks – Parabolic Mirror

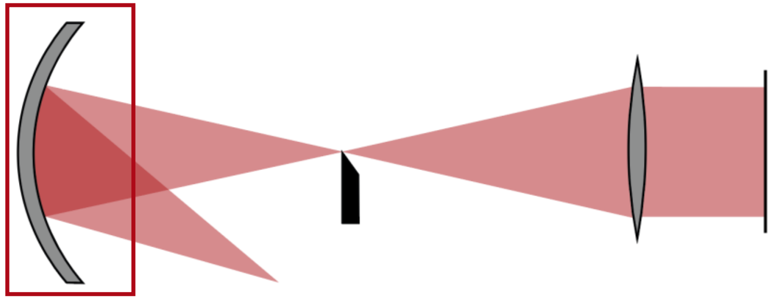


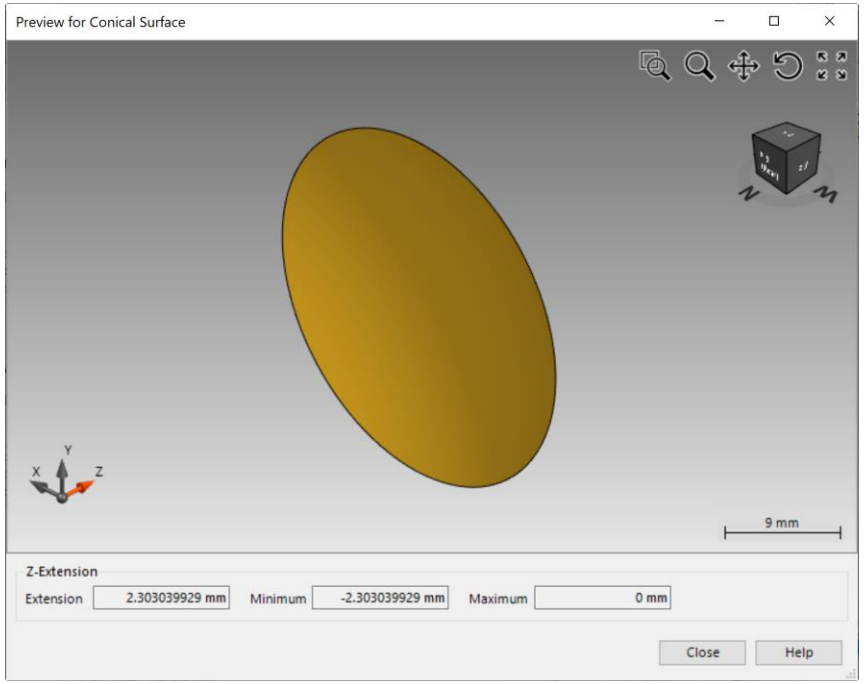


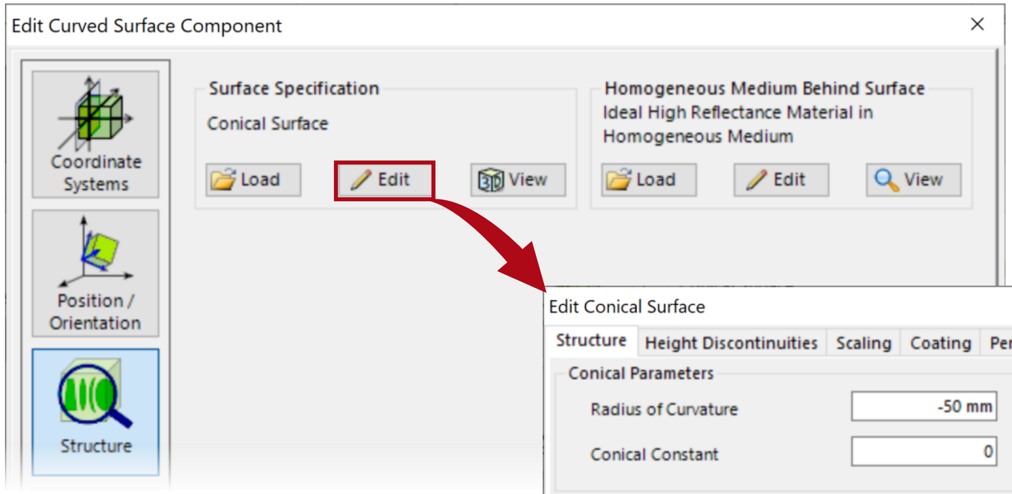


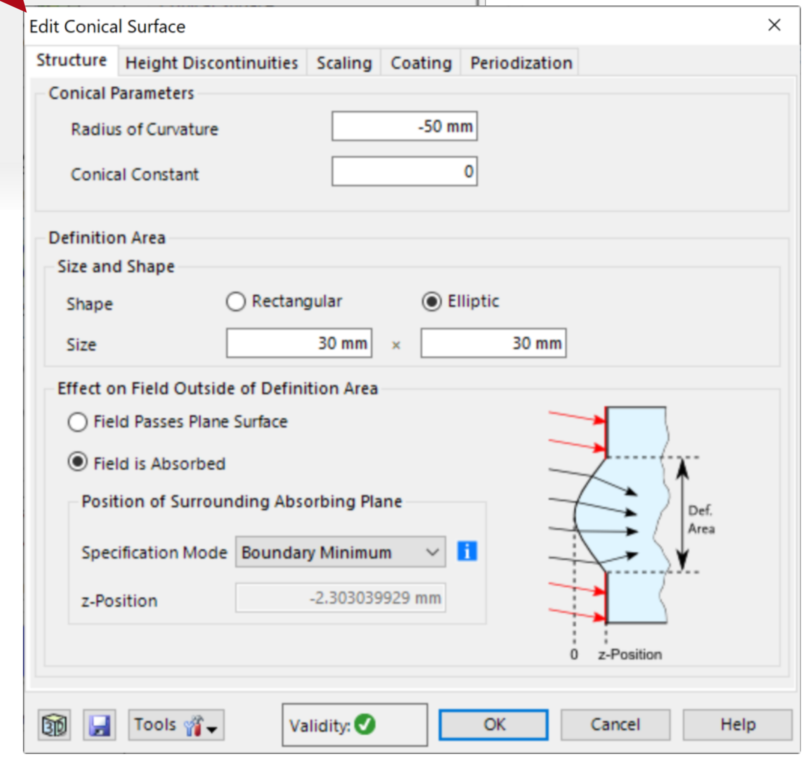
The *Off-Axis Parabolic Mirror (Wedge Type) Component* provides the definition of a parabolic mirror. While it is possible to select any material for the bulk of the mirror, and to add a coating to the reflective surface, for the purposes of this use case an idealized high reflective material is chosen. This also makes the need for an additional high-reflection coating unnecessary.

System Building Blocks – Spherical Mirror



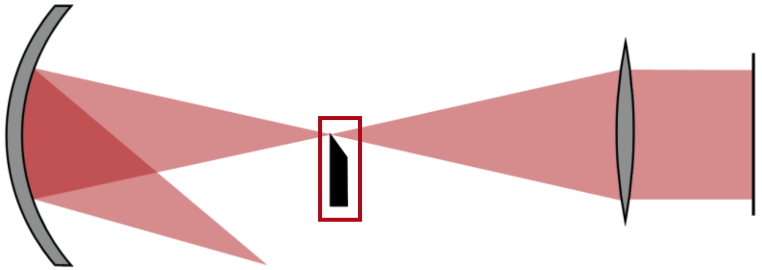




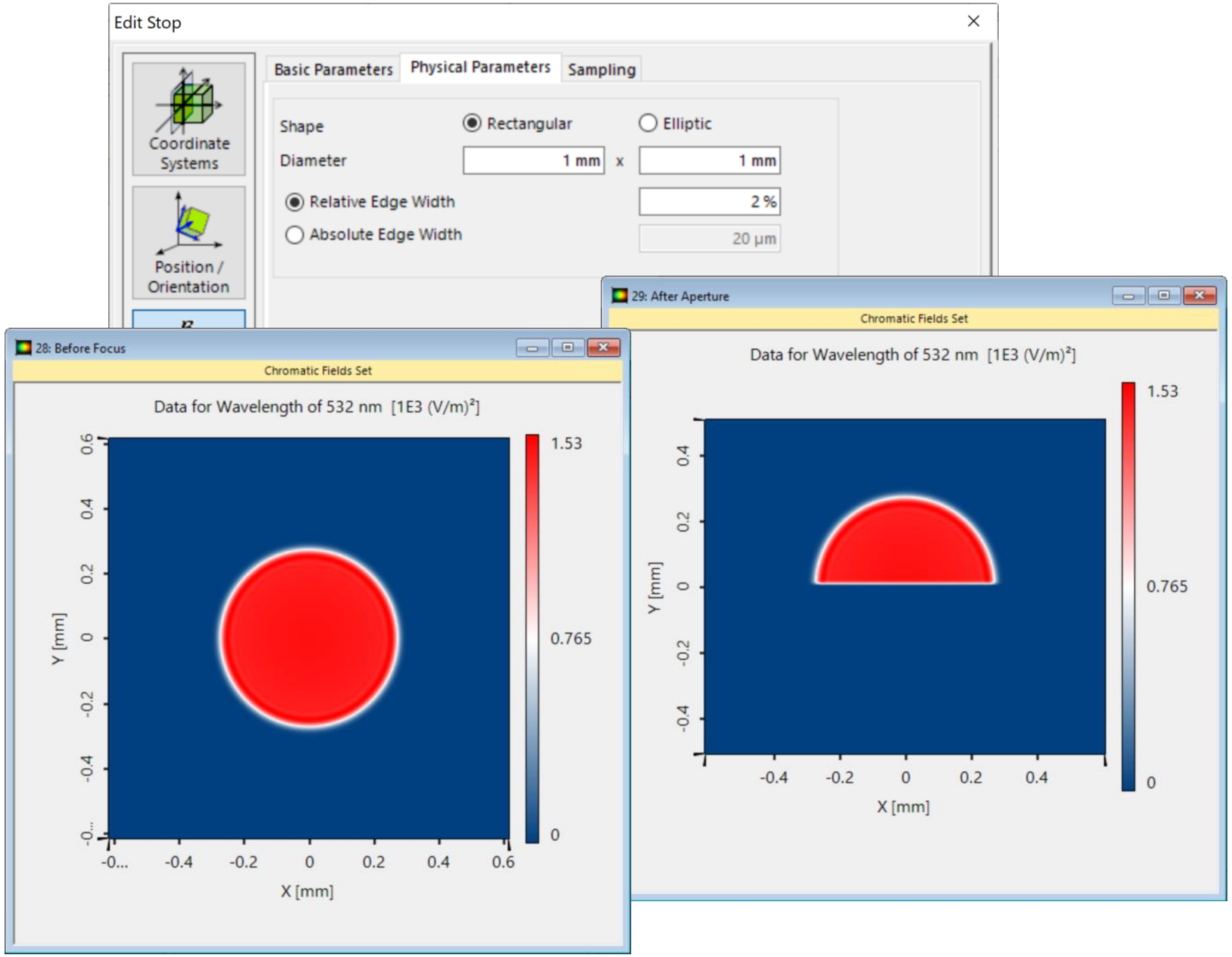


By using the *Curved Surface Component*, a single, arbitrarily shaped surface can be added to an optical system. In this case, a *Conical Surface* is loaded from the surface catalog, to model the spherical mirror.

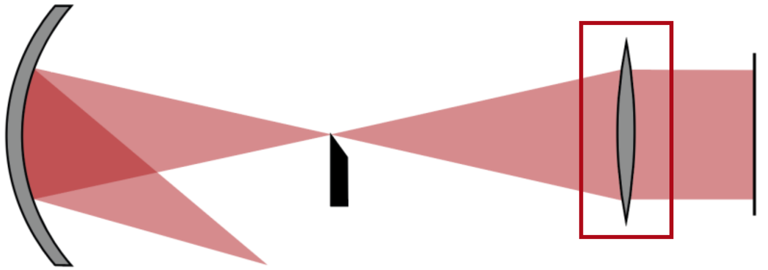
System Building Blocks – Stop



The knife-edge is modeled by a *Stop* that can be moved along and perpendicular to the optical axis (z-axis).



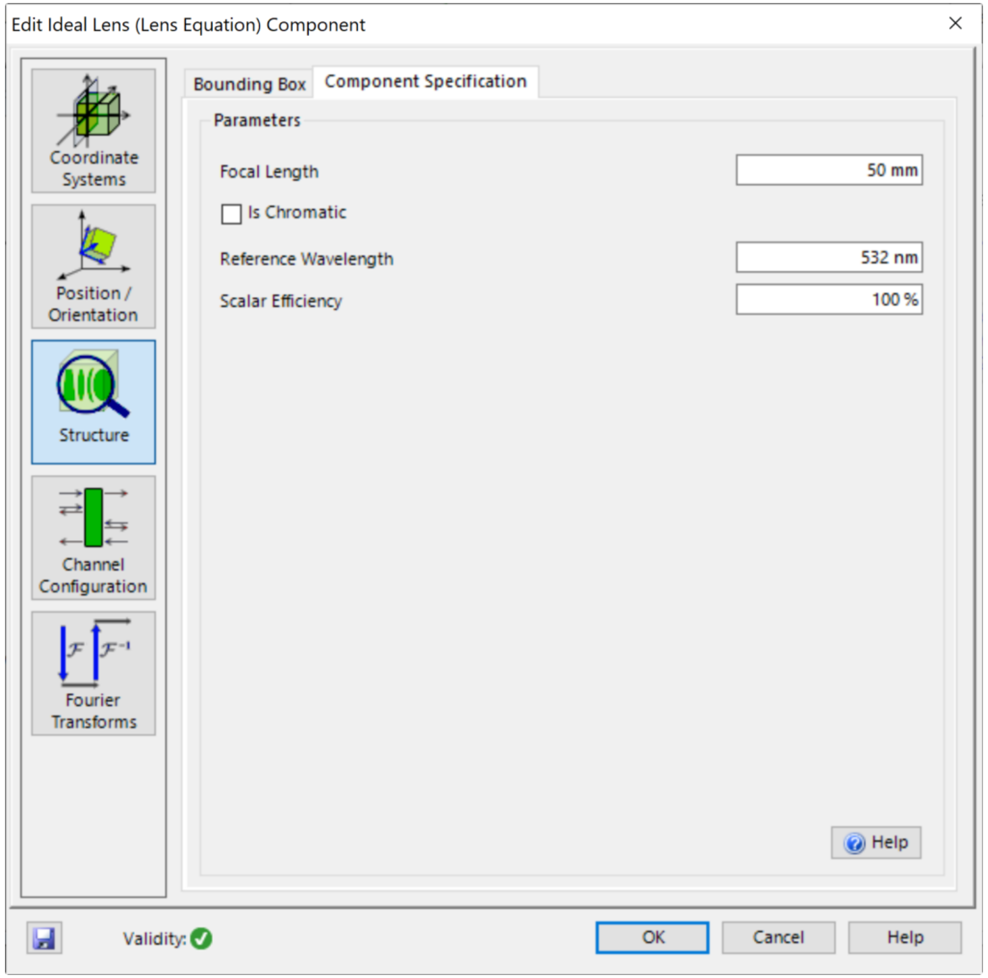
System Building Blocks – Idealized Collimation Lens



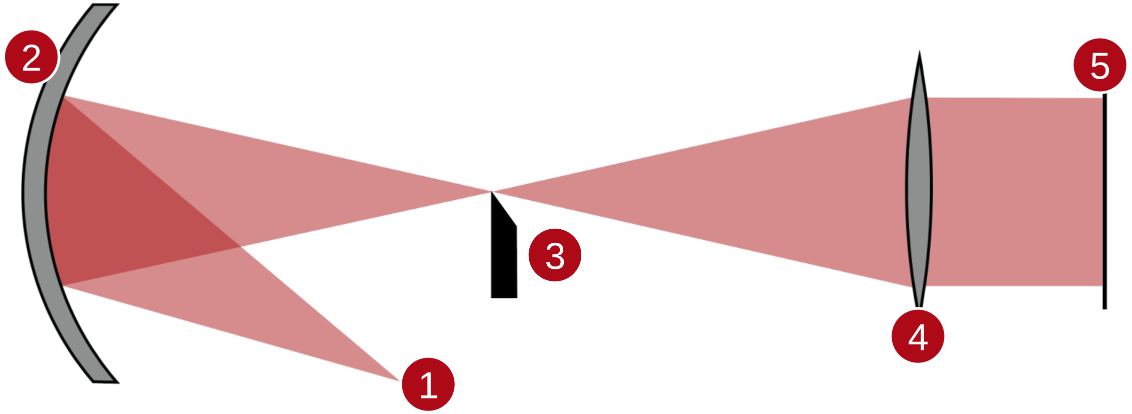
An idealized lens function is applied in the system to ensure the collimation of the field after the knife-edge. Therefore, the surfaces and materials of the lens are not considered in this case. The lens instead provides an ideal collimation function for a selected wavelength and focal length.

Learn more about this function via:

[Idealized Lens Functions]

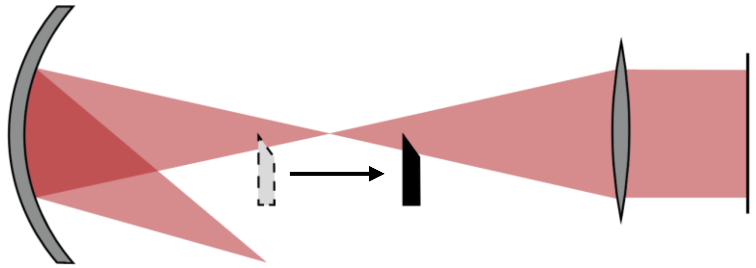


Summary of Model



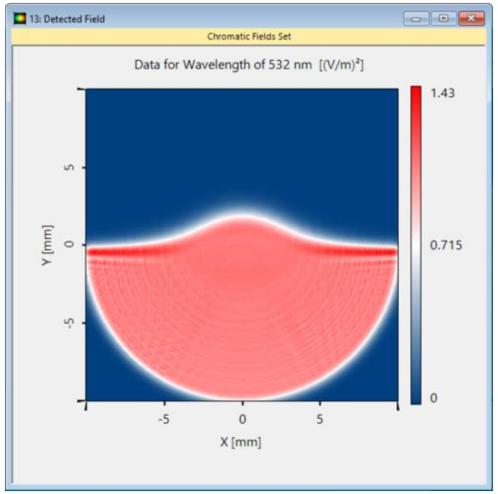
Optical System	Elements in VirtualLab Fusion	Model/Solver/Detected Value
1. source	*Spherical Wave*	point source
2. concave mirror	*Off-axis Parabolic Mirror/Curved Surface*	Local Plane Interface Approximation
3. knife-edge tester	*Stop*	transmission function
4. lens	*Ideal Lens (Lens Equation)*	idealized collimation
5. detector	*Camera Detector*	energy density measurement

Parabolic Mirror: Scan along Z-axis

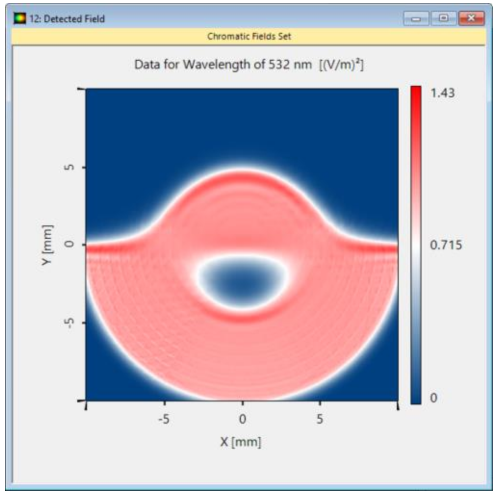


If the knife-edge is located very close to the focus, diffractive effects shape the light to the expected Foucault Donut form. The larger the distance of obstacle and focus become, the less influence the diffractive effects have.

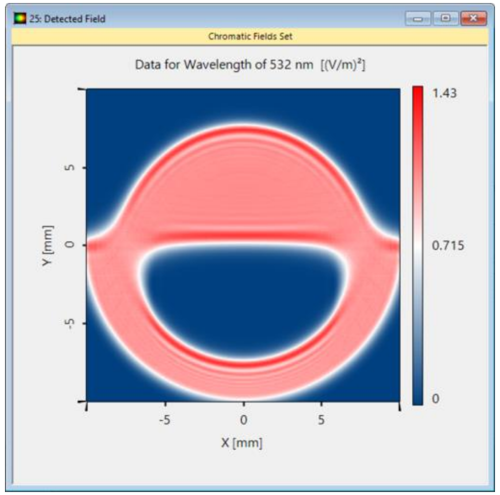
Knife's aperture is positioned…



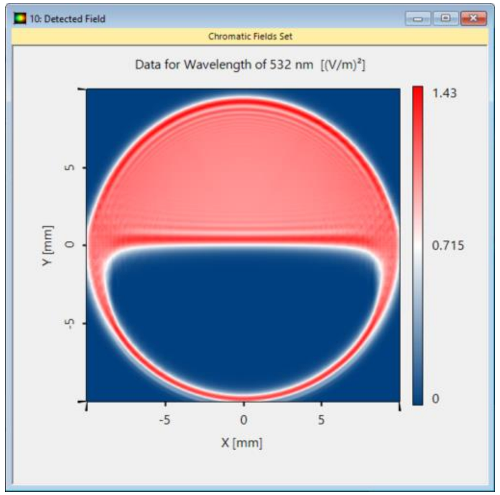
… 1.25mm before focus



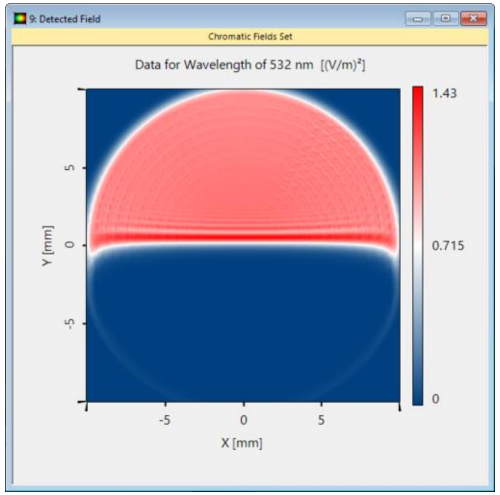
… 750µm before focus



… in focus

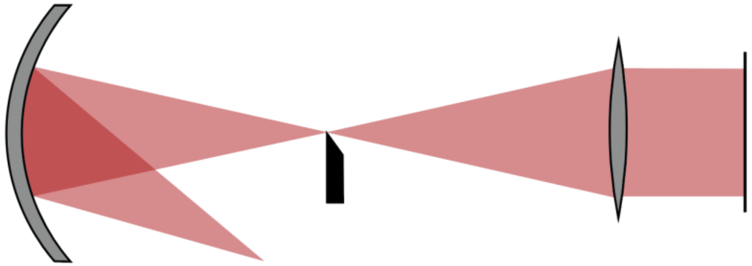


… 750µm after focus

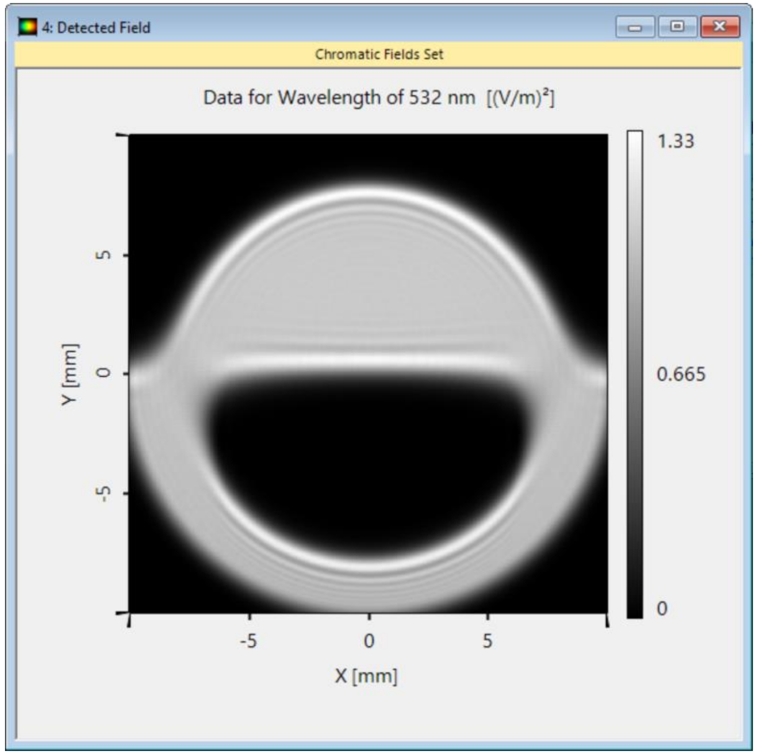


… 1.25mm after focus

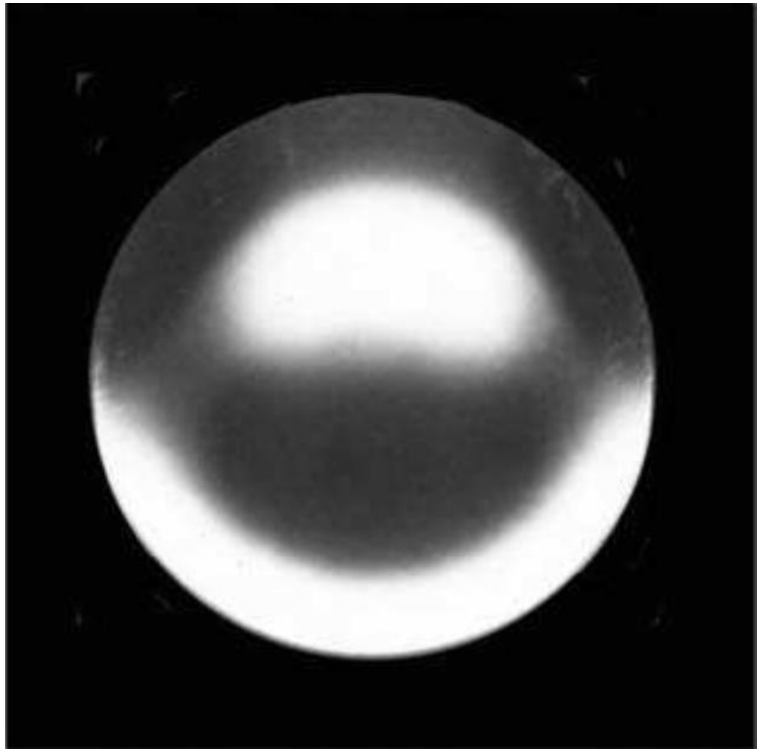
Parabolic Mirror: Aperture in Focus



In case, the aperture is placed directly in the focus, the light pattern generated by the setup depends highly on the shape of the used concave mirror. In the case of a parabolic mirror, a sol-called donut-shaped mode is exhibited. This information can be used to characterize the mirror.

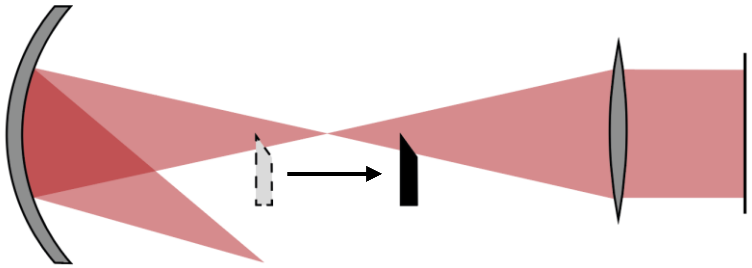


Foucault Donut mode



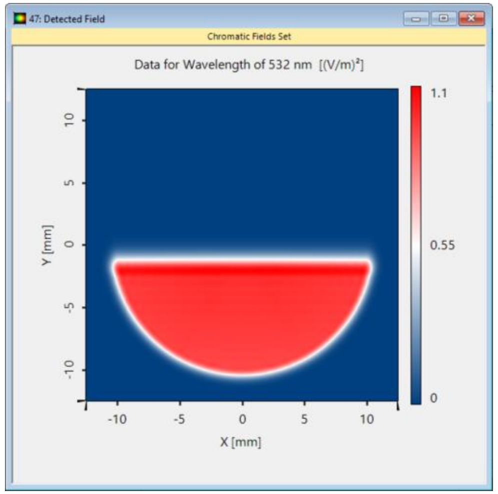
Reference: Ojeda-Castaneda, Jorge. (2006). Foucault, Wire, and Phase Modulation Tests. 10.1002/9780470135976.ch8

Spherical Mirror: Scan along Z-axis

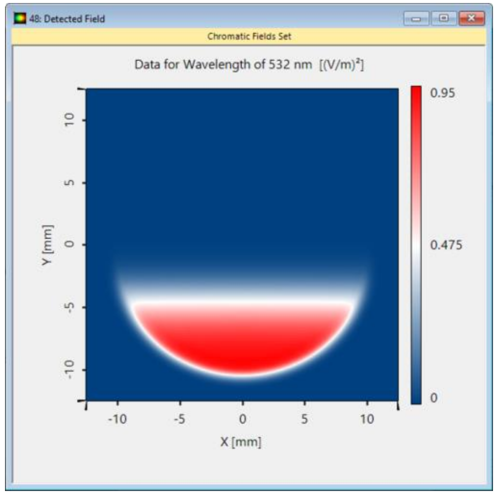


Similar to the case of the parabolic mirror, diffractive effects only take the reins if the knife edge is placed directly in the focus. If slightly shifted, the obstacle will just cause a truncation of the field, also in the final detector plane.

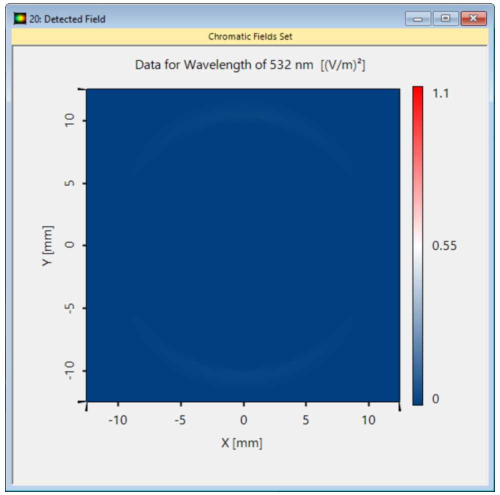
Knife aperture is positioned…



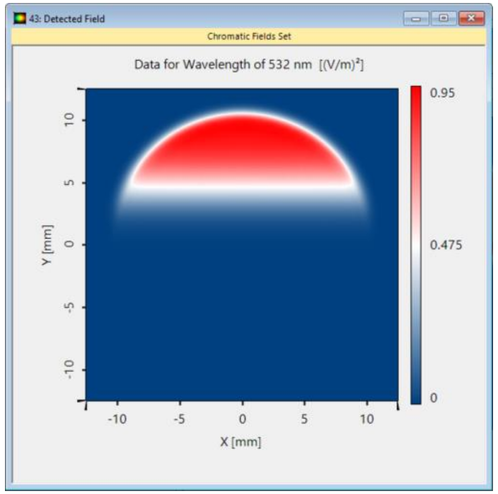
… 0.5mm before focus



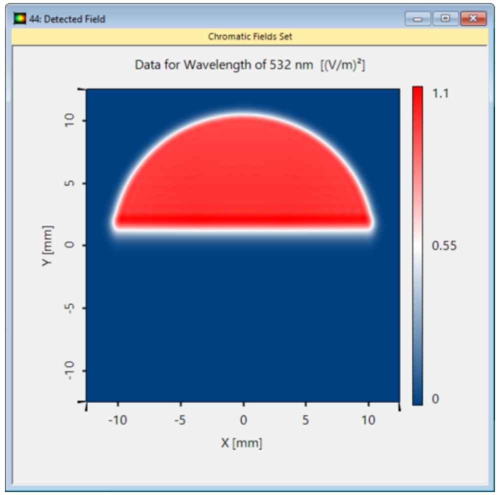
… 100µm before focus



… in focus

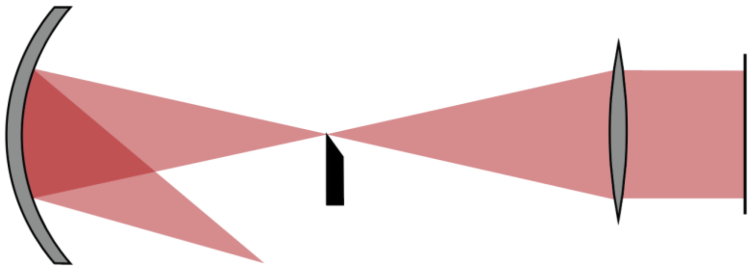


… 100µm after focus

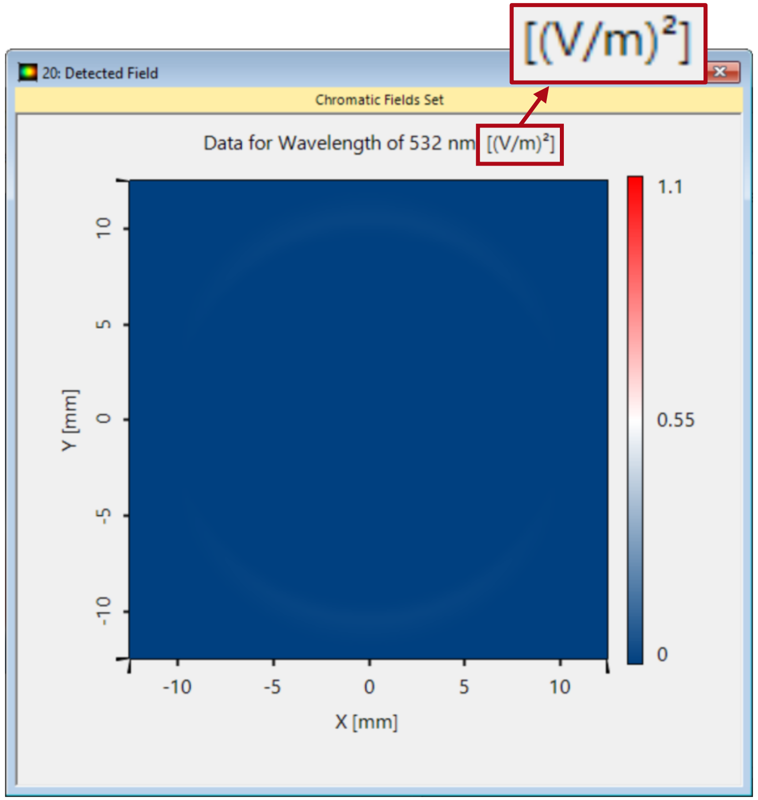


… 0.5mm after focus

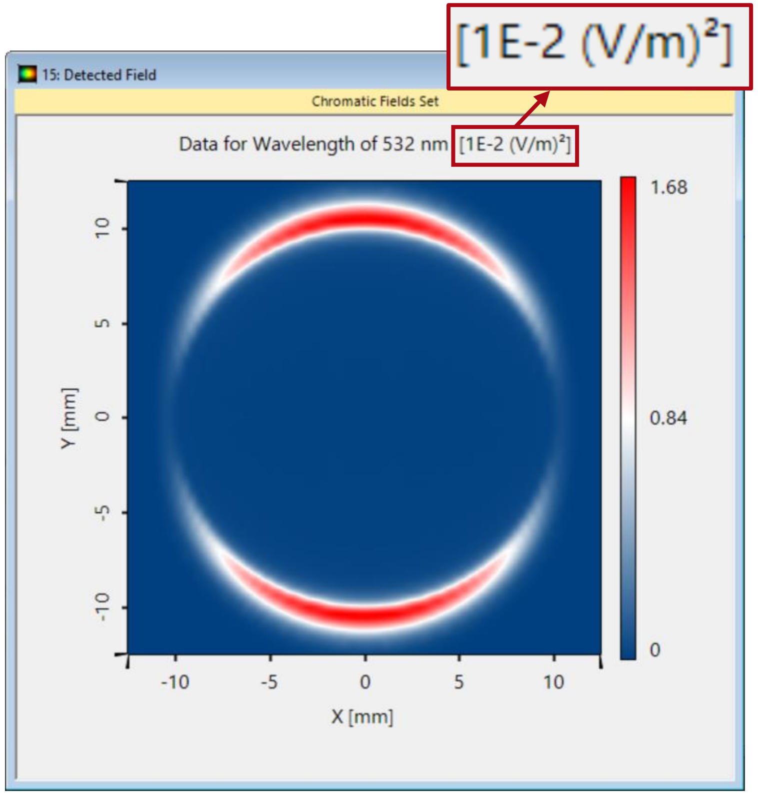
Spherical Mirror: Aperture in Focus



For ideal spherical mirrors, the diffractive effects generate a ring like structure when the aperture is placed in the focus. But as the intensity is magnitudes lower than when the aperture is moved slightly off focus, it will appear as if the light has vanished in this case.

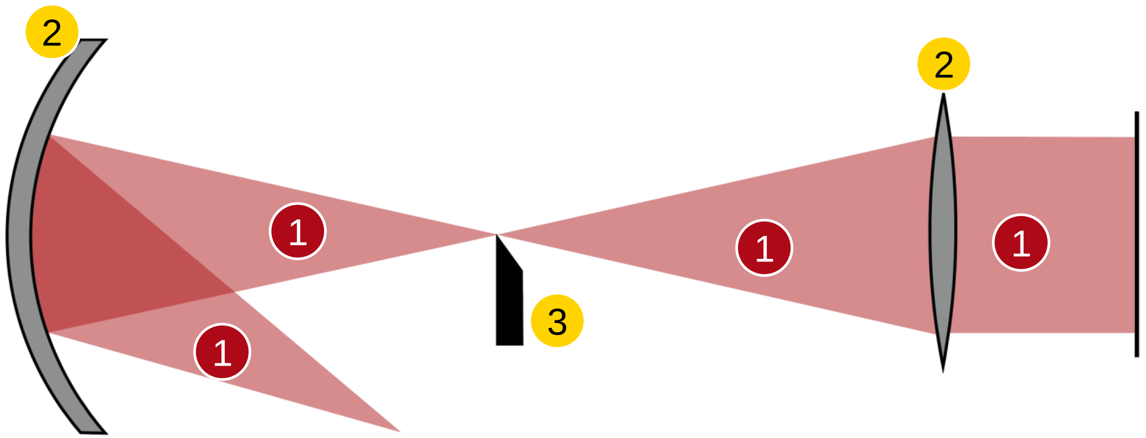


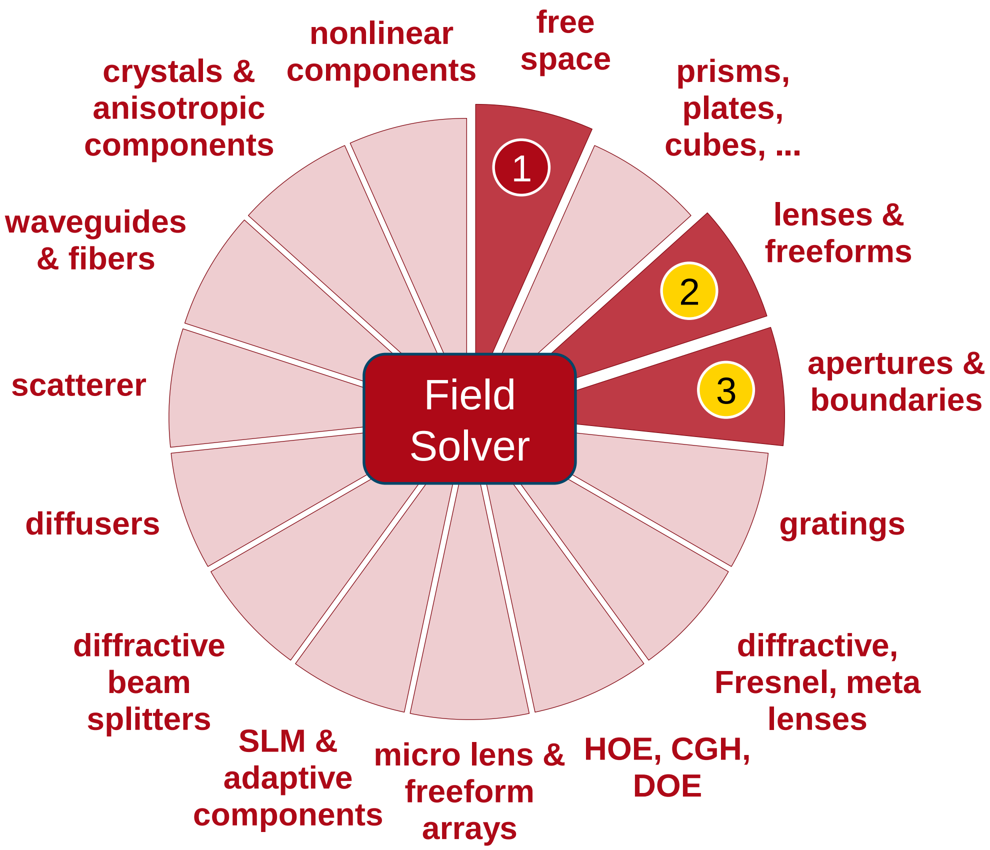
detected field with same sensitivity as in the non-focus case



detected field with higher sensitivity than in the non-focus case

VirtualLab Fusion Technologies





\# idealized component

Document Information

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software version	2021.1 (Build 1.180)
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further reading	- Observation of the Poisson Spot - Circularly Serrated Aperture for Beam Apodization - Simulation of Reflective Pyramid Wavefront Sensor