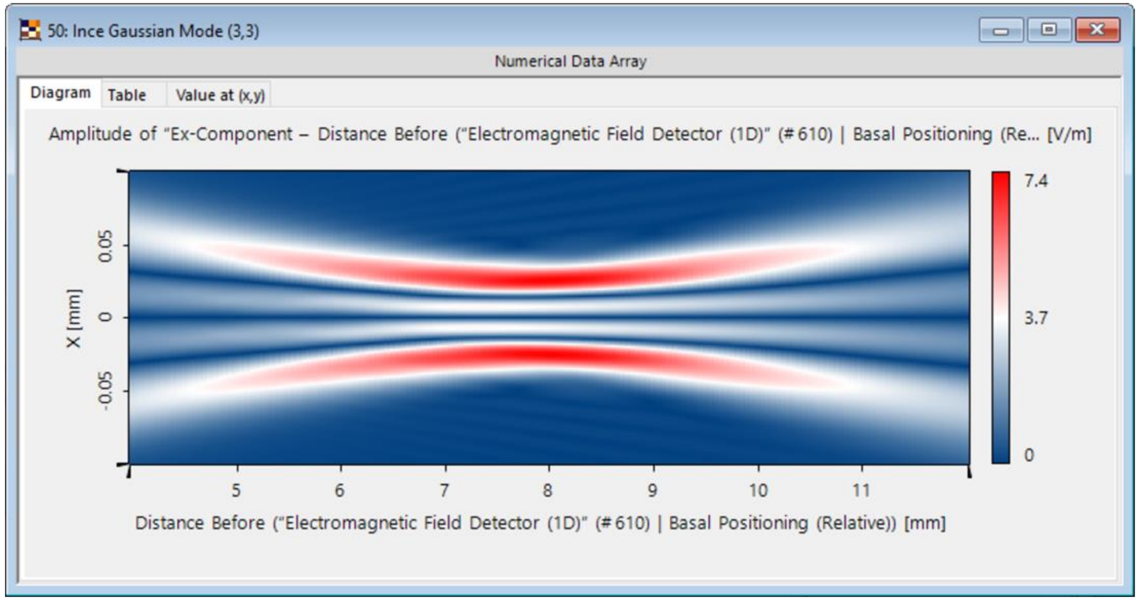
Focusing of an Ince-Gaussian Beam

Abstract

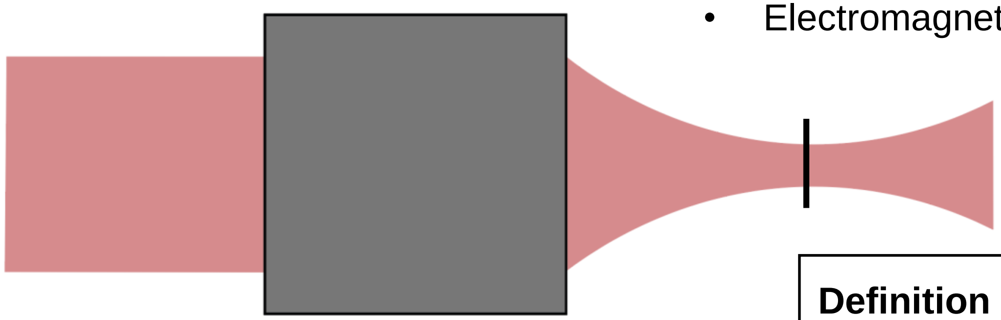


Ince-Gaussian modes are a well-known exact and orthogonal solution family for the paraxial wave equation. This kind of source mode can be advantageous for different applications in the areas of optical tweezers and particle trapping. In this use case we demonstrate the focal properties of the Ince Gaussian Beam Source in VirtualLab Fusion by propagating the modes through a GRIN medium. This medium represents a thermal lens, an effect which can be encountered often in applications for high-energy laser beams.

Task Description

Ince-Gaussian Beam (spatially)
- Ellipticity Parameter = 3
- Waist diameter = 300 µm
- Modes: (1,1), (3,3) (even)
- Wavelength: 532 nm
- Input Power: 8 kW

Detector
- Electromagnetic field



Thermal Lens Component
- Size: 7 mm x 7 mm
- Thickness: 75 mm

Definition of the GRIN medium

$$n(x,y) = n_0 - \frac{\eta P_{\text{in}}}{4K\pi d} \cdot \frac{\delta n}{\delta T} \cdot \frac{r^2}{r_0^2}$$

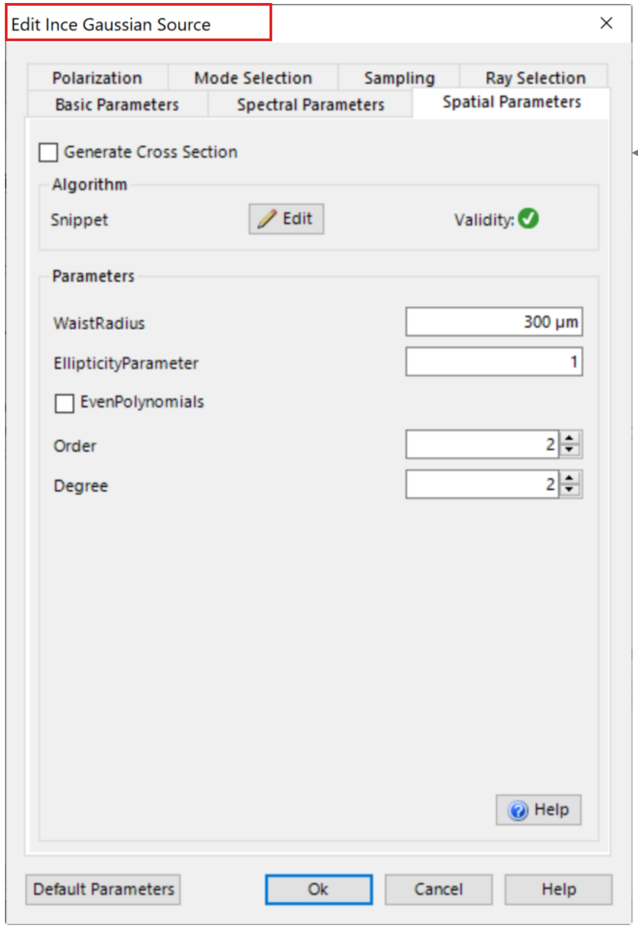
$$\eta = 0.05, K = 11.1\,\frac{\mathrm{W}}{\mathrm{cm^\circ C}}, r_0 = 3.1\ \mathrm{mm}$$

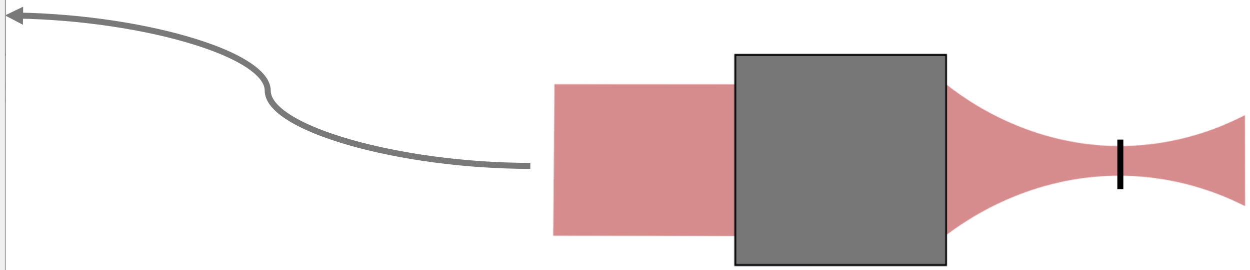
Task:
Simulate the electromagnetic field of various Ince-Gaussian modes in the focal area

Ref: Koechner W. Thermal Lensing in a Nd:YAG Laser Rod. Appl Opt. 1970 Nov 1;9(11):2548-53.

Building the System in VirtualLab Fusion

System Building Blocks – Source

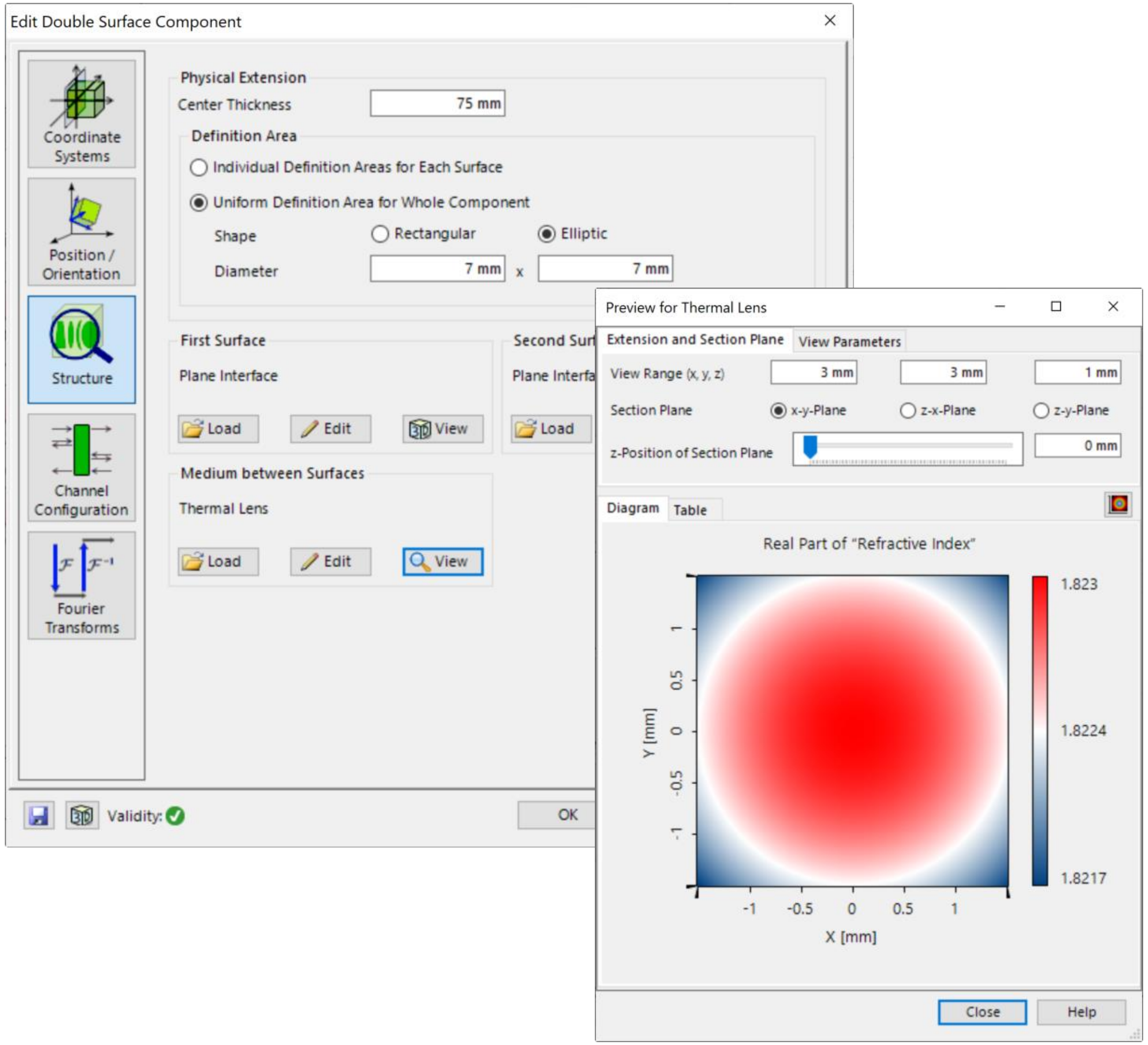


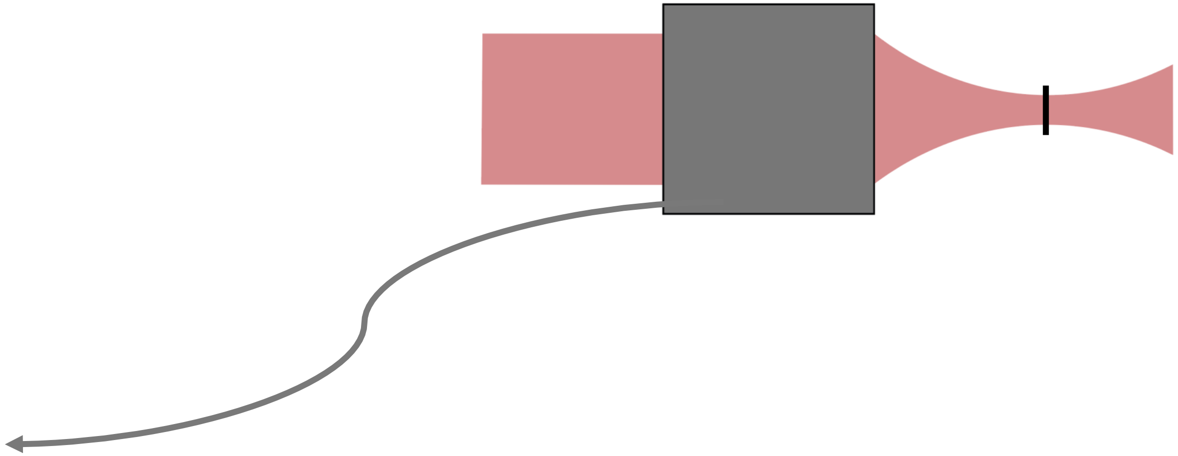


The source is modeled by calculating an individual Ince-Gaussian mode. More information about the parameters and their meaning can be found in the following use case:

Ince Gaussian Modes

System Building Blocks – Components

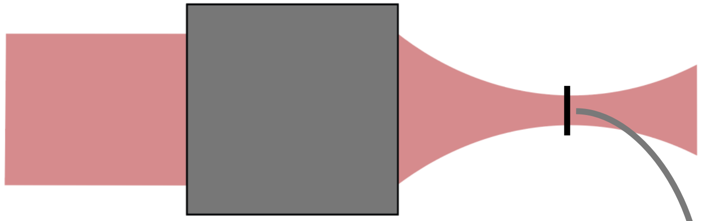




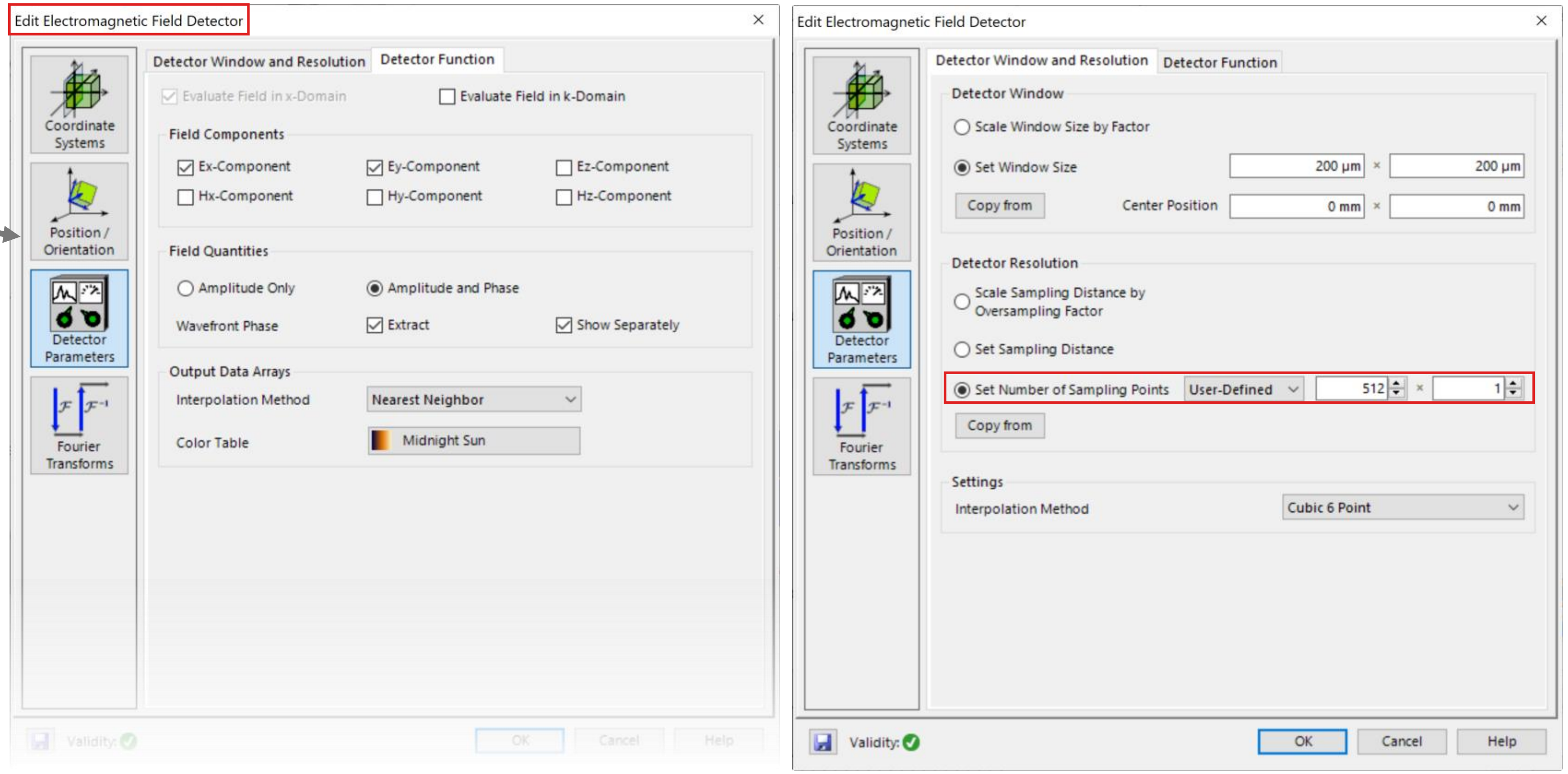
For the definition of the thermal lens, we assume a GRIN medium. More information about this can be found in:

[Gaussian Beam Focused by a Thermal Lens]

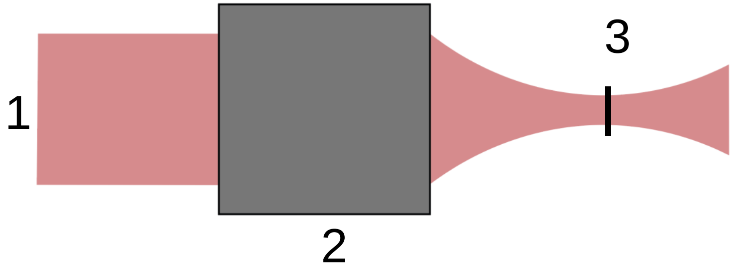
System Building Blocks – Detectors



The Electromagnetic Field Detector allows for the detection of all 6 vector components of the electromagnetic field. It is possible to visualize a 1D cut through the field by setting the sampling numbers accordingly.

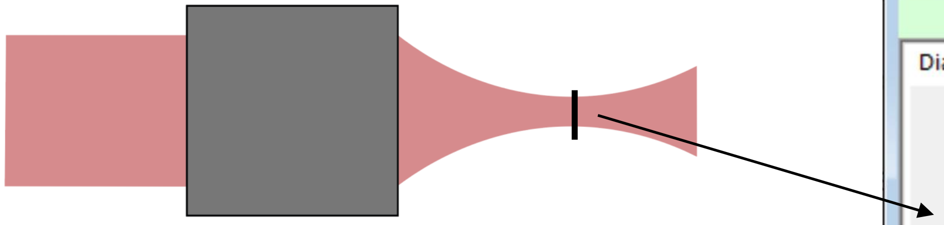


Summary – Elements...

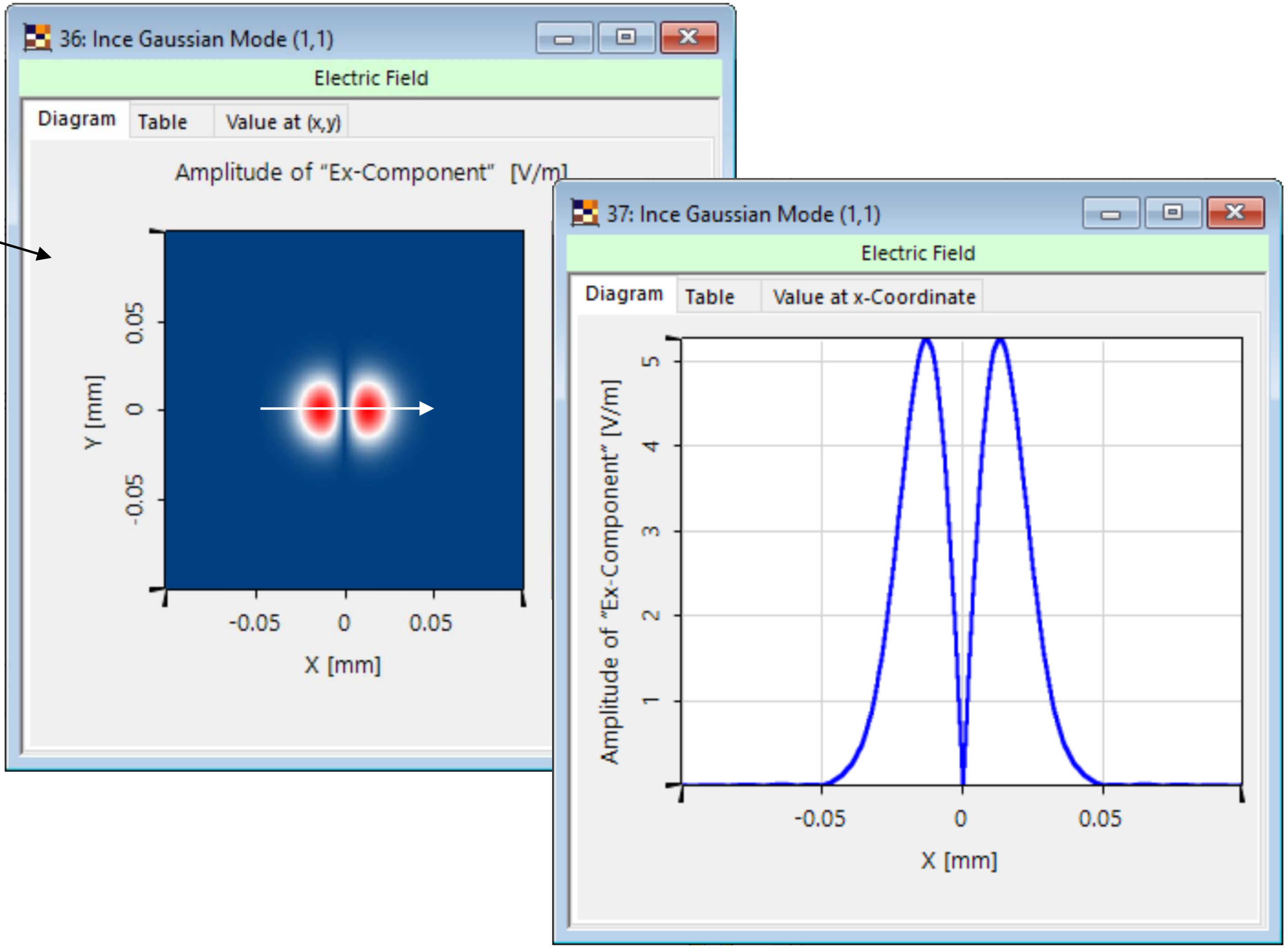


… of Optical System	… in VirtualLab Fusion	Model/Solver
1. Source	Ince-Gaussian Beam	Ince-Gaussian mode calculation
2. Thermal Lens	Inhomogeneous Medium Component	Runge-Kutta Algorithm
3. Detector	Electromagnetic Field Detector	Calculation of individual field component

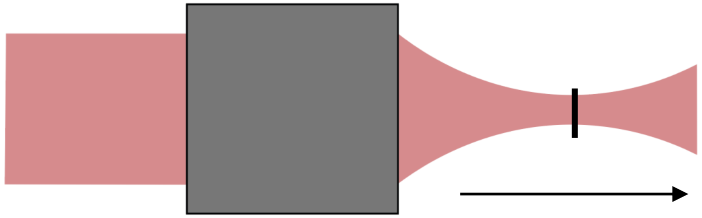
Focus Spot – Mode (1,1)



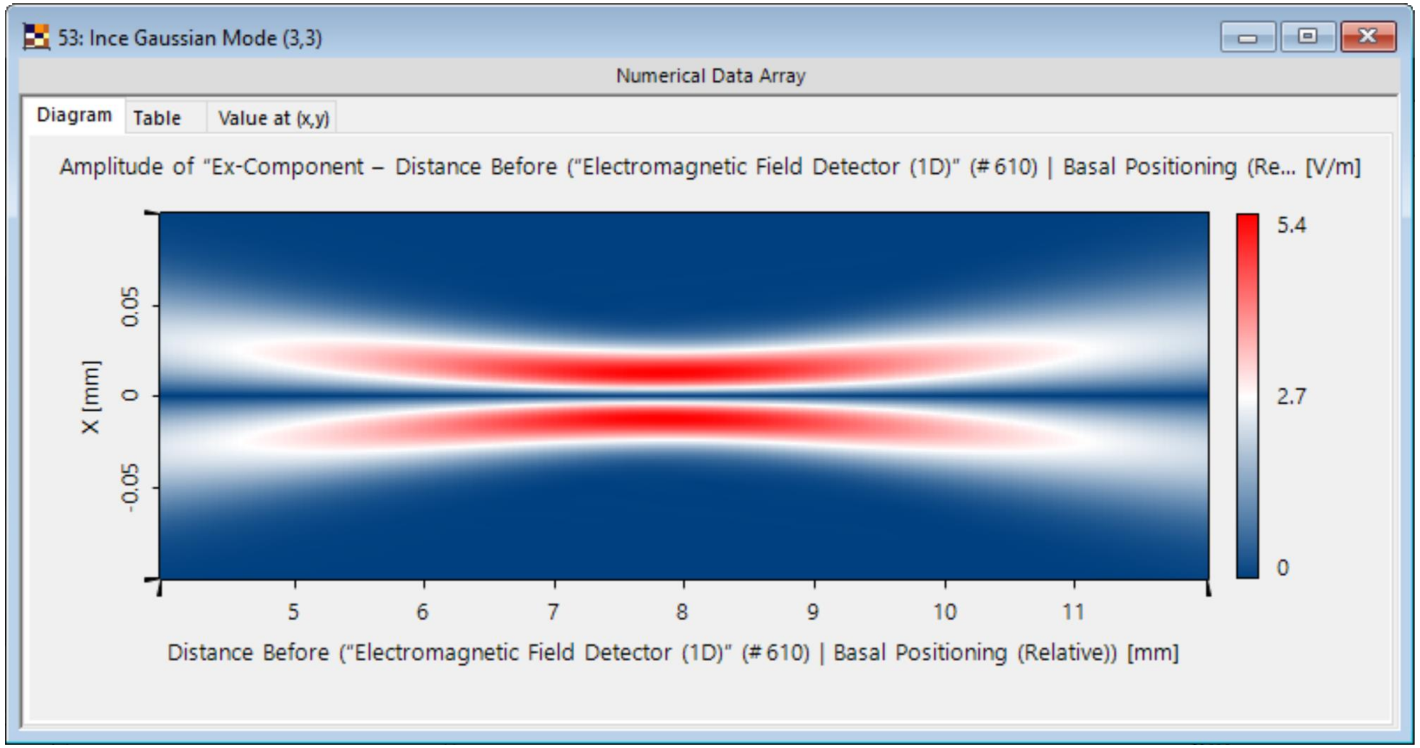
The focal position can be determined using the *Find Focus Position* tool in the *Optical Setup* menu tab. Results can be displayed as the full 2D field or as a 1D cut along e.g. the x axis.



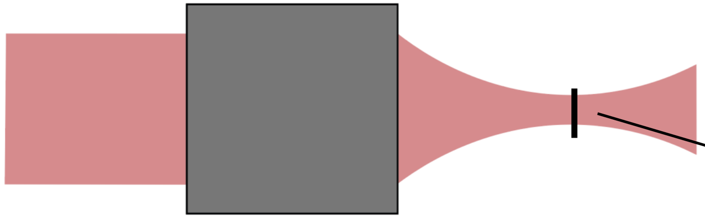
Scan – Mode (1,1)



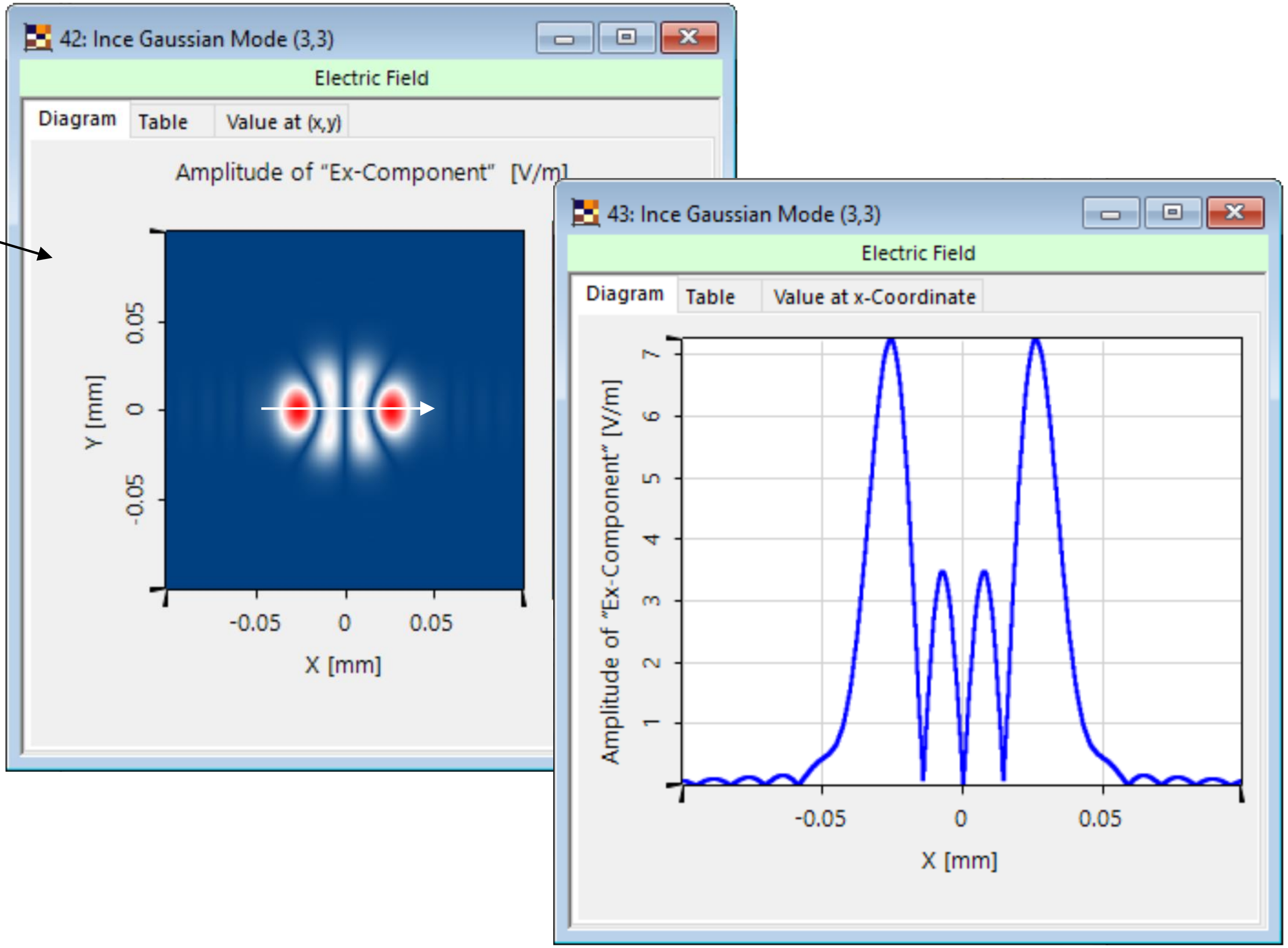
With the *Parameter Run* the behavior of the field when propagating through the focal plane can be visualized.



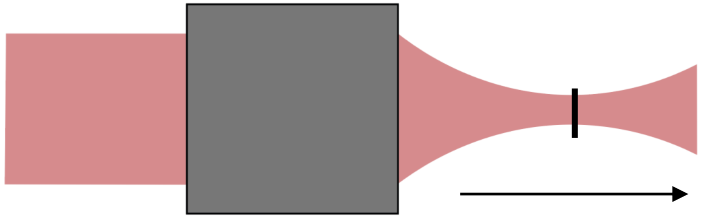
Focus Spot – Mode (3,3)



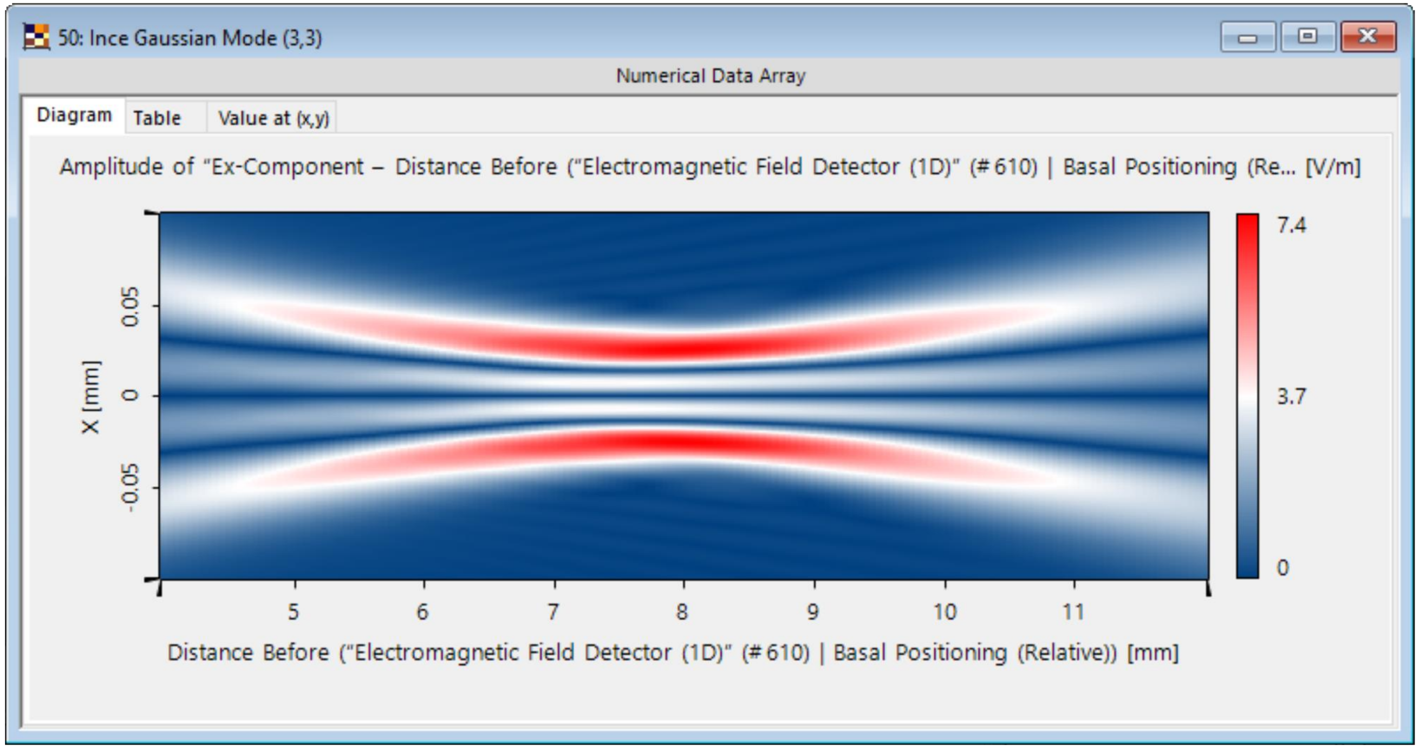
Focusing higher-order Ince-Gaussian Modes leads to steeper side slopes in the focus but also additional peaks.



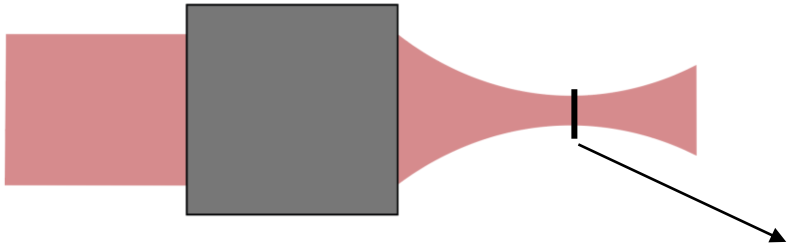
Scan – Mode (3,3)

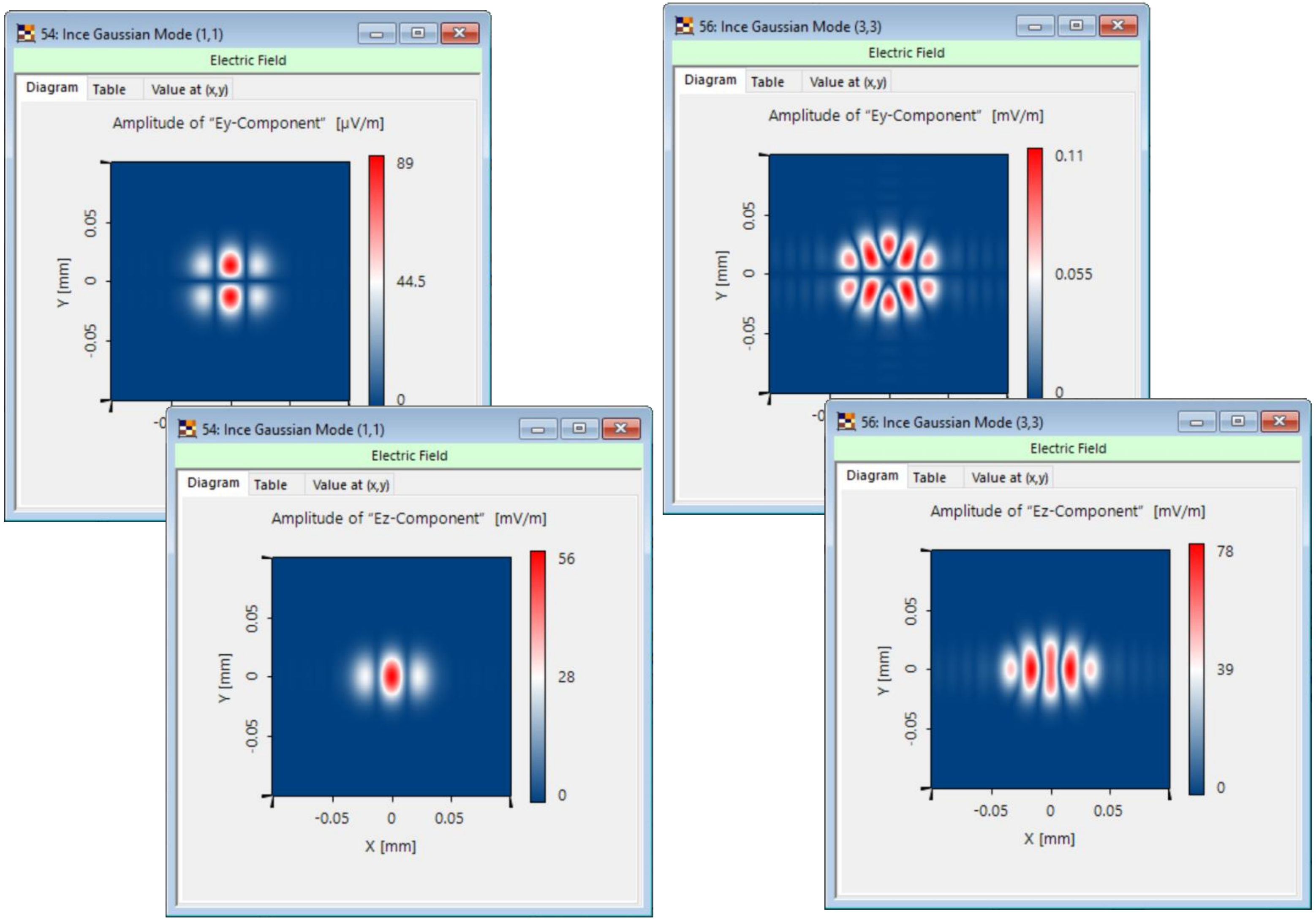


This behavior can also be seen in the *Parameter Run*.



Polarization Crosstalk





Focusing the Ince-Gaussian Beam through a thermal lens generates polarization crosstalk. Form and intensity of the crosstalk depends on the mode used and the power of the input light.

Document Information

title	Focusing of an Ince-Gaussian Beam
document code	SRC.0002
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further reading	- Gaussian Beam Focused by a Thermal Lens - Ince Gaussian Modes