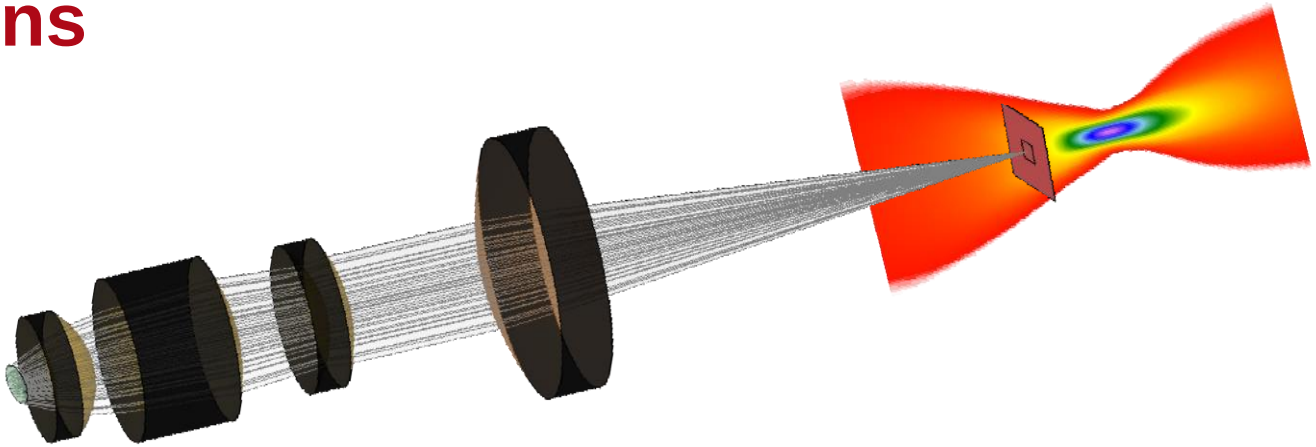
Beam Delivery Systems (BDS.0002 v1.4)

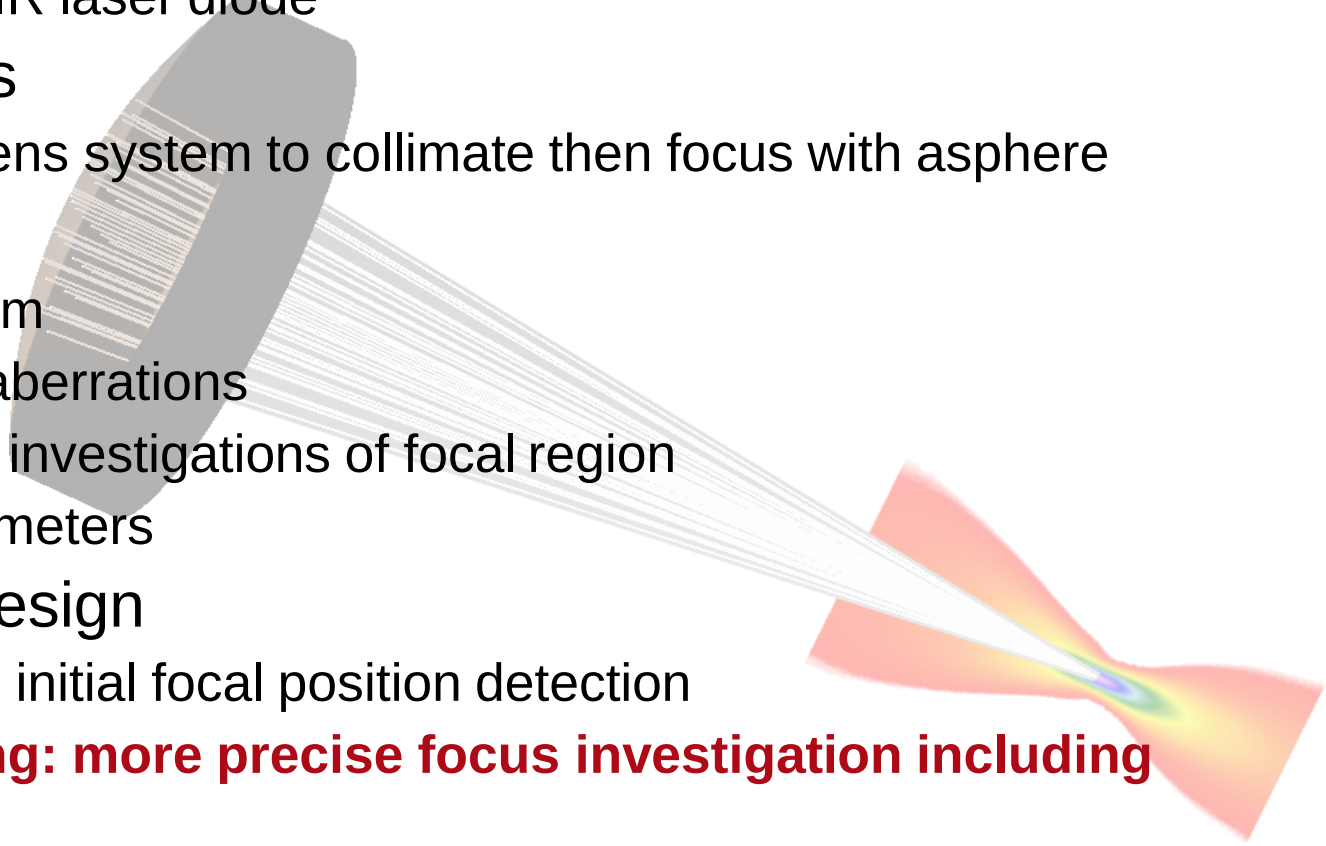
Focus Investigation behind Aspherical Lens



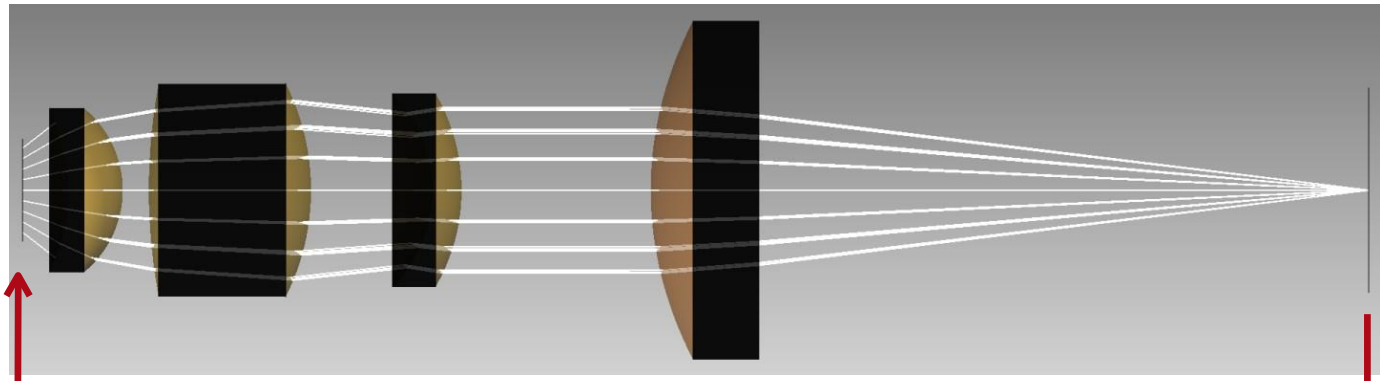
Application Example in a Nutshell

System Details

- Source
  - astigmatic IR laser diode
- Components
  - refractive lens system to collimate then focus with asphere
- Detectors
  - spot diagram
  - wavefront aberrations
  - 1D and 2D investigations of focal region
  - beam parameters
- Modelling/Design
  - ray tracing: initial focal position detection
  - **field tracing: more precise focus investigation including diffraction**

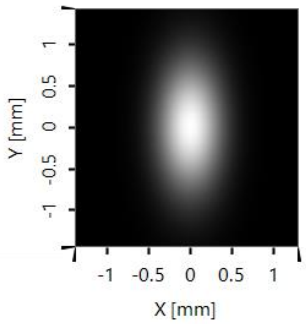


System Illustrations

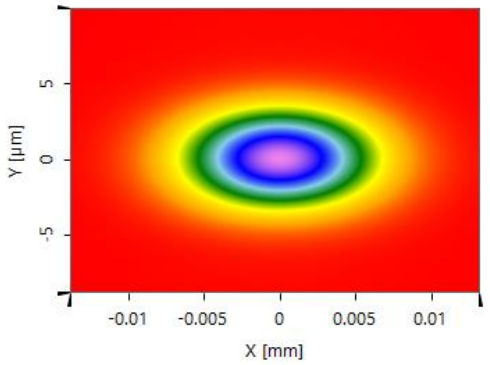


collimation objective lens

focusing asphere from catalog **to be analyzed**

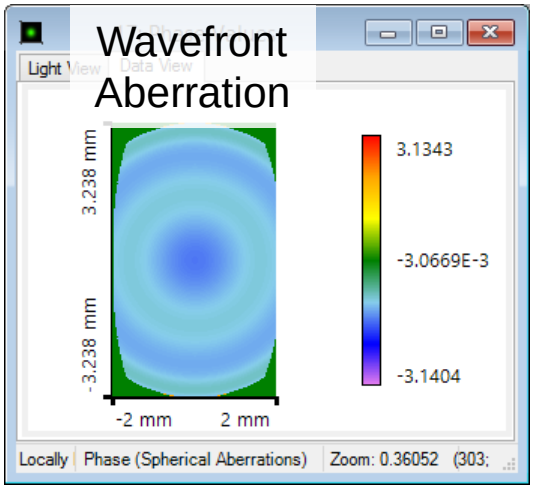


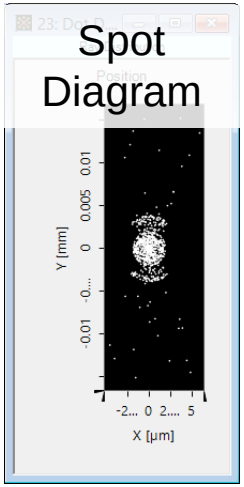
asymmetric Gaussian beam of IR laser diode

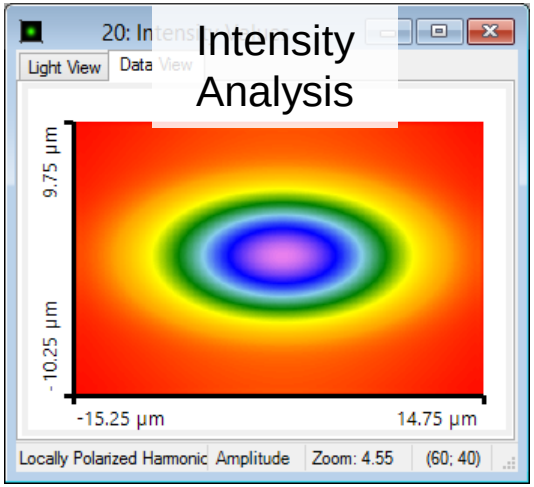


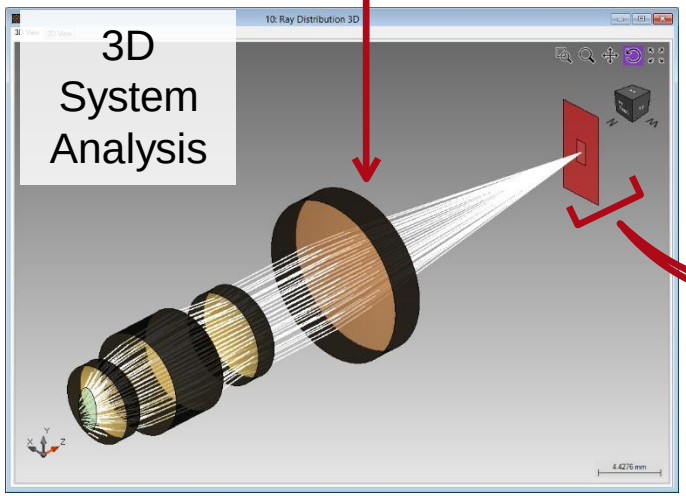
focused intensity distribution

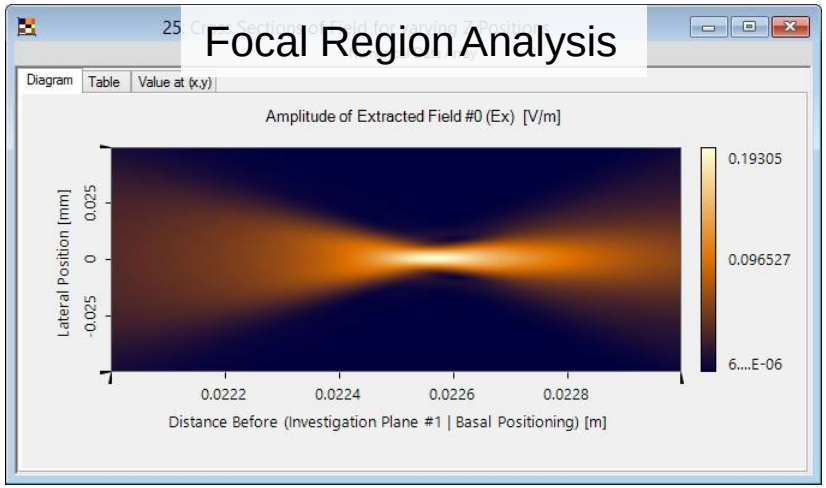
Modelling and Design Results











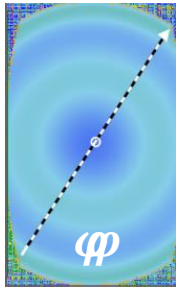
Additional VirtualLab Features

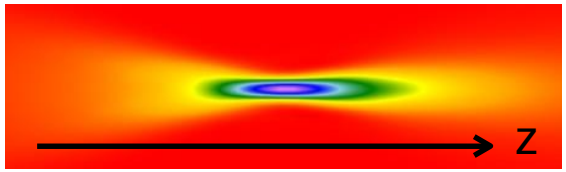
In this example you benefit from the following selected features:

- analyze the focusing capabilities of an aspherical lens

- ascertain the focus position via:
  - focus finder tool
  - parameter run document
  - beam parameter detector

- get different informative/illustrative results such as
  - lens aberrations
  - quality of beam: spot size/shape, M^2 value
  - diverse 2D & 3D diagrams demonstrating the focus development

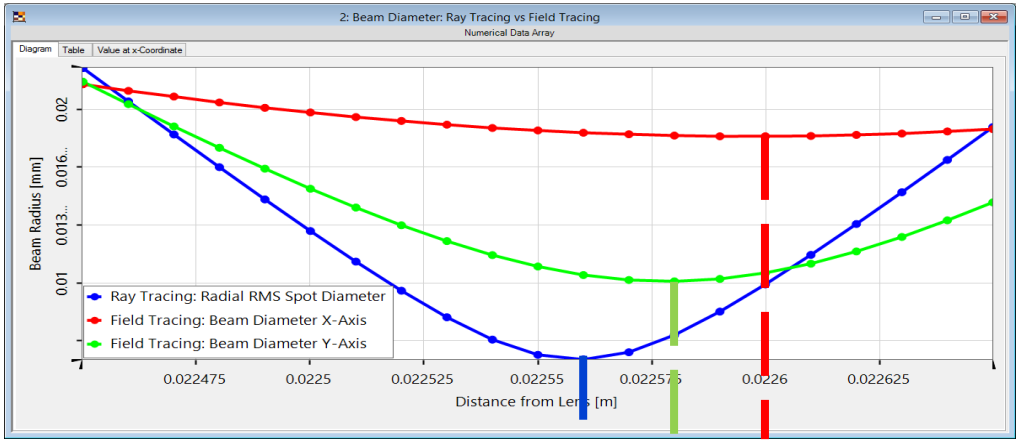




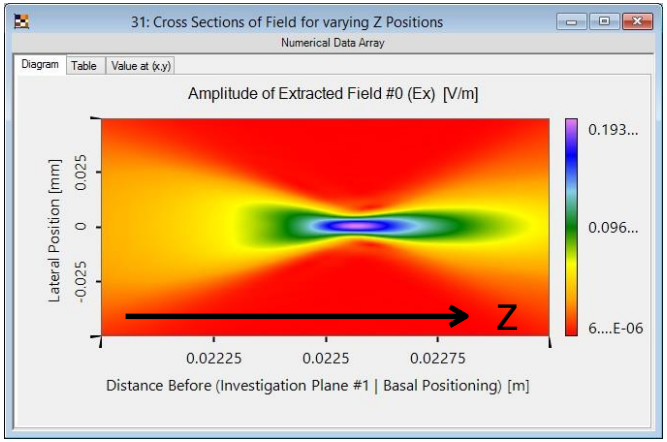
Summary

VirtualLab enables:

- high precision focal positioning by field tracing
- positioning is done in two steps:
  - quick focus finding by ray tracing
  - high precision focus investigation by field tracing



22.56mm | 22.60mm
22.58mm

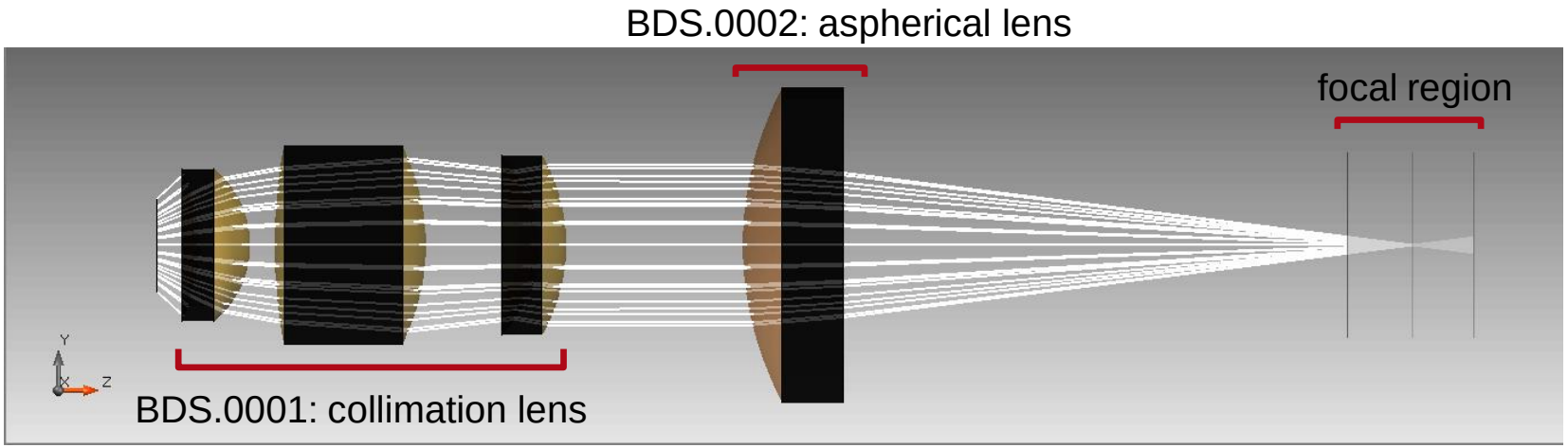


Application Example in Detail

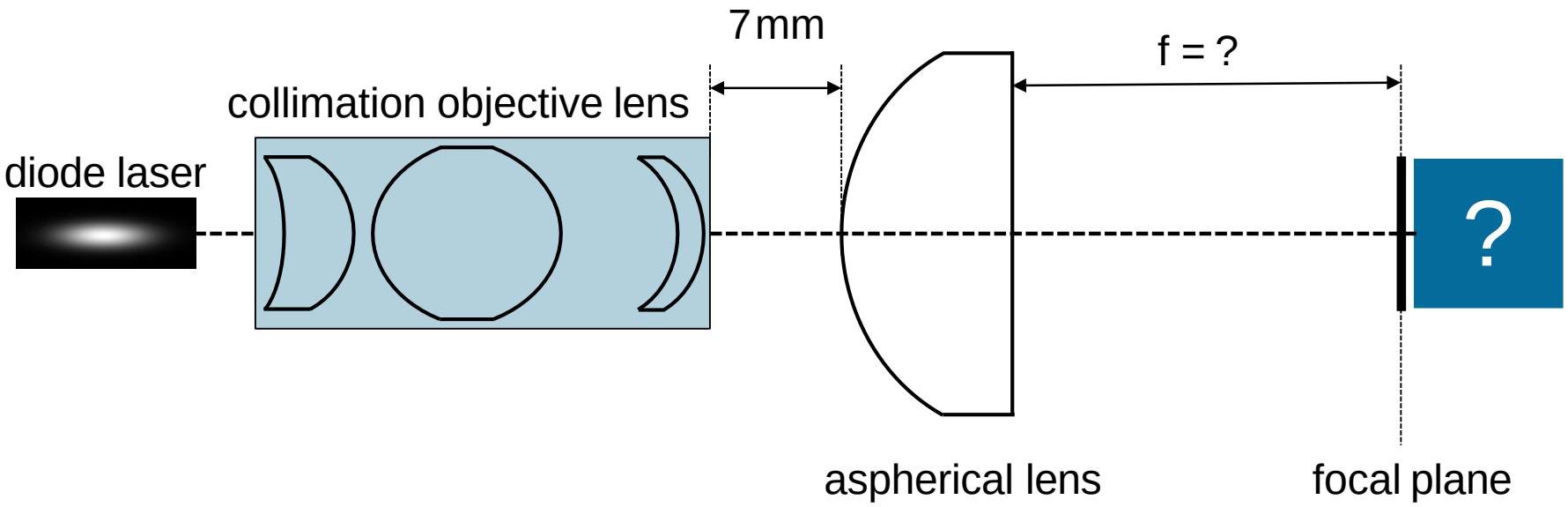
System Parameters

Context of this Application Example

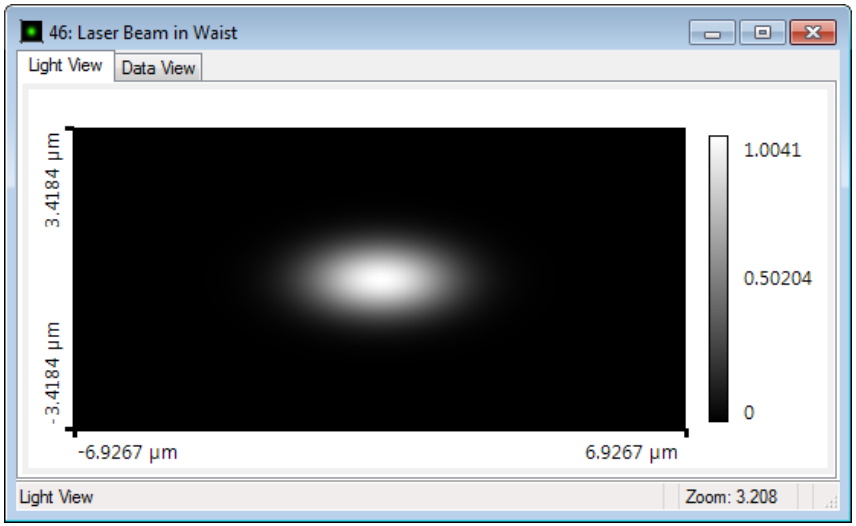
- BDS.0001, BDS.0002 and BDS.0003 deal with a **refractive beam delivery system**.
- In this example the **focal region** investigation of an aspherical catalog lens is demonstrated.
- In BDS.0003 a double lens design for beam focusing is performed.



Simulation Task



Specs: Uncollimated Input Laser Beam

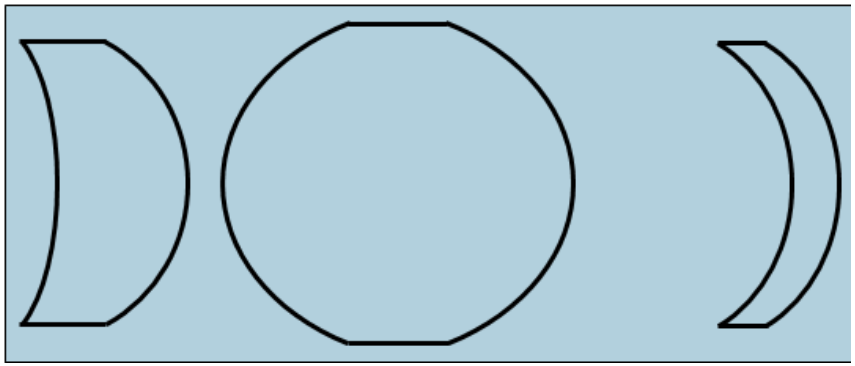


Single Mode IR Diode Laser from Laser Components

Parameter	Value (& Unit)
name/type	WSLD-1064-050m-1-PD
wavelength	1064 nm
divergence of beam intensity	**10° × 20°** (FWHM) i.e. 8.49° × 16.99° (referring to $1/e^2$)
polarization	linear (e.g. parallel to x-axis)

same as in BDS.0001

Specs: Collimation Lens and Subsequent Light

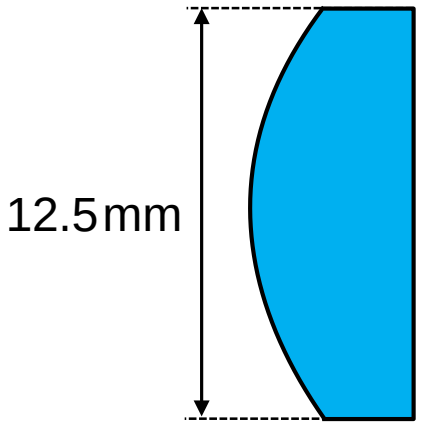


Lens from BDS.0001;
Beam Parameters behind it:

Parameter	Value & Unit
$1/e^2$ radius X x Y	936.22 µm × 1.8607 mm
$1/e^2$ divergence angle X x Y	0.021245° × 0.012396°
M^2 in X x Y direction	1.0180 × 1.1802
RMS of wavefront error	~0.03λ

Specs: Aspherical Lens

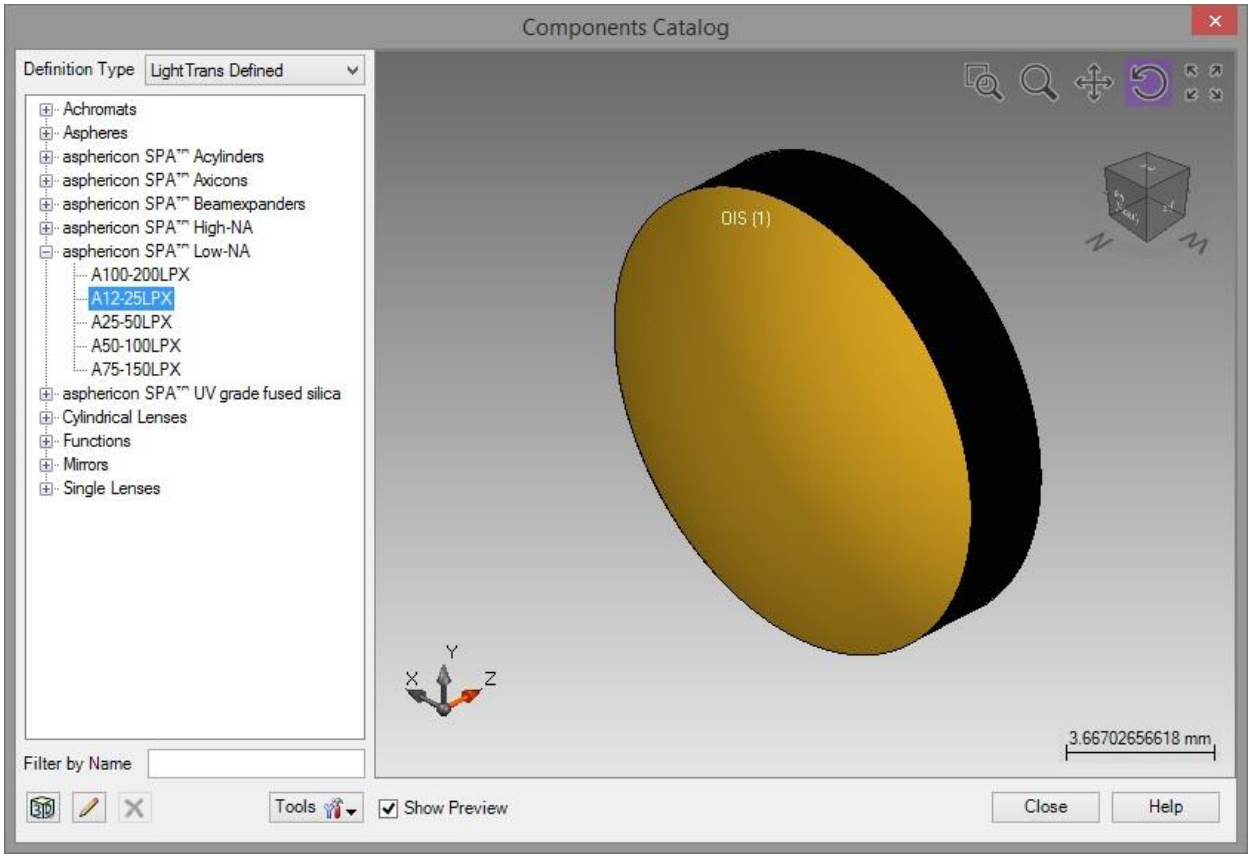
- A convex-plano aspherical lens from Asphericon is chosen from catalog.
- Model: ALL12-25-S-U
  (A12-25LPX)



Parameter	Value & Unit
diameter	12.5 mm
effective focal length	25 mm
back focal length	22.3539 mm
numerical aperture	0.23
design wavelength	780 nm
center thickness	4.0 mm
marginal thickness	2.4 mm
material	N-BK7
working distance	22.4 mm

Because this lens was designed for a different wavelength, its suitability and quality has to be checked for 1064 nm initially.

Lens Origin (Catalog & Website)



The “LightTrans Defined” **component catalog** of VirtualLab contains e.g. lenses from the company Asphericon.
Additionally Asphericon provides also VirtualLab files on their website.

Application Example in Detail

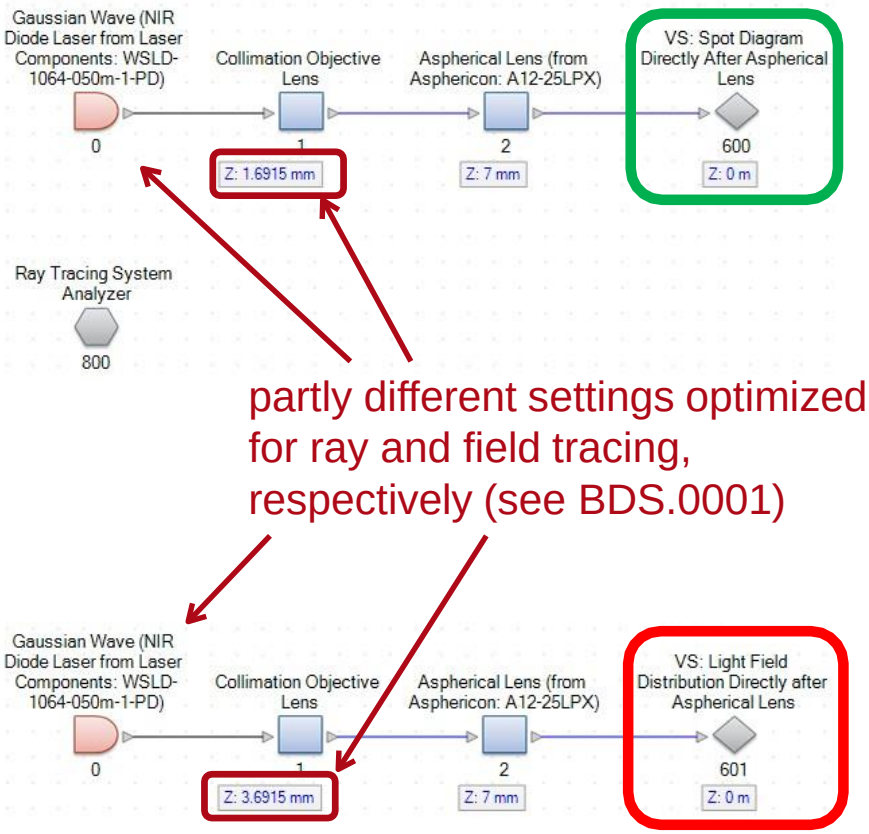
Simulations & Results

Settings for Ray and Classic Field Tracing

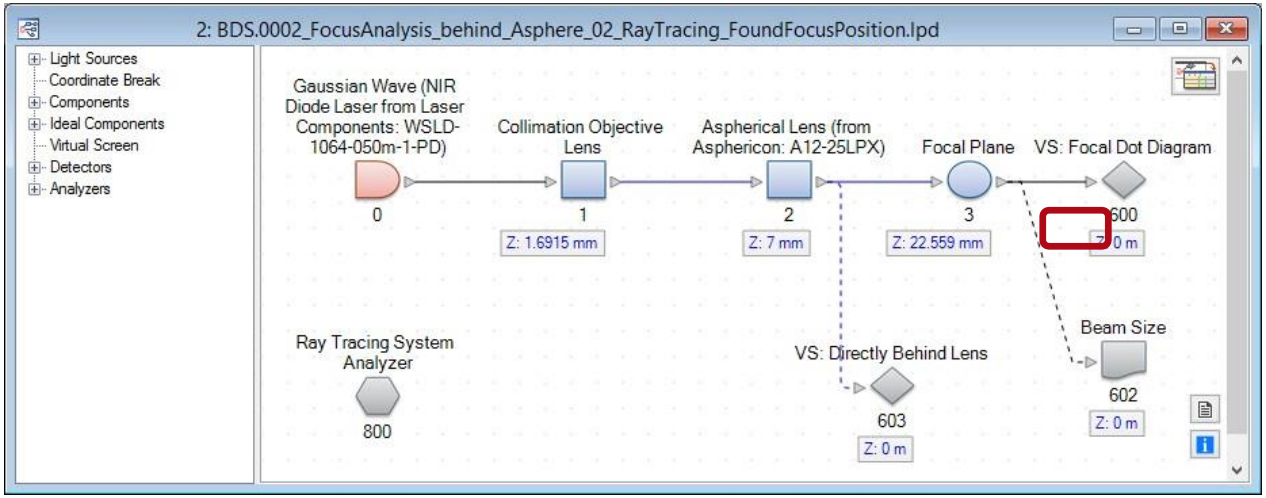
For a **detailed investigation** of the focus region **ray tracing and classic field tracing** simulations are applied.

- We will also check the light in **varying Z-distances around the focus**.
- The unchanged part of the system doesn‘t need to be simulated multiple times, thus the dot diagram and the light field distribution directly after the aspherical lens is calculated and stored in order to execute a **parameter run** evaluation.

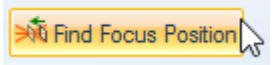
ray tracing

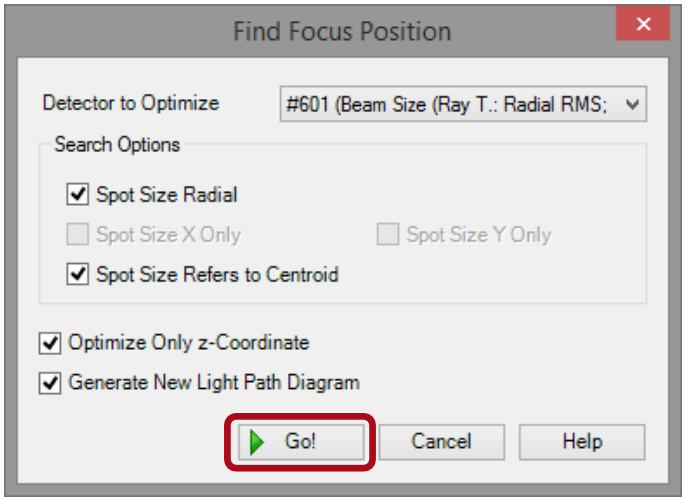


Finding the Focus Position via Ray Tracing



- The provided Asphericon files state only the back focal distance for the design wavelength of 780 nm.
- We use the **Focus Finder Tool** for desired wavelength of 1064 nm with a starting distance of 0 mm.

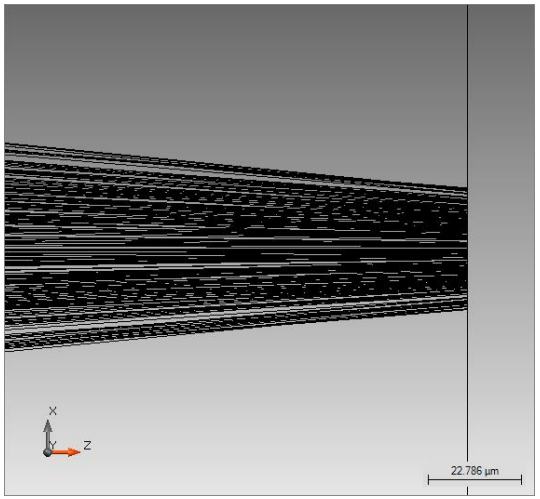


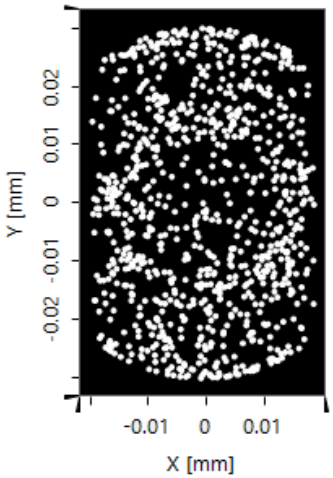


Ray Tracing: Optimized Working Distance

Simulated Wavelength

1064 nm

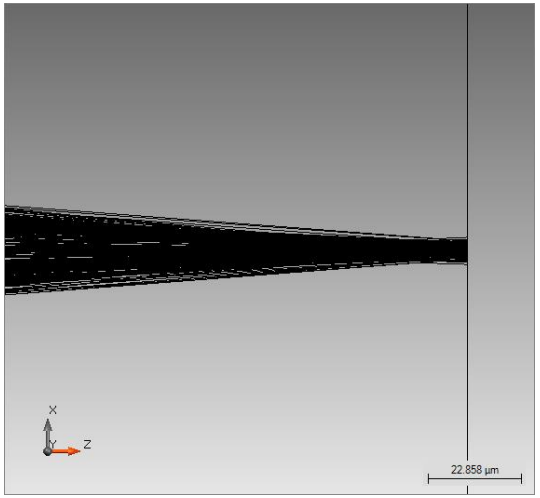


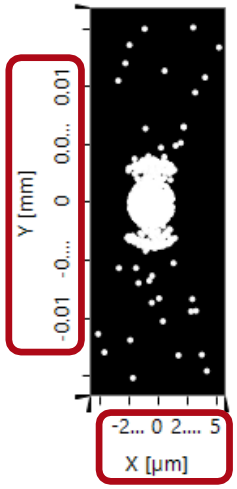


Back Focal Length

given focus position for 780 nm: 22.354 mm

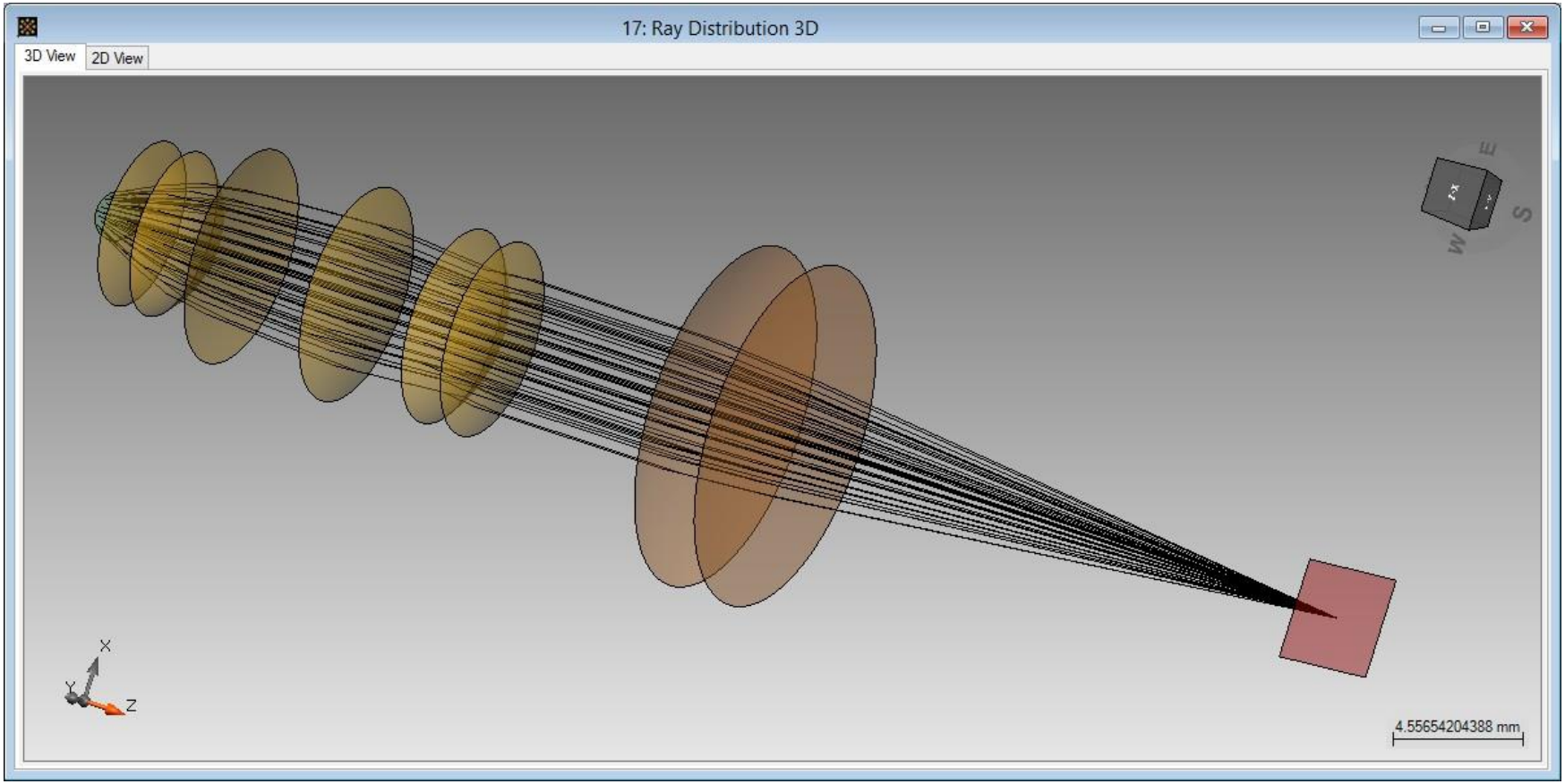
1064 nm



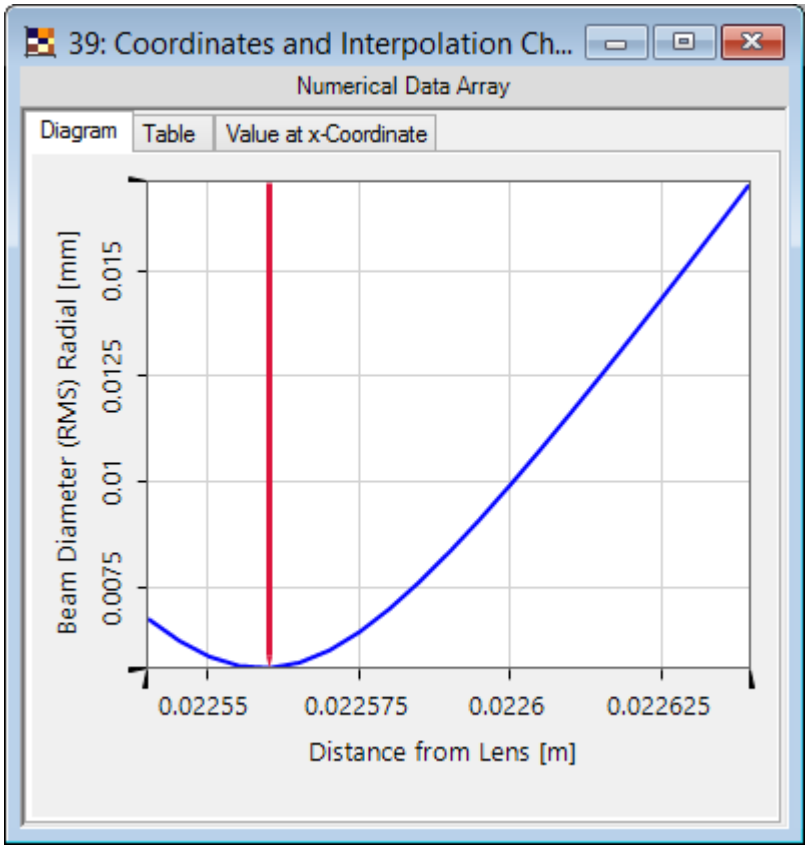


found **focus position** for 1064 nm: **22.559 mm** (smallest RMS)

3D Ray Tracing Analysis for BFL=22.60mm



Ray Tracing: Radial RMS Diameter Evaluation



- The minimum radial RMS diameter is found by ray tracing at a back focal **distance of 22.56 mm**.
- For this distance the calculation of the radial **RMS diameter** yields **5.55 µm**.

Next we will evaluate the setup with classic field tracing.

 file used: BDS.0002_FocusAnalysis_behind_Asphere_04_PR.run

Field Tracing: Detailed Analysis

Field tracing simulations allow the evaluations of all light field properties.

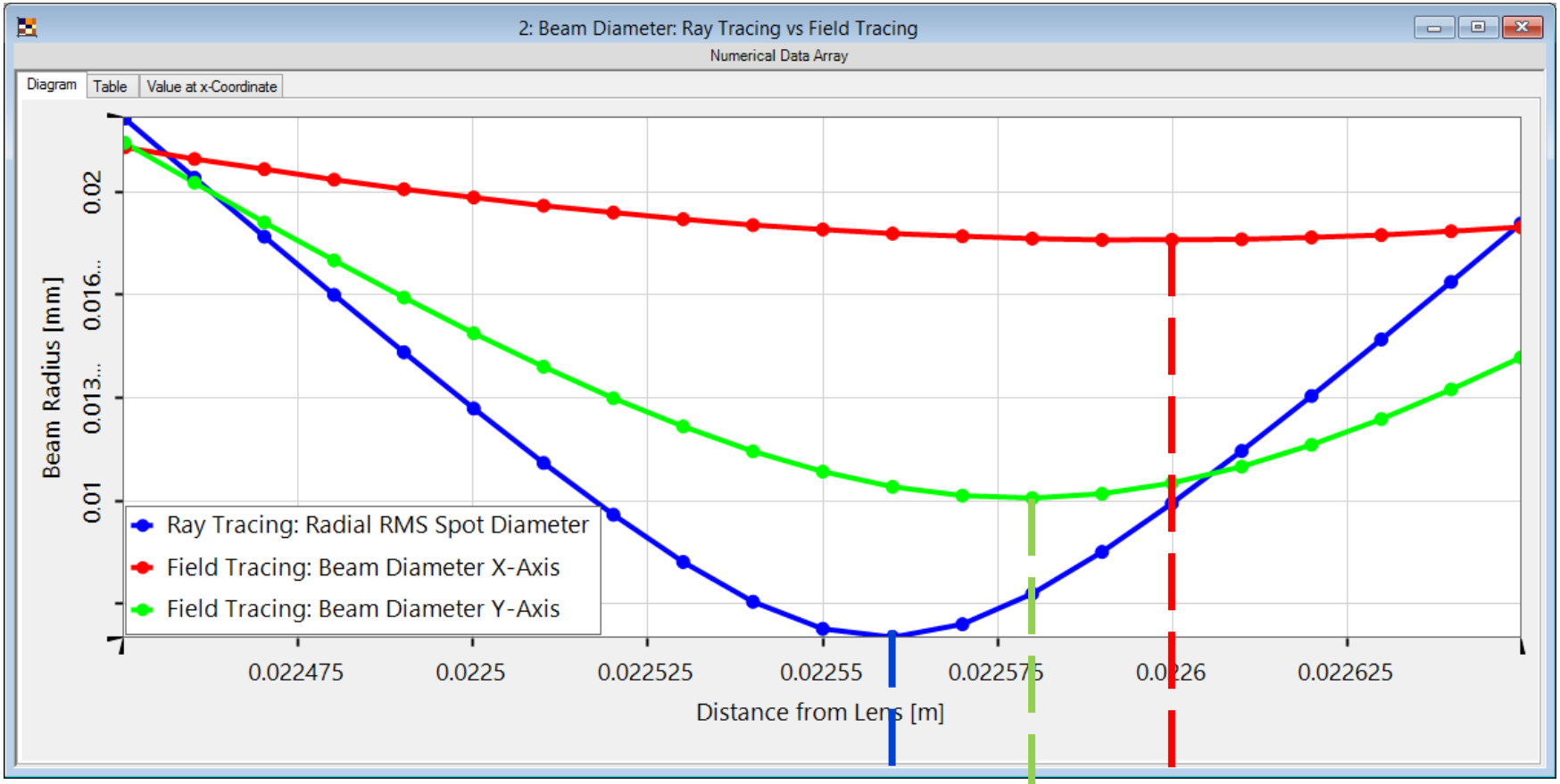
For this example …

- we check the **intensity and phase** values.
- we apply a **beam parameter detector** to investigate the beam in more detail.

Field tracing allows the consideration of **diffraction effects** which are most relevant for focus spot investigations.

By analyzing the fields in different Z-positions around the assumed focus plane we can observe the **development of the focused light** and compare the results from **ray tracing versus field tracing simulations**.

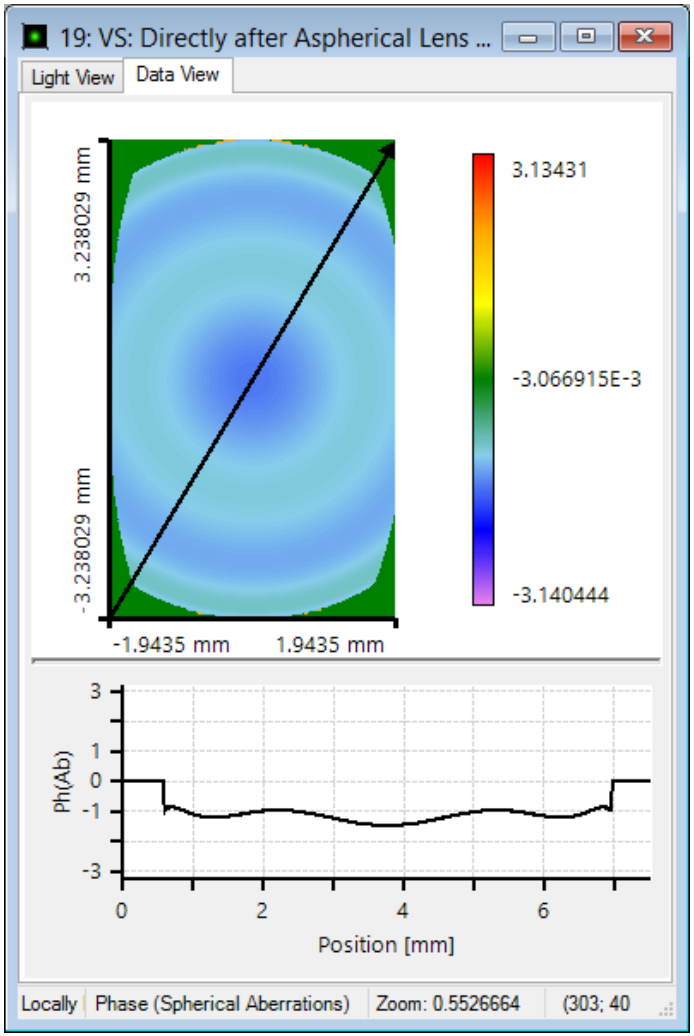
Beam Radius vs. Distance from Lens



There are **focal length differences** between the ray and the field tracing results, due to **diffraction effects** (which are not included in ray tracing simulation).

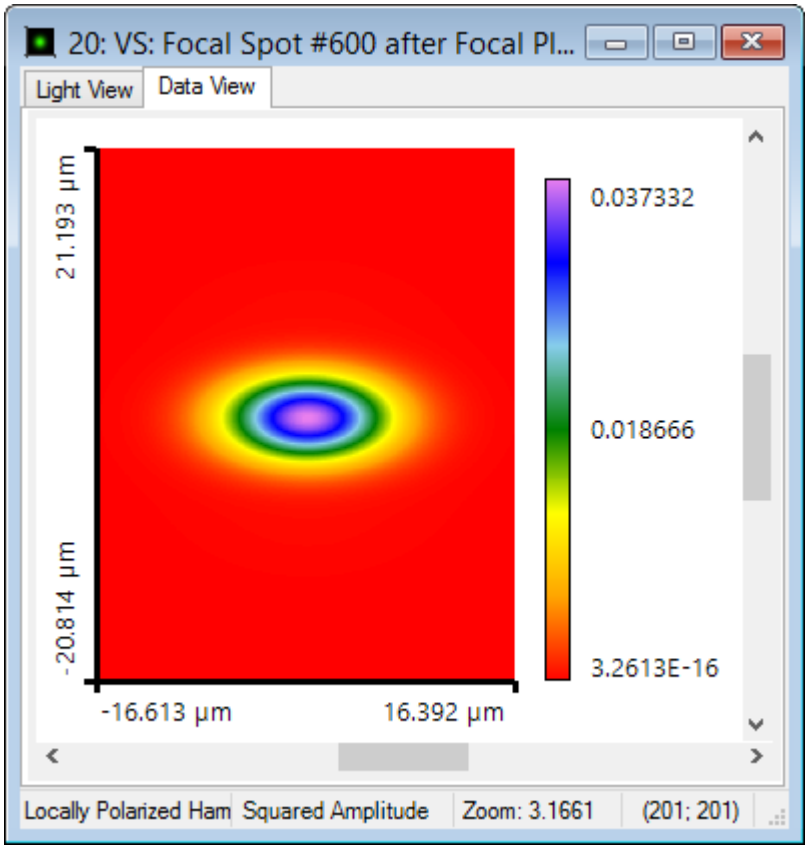
 file used: BDS.0002_FocusAnalysis_behind_Asphere_04_PR.run

Field Tracing: Wavefront Aberrations



- VirtualLab allows to **investigate the phase** directly behind the aspherical lens and to **disregard the intended spherical phase** values.
- Thus only the **residual phase modulations** remain.
- They do not represent this lens‘ aberrations. They are the unchanged remaining minor phase aberrations **from the collimated incoming light**.

Focus Spot Intensity in 22.60 mm Distance



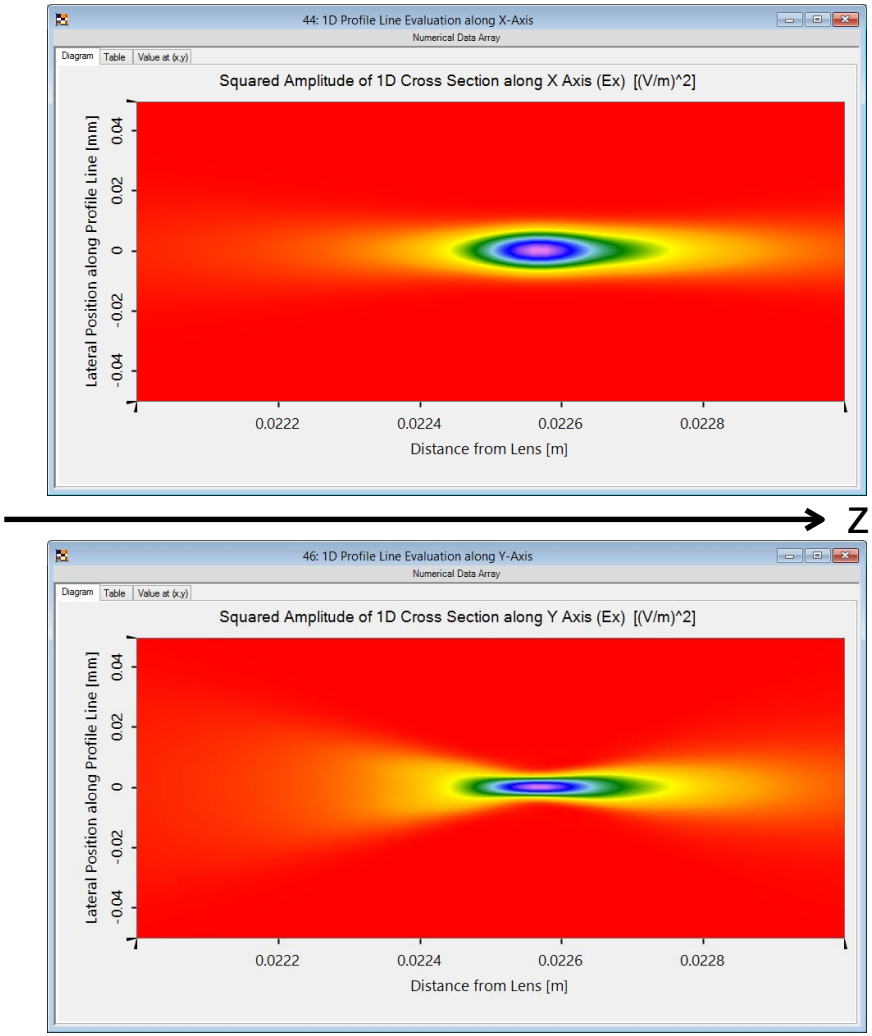
- Due to lens aberrations and cut off light portions (at lens aperture) the beam quality (M^2 value) suffers a bit.
- The evaluation of the phase values allow already the **ascertainment of the focus positions** (waist distance).

Results from Beam Parameter Detector

Beam Parameter	Value & Unit
waist radius (X x Y)	9.2µm × 5µm
M^2 values (X x Y)	1.0 x 1.1
waist distance (X x Y)	-40µm × -20µm

 file used: BDS.0002_FocusAnalysis_behind_Asphere_03_FieldTracing_Initial.lpd

1D Field Evaluations in Focal Region



VirtualLab enables also **1D cross section evaluations** for a better understanding of the **focus spot development**.

Adjacent figures (in rainbow colors) show how the focus region looks like along the

- X-axis (top)
- Y-axis (bottom)

regarding Z distances from the lens of 22 mm – 23 mm.

 file used: BDS.0002_FocusAnalysis_behind_Asphere_05_PR_1D-Y.run

Additional VirtualLab Features

In this example you benefit from the following selected features:

- analyze the focusing capabilities of an aspherical lens

- ascertain the focus position via:
  - focus finder tool
  - parameter run document
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- get different informative/illustrative results such as
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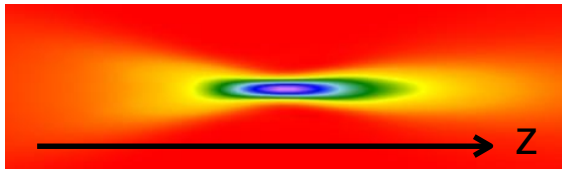
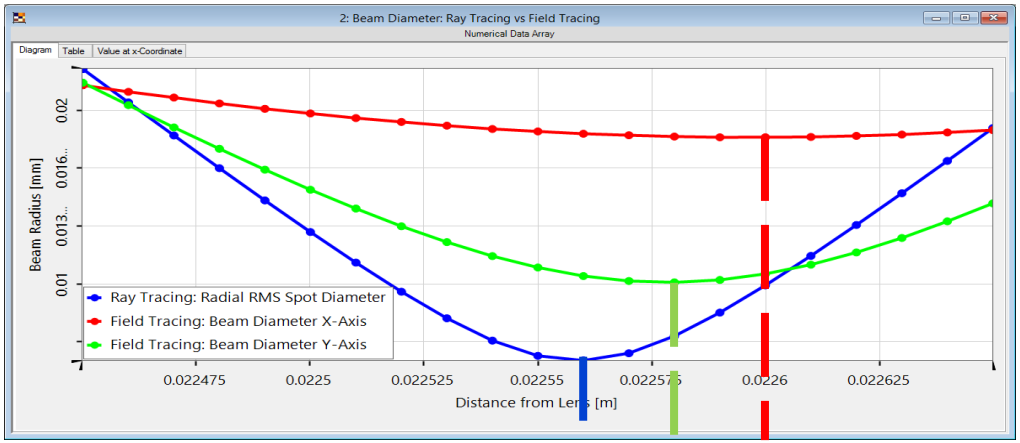


Summary

VirtualLab enables:

- High precision focal positioning by field tracing
- Positioning is done in two steps:
  - Quick focus finding by ray tracing
  - High precision focus investigation by field tracing



22.56mm | 22.60mm
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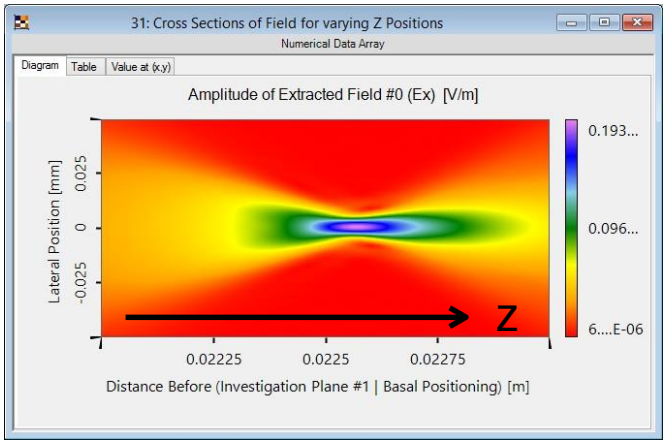

Further Readings

Further Readings

- Get Started Videos:
  - Introduction to the Light Path Diagram
  - Introduction to the Parameter Run
  - Introduction to Parametric Optimization