

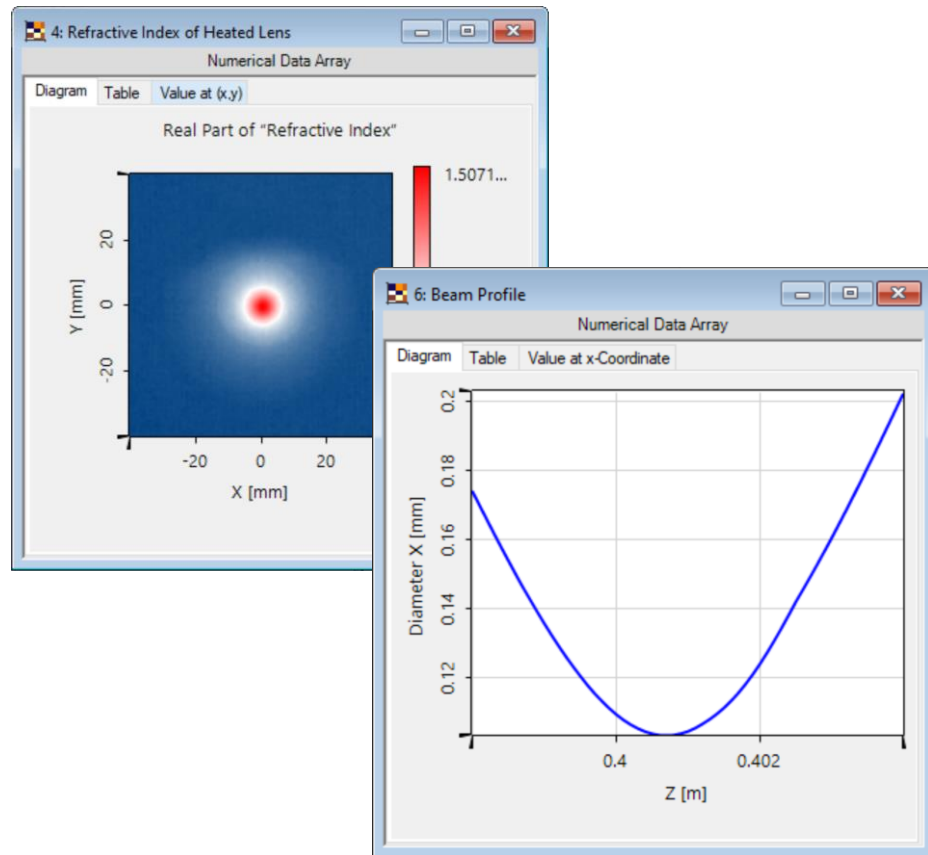
Investigation of Focus Shift due to Thermal Lensing

GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung

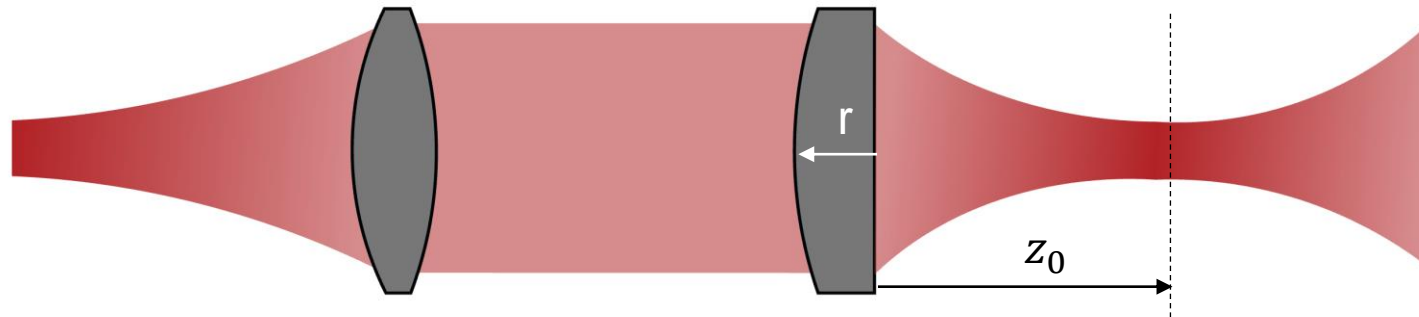
Abstract



The advance of material processing technologies leads to more and more applications which utilize high-power laser sources. This generates a significant amount of heat in the individual components in the optical system which may introduce various optical effects such as the thermal lensing effect which will shift the focal length in a lens. In this use case, we demonstrate the focus shift generated by thermal lensing inside a focusing lens. The thermal lensing effect itself is defined by imported deformed surfaces and an inhomogeneous media which is calculated according to imported temperature data.

Modeling Task

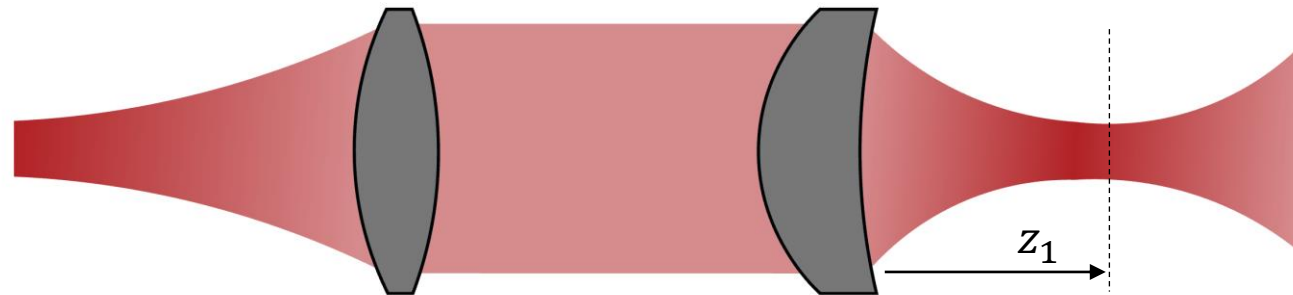
a) Reference system



- Lens
- Convex-plane
 - $r = 10$ mm (without deformation)
 - Material: bk7

b) System with thermal effects

- Gaussian wave
- 1070 nm wavelength
 - 6° divergence
 - 100 W power



Ideal collimation lens

Deformed lens

Temperature distribution and surface deformation have been calculated and exported via Ansys Mechanical(*).

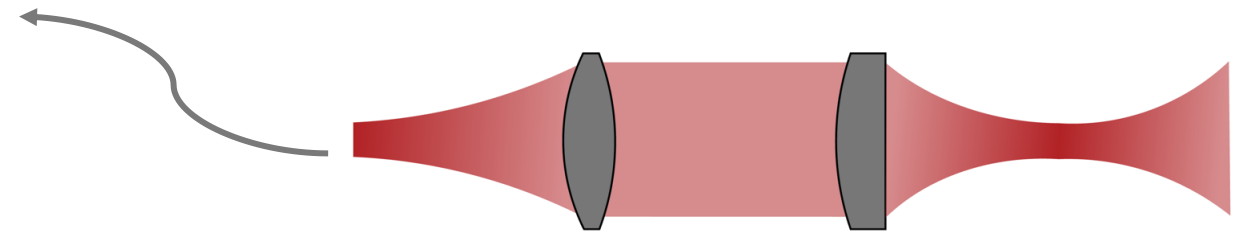
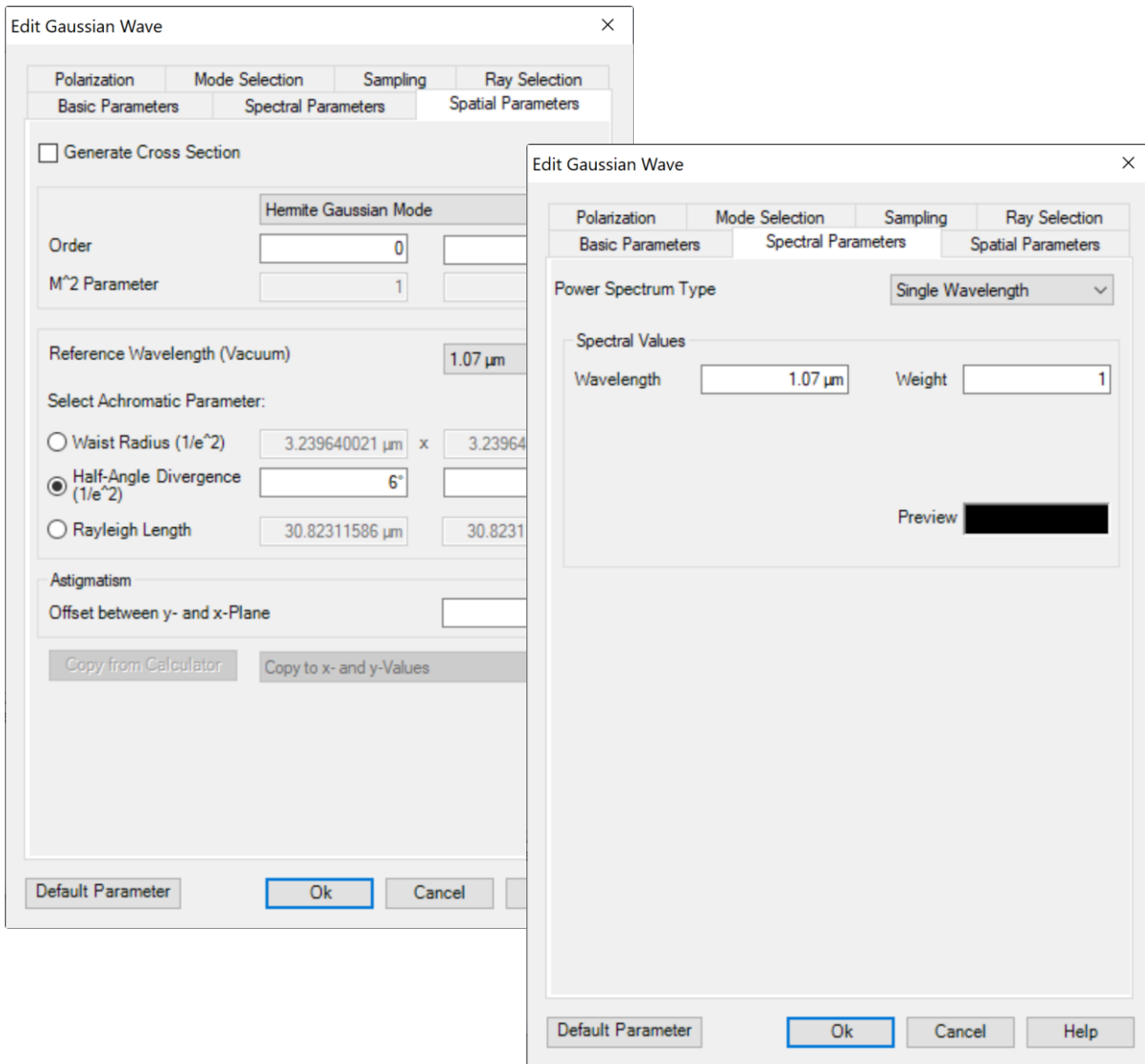
Simulation task:

Comparing the lens focus and focal spot of the heated lens with the unheated reference system

(* Ansys Inc, Ansys Mechanical (R1 2021) [Software]. 2021.
<https://www.ansys.com/>

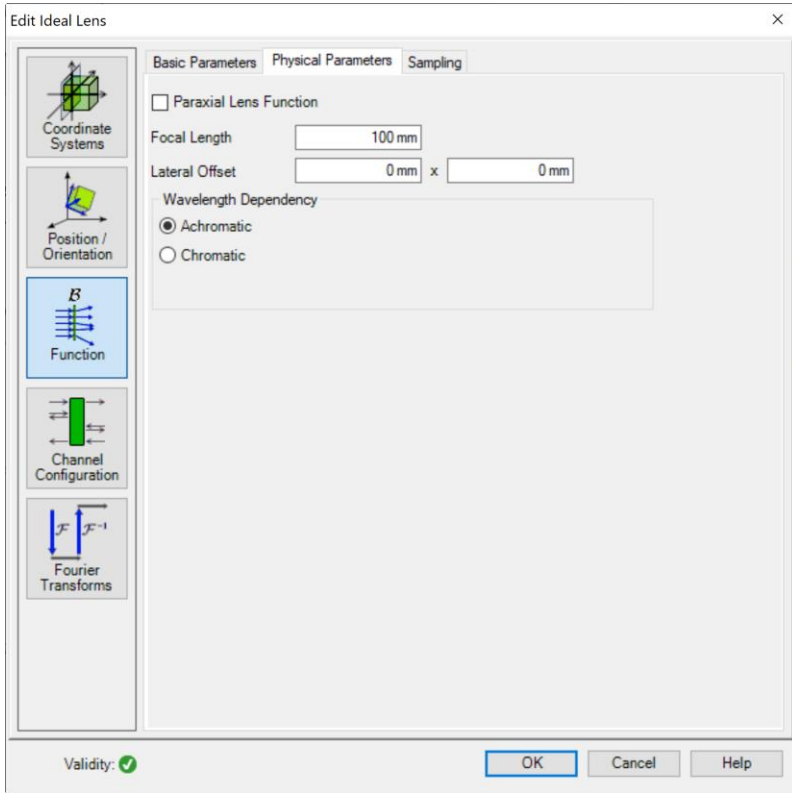
Building the System in VirtualLab Fusion

System Building Blocks - Source

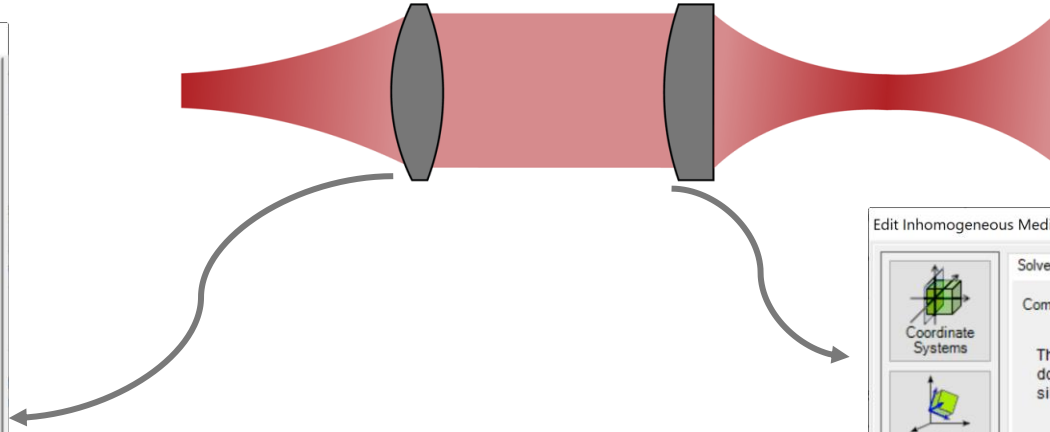


The Gaussian source model allow for a definition of a spatial Gaussian. The user can choose if the Gaussian shall be defined by its waist radius, divergence or Rayleigh length.

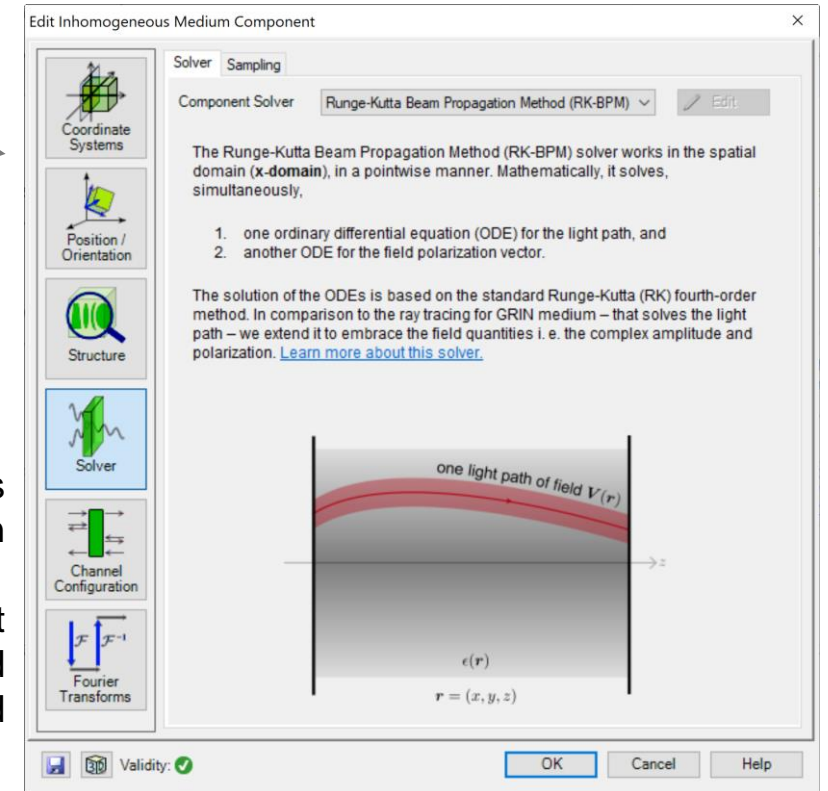
System Building Blocks - Components



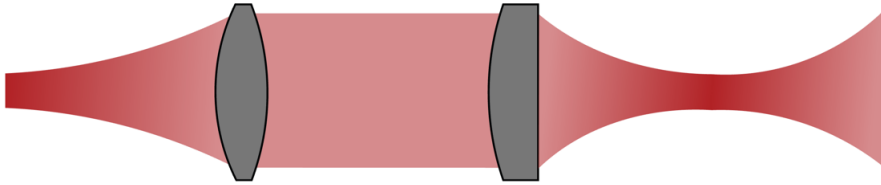
An ideal lens component is used to collimate the source. There are no thermal effects applied to the collimation lens.



The heated lens is represented by an inhomogeneous media. The temperature-dependent refractive index is calculated according to the imported temperature data.



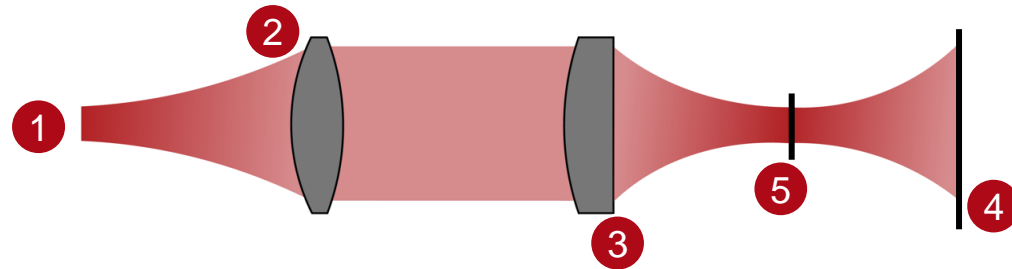
System Building Blocks - Detectors



To determine the focal position, Beam Parameters Detectors applies the second moment theory, whereas the actual focal spot can be visualized by Electromagnetic Field Detector.

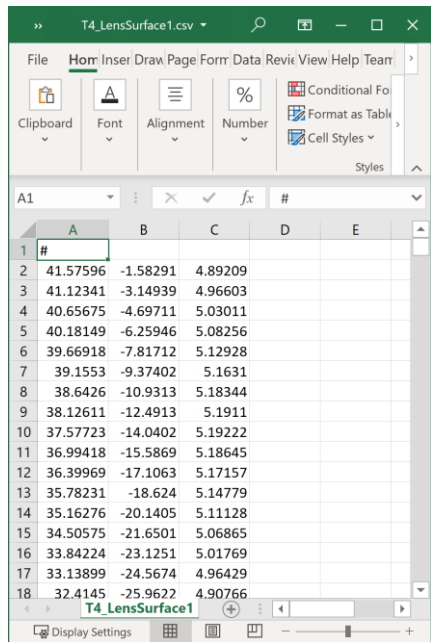
The image shows two software dialog boxes side-by-side. The left dialog is titled 'Edit Beam Parameters Detector' and has two tabs: 'Detector Window and Resolution' and 'Detector Function'. It features a sidebar with icons for 'Coordinate Systems', 'Position / Orientation', 'Detector Parameters', and 'Fourier Transforms'. The main area has a 'Vectorial Component' dropdown set to 'Ex Component'. Under 'Beam Parameters', several checkboxes are visible, with 'Diameter X', 'Waist Distance X', and 'M²-Parameter in x-Direction' checked. At the bottom, there are checkboxes for 'Calculate Beam Parameters Relative to the Centroid' (checked), 'Calculate Beam Parameters Relative to the Principal Axes', and 'Refine Sampling to Fully Sampled Spherical Phase'. A text field shows 'Values having less than 0.001 % of the maximum intensity are ignored.' The right dialog is titled 'Edit Electromagnetic Field Detector' and also has 'Detector Window and Resolution' and 'Detector Function' tabs. Its sidebar is identical to the left dialog. The main area has 'Evaluate Field in x-Domain' checked and 'Evaluate Field in k-Domain' unchecked. Under 'Field Components', 'Ex-Component', 'Ey-Component', and 'Show Separately' are checked. Under 'Field Quantities', 'Amplitude and Phase' is selected. Under 'Output Data Arrays', 'Interpolation Method' is set to 'Nearest Neighbor' and 'Color Table' is set to 'Midnight Sun'. Both dialogs have 'OK', 'Cancel', and 'Help' buttons at the bottom.

Summary – Components ...

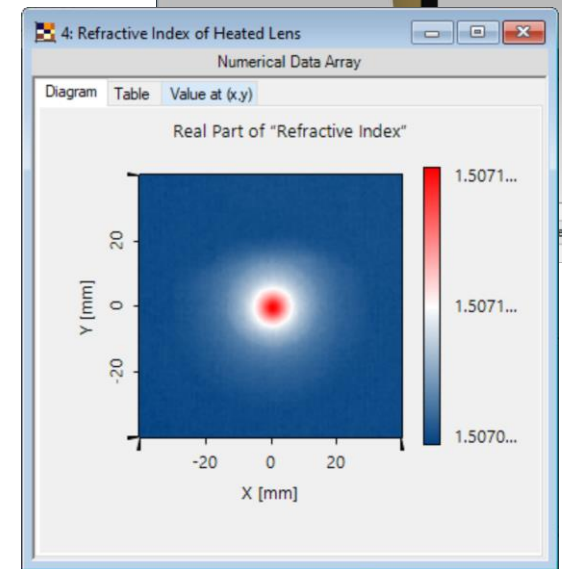
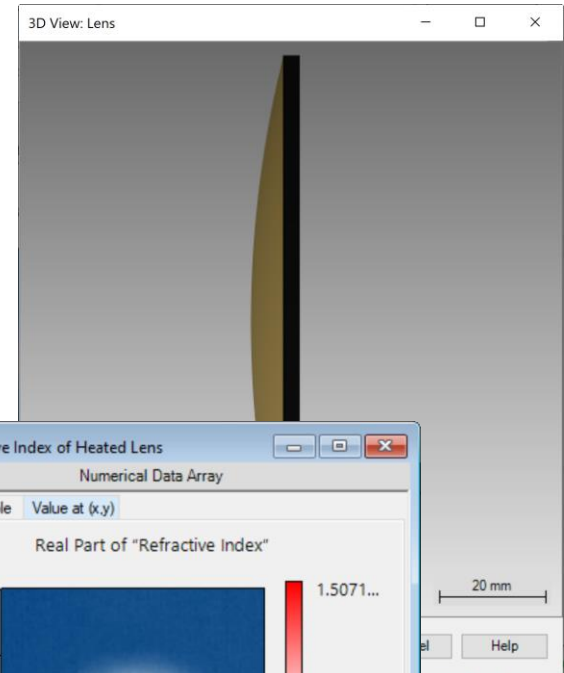
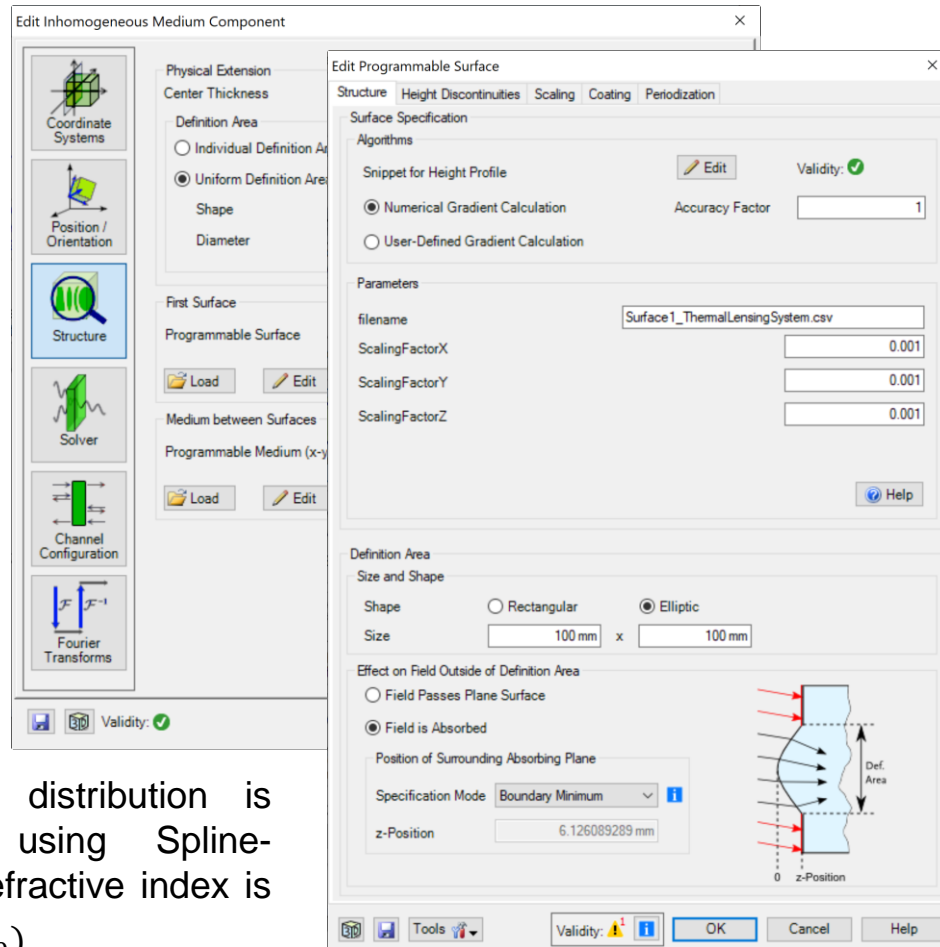


... of Optical System	... in VirtualLab Fusion	Source Model/Component Solver
1. Source	Gaussian Wave	Spatial Gaussian Function
2. Collimation Lens	Ideal Lens	Wavefront Response
3. Lens with Thermal Lensing	Inhomogeneous Component	RK-BPM & Local Plane Interface Approximation
4. Detector	Beam Parameter Detector	-
5. Detector	Camera Detector	-

Data Import



#	A	B	C	D	E
1	#				
2	41.57596	-1.58291	4.89209		
3	41.12341	-3.14939	4.96603		
4	40.65675	-4.69711	5.03011		
5	40.18149	-6.25946	5.08256		
6	39.66918	-7.81712	5.12928		
7	39.1553	-9.37402	5.1631		
8	38.6426	-10.9313	5.18344		
9	38.12611	-12.4913	5.1911		
10	37.57723	-14.0402	5.19222		
11	36.99418	-15.5869	5.18645		
12	36.39969	-17.1063	5.17157		
13	35.78231	-18.624	5.14779		
14	35.16276	-20.1405	5.11128		
15	34.50575	-21.6501	5.06865		
16	33.84224	-23.1251	5.01769		
17	33.13899	-24.5674	4.96429		
18	32.4145	-25.9622	4.90766		

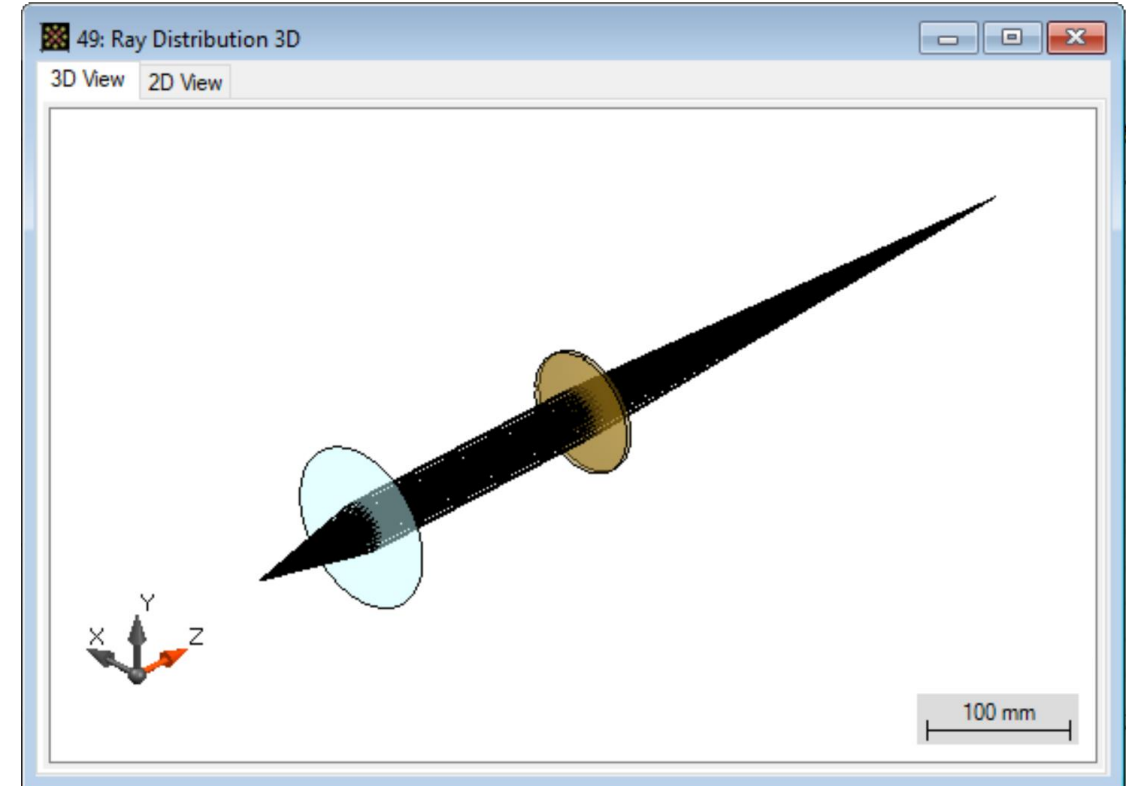
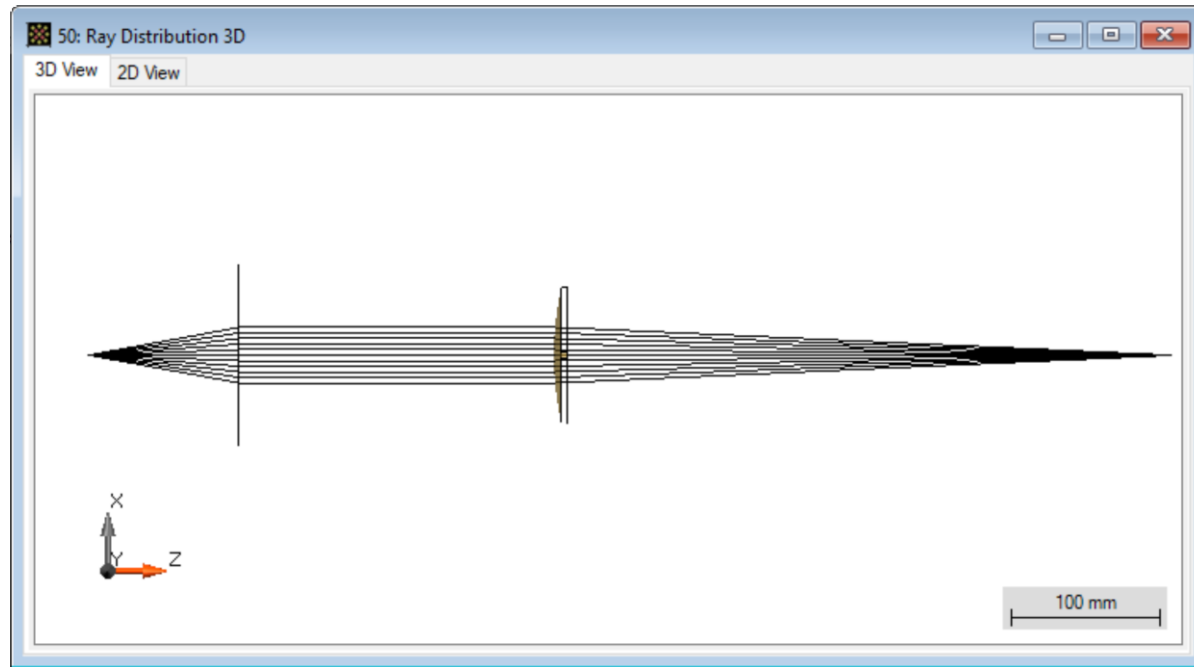
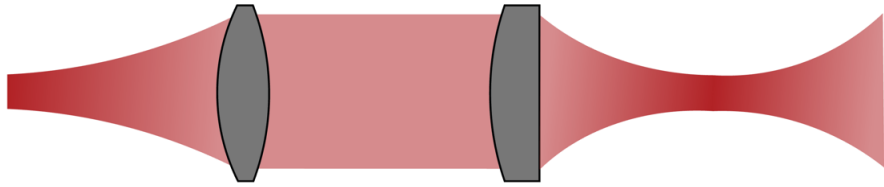


The surfaces and temperature distribution is imported from point clouds using Spline-Interpolation. The change in the refractive index is calculated by $n(T) = n_0 + \frac{dn}{dT}(T - T_0)$.

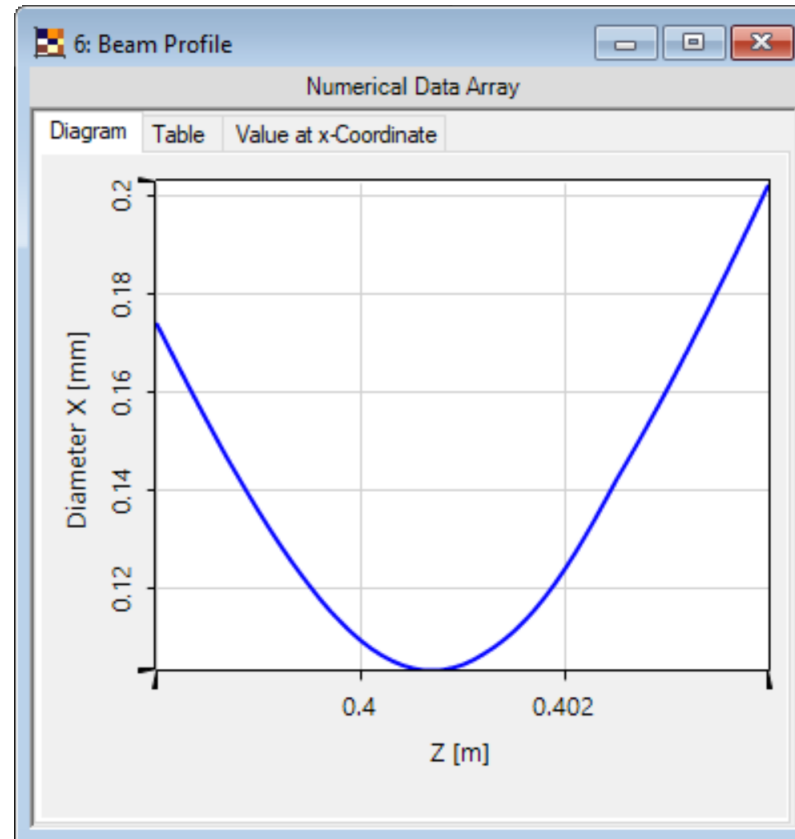
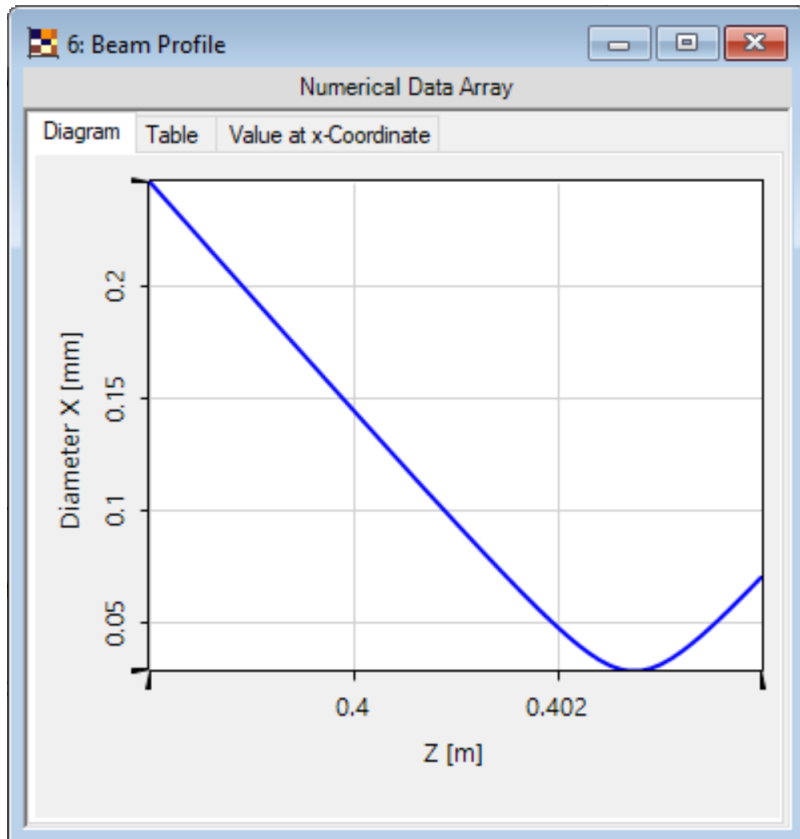
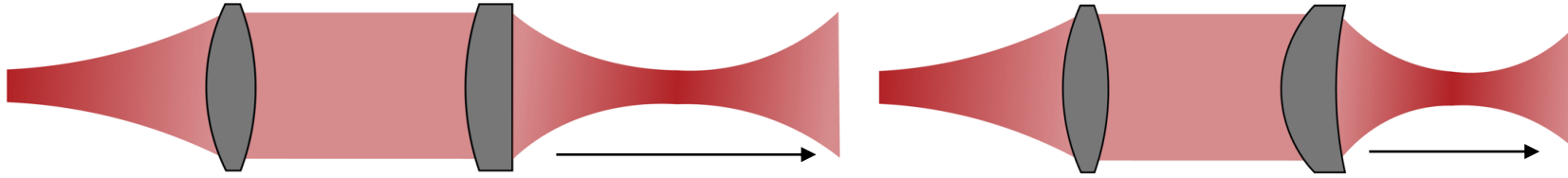
Please save the import files in the same directory as the os-files or adjust the „filename“ parameter.

Simulation Results

Ray Tracing Result



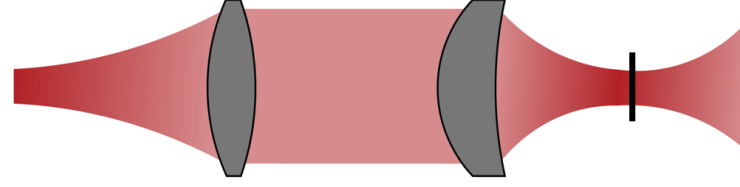
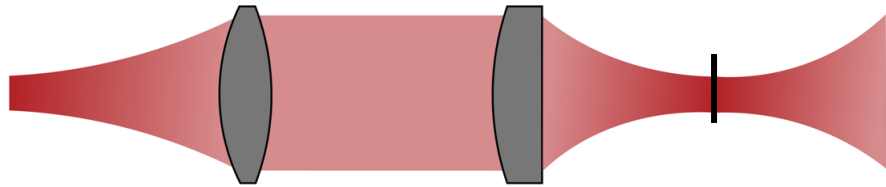
Field Tracing Result - Focus Shift



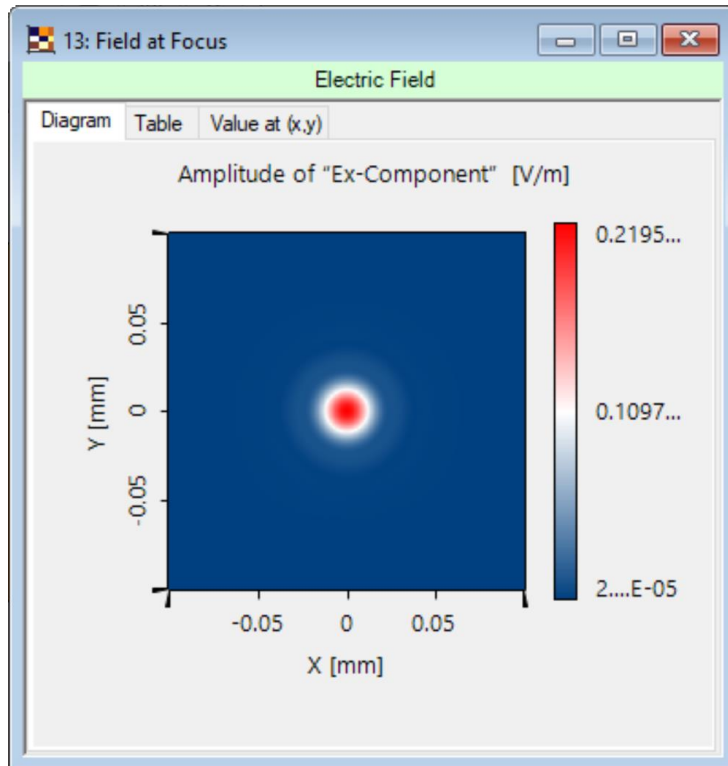
The deformation of the lens surface and the internal change of the refractive index result in a shorter effective focal length.

The beam caustic is visualized by using the second moment theory with a Parameter Run session in Virtual Lab.

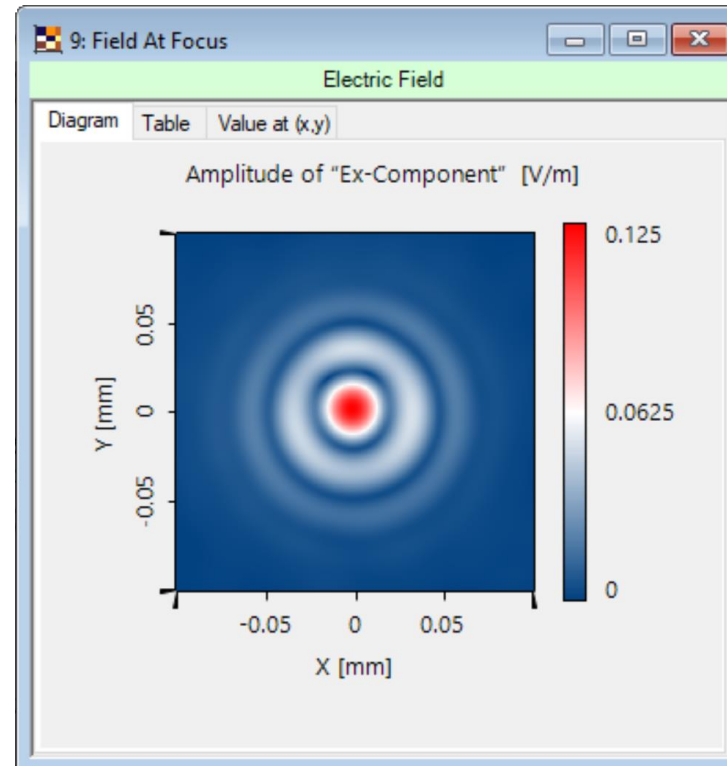
Field Tracing Result – Focal Spot



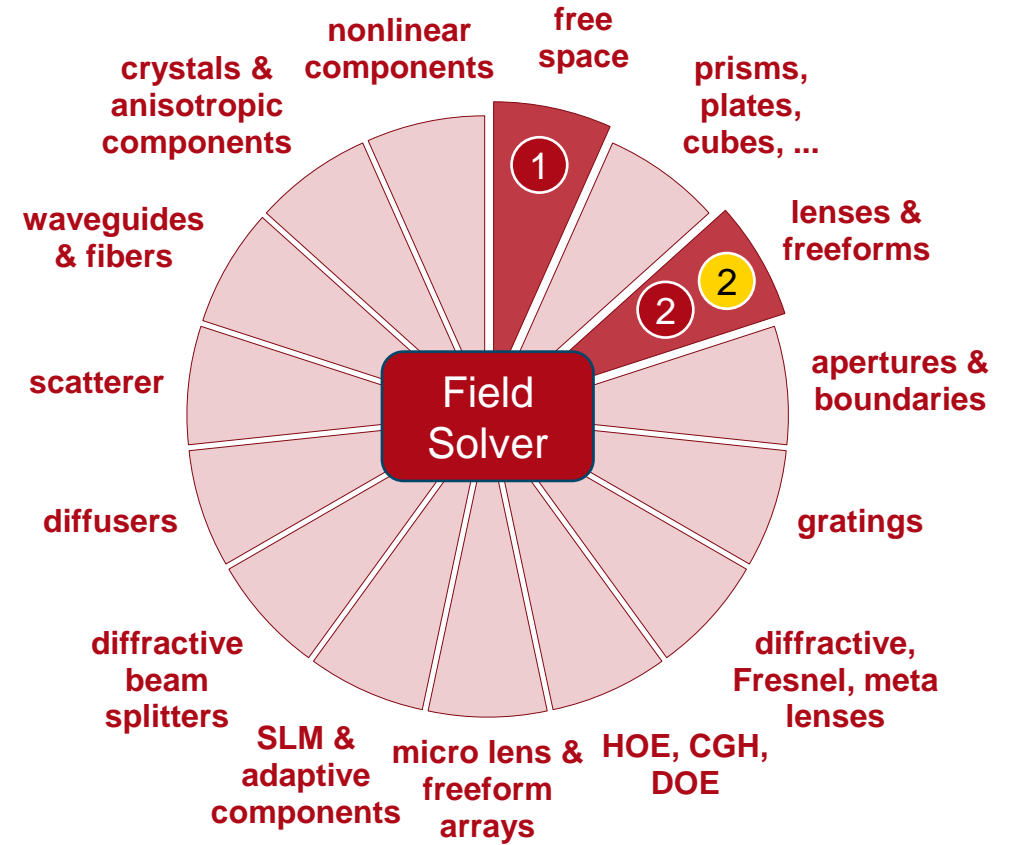
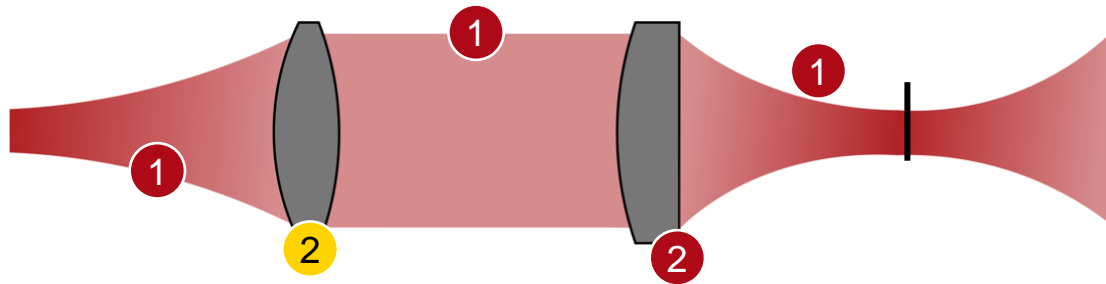
Reference system



System with thermal lensing



VirtualLab Fusion Technologies



idealized component

Document Information

title	Investigation of Focus Shift due to Thermal Lensing
document code	
version	1.0
edition	VirtualLab Fusion Basic
toolbox(es)	-
software version	2020.1 (Build 3.4)
category	Application Use Case
further reading	<ul style="list-style-type: none">- Gaussian Beam Focused by a Thermal Lens- How to Work with the Programmable Medium and Example (Thermal Lens)

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