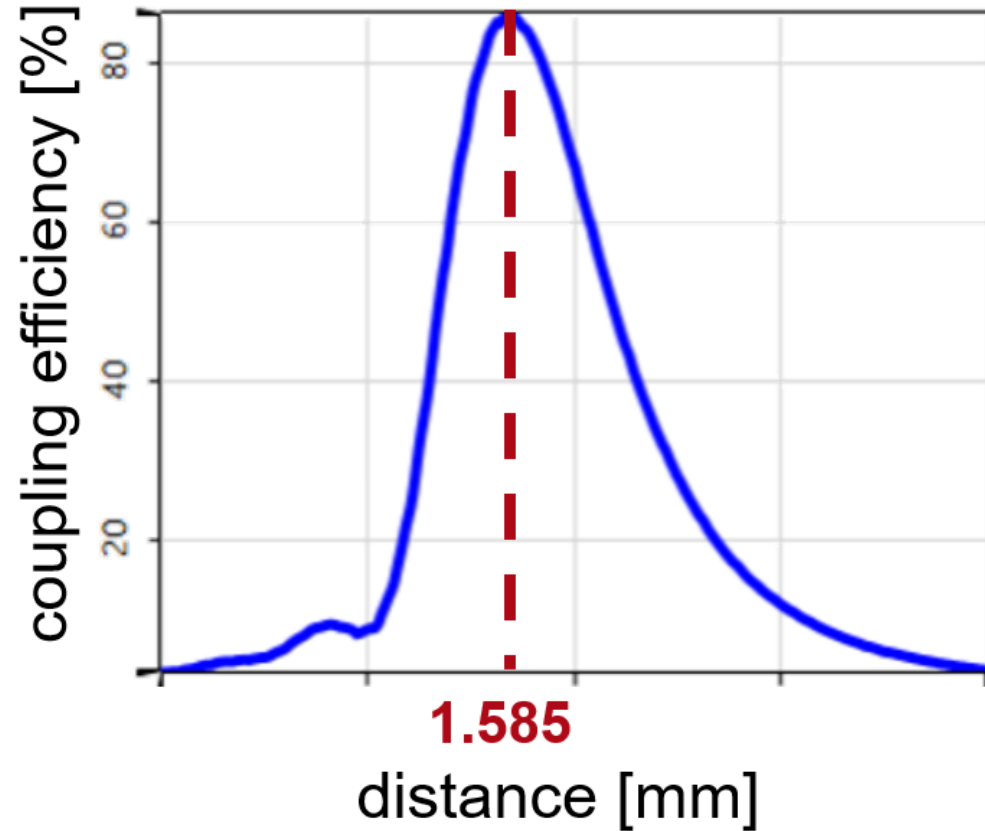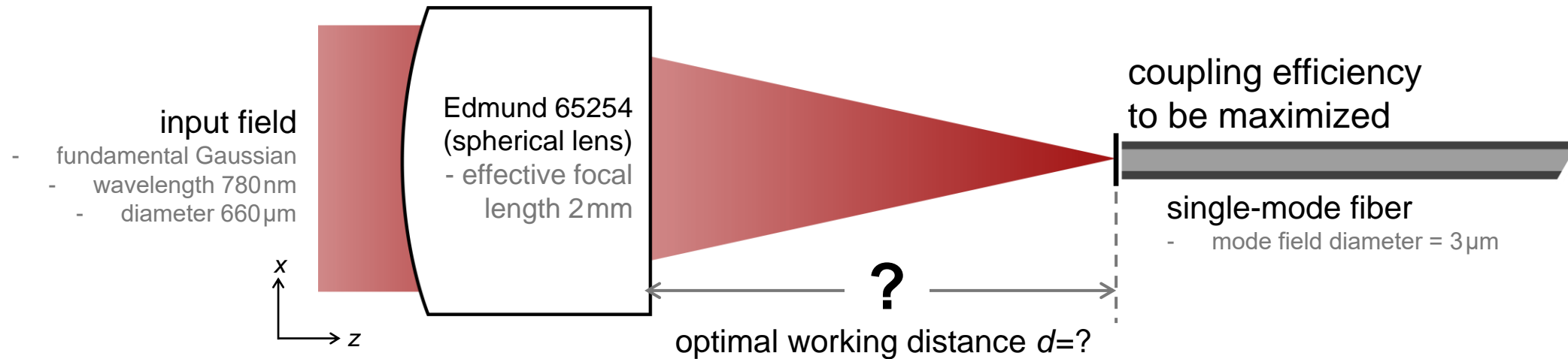# Optimal Working Distance for Coupling Light into Single-Mode Fibers

Abstract

Single-mode optical fibers are widely used in different applications, and they play a crucial role in long-distance optical communication. Launching light into such kind of single-mode fibers can be a challenging task in practice. In this example, we select one commercially available lens, and show how to find the optimal working distance to achieve maximum coupling efficiency. Particularly, we demonstrate that the optimal working distance found by field tracing differs from the focal distance predicted by ray optics.

Modeling Task

input field
- fundamental Gaussian
- wavelength 780 nm
- diameter 660 µm

Edmund 65254
(spherical lens)
- effective focal
length 2 mm

coupling efficiency
to be maximized

single-mode fiber
- mode field diameter = 3 µm

?

optimal working distance d=?

- Is it the best solution to place the fiber end at the ray-optics focal plane behind the lens?
- How to find the optimal working distance to achieve maximum coupling efficiency?
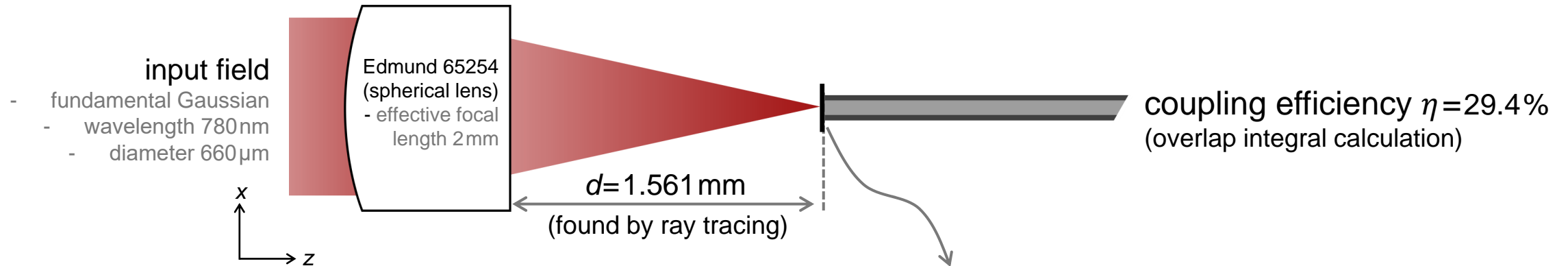
Focal Distance Found by Using Ray Tracing

Edmund 65254
(spherical lens)

x

z

$d=1.561\,\text{mm}$
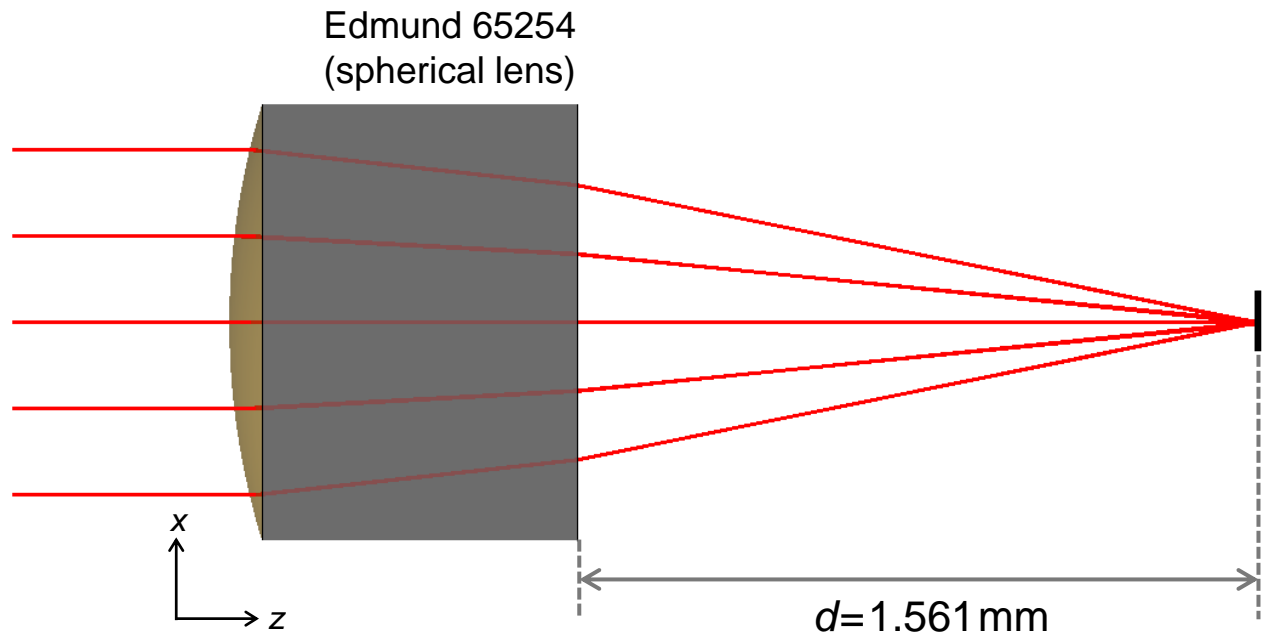
Focal distance for the spherical
lens is found first by using ray
tracing in VirtualLab.
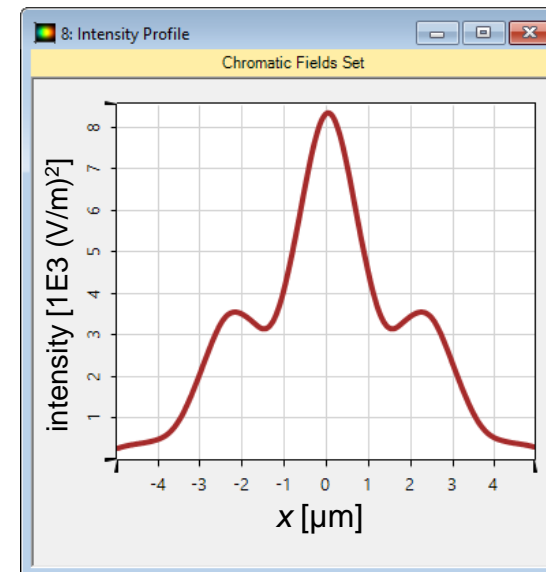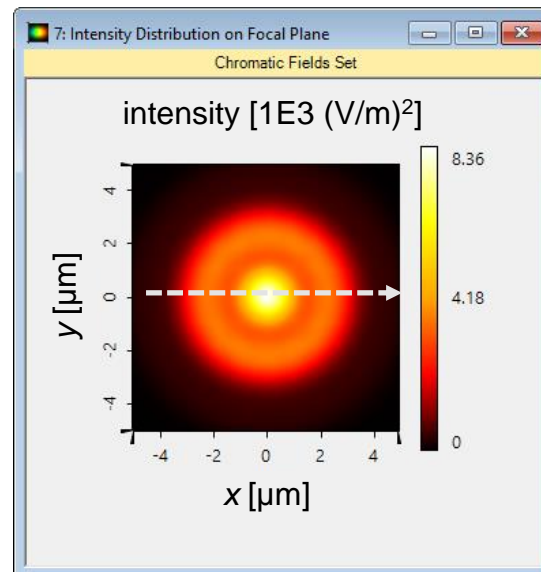
42: Dot Diagram on Focal Plane

Ray Distribution

Position

Y [µm]

X [µm]
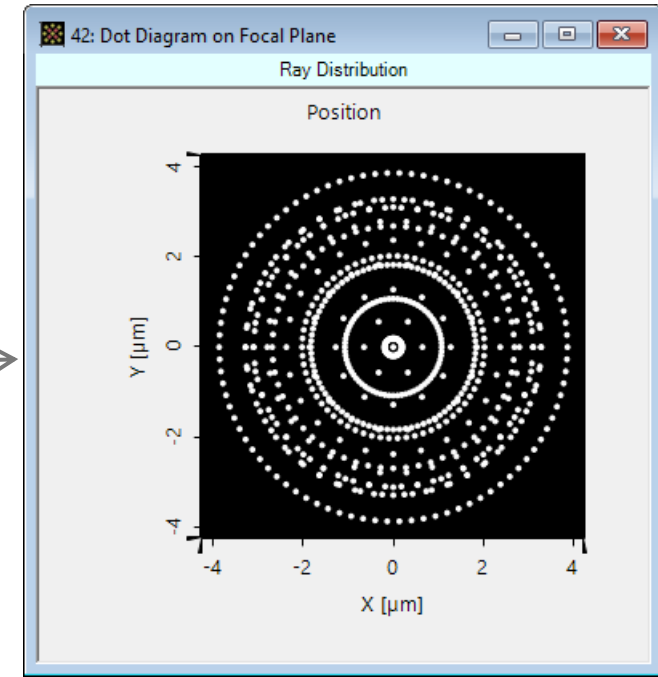
The beam diameter (RMS)
evaluated with ray tracing is 5.11 µm.

Field Tracing Evaluation at Ray-Optics Focal Distance

input field
- fundamental Gaussian
  - wavelength 780 nm
    - diameter 660 μm

Edmund 65254
(spherical lens)
- effective focal
  length 2 mm

x

z

$d=1.561\,\text{mm}$
(found by ray tracing)

coupling efficiency $\eta=29.4\%$
(overlap integral calculation)

Field tracing in VirtualLab provide access to the full field information at any desired plane in the system.

7: Intensity Distribution on Focal Plane

Chromatic Fields Set

intensity [1E3 (V/m)²]

8.36

4.18

0

y [μm]

x [μm]

8: Intensity Profile

Chromatic Fields Set

intensity [1E3 (V/m)²]

x [μm]

Find Optimal Working Distance by Using Field Tracing

input field
- fundamental Gaussian
- wavelength 780 nm
- diameter 660 μm

Edmund 65254
(spherical lens)
- effective focal
length 2 mm

coupling efficiency $\eta = ?$

varying ⋯
(from 1.5 to 1.7 mm)

19: Searching Optimal Incoupling Position

Numerical Data Array

Diagram | Table | Value at x-Coordinate

Fiber Coupling Efficiency [%]

Working Distance [mm]
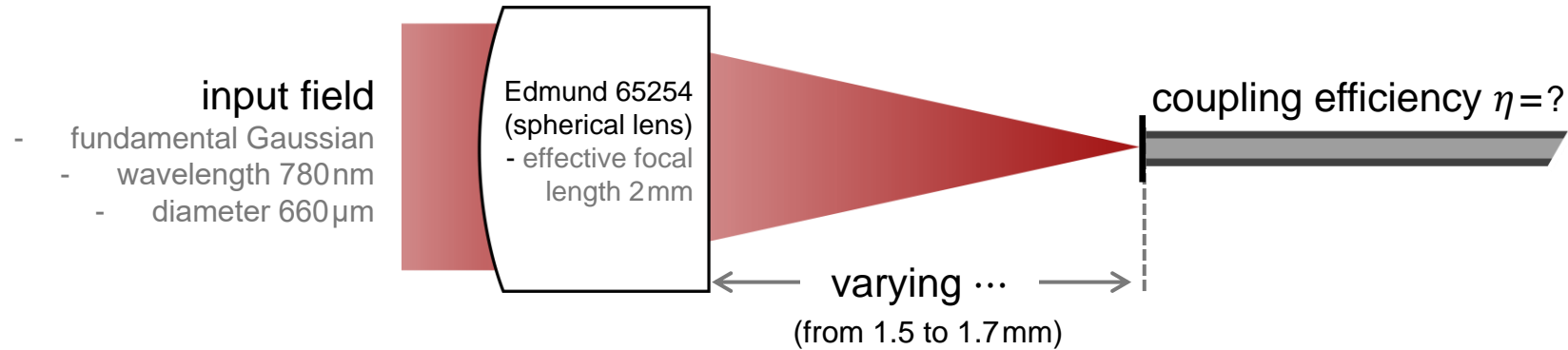
13: C:\Users\...\Fiber coupling with spherical lens Edmund_65254_PhysicalOptics.lpd_ParameterRun.run

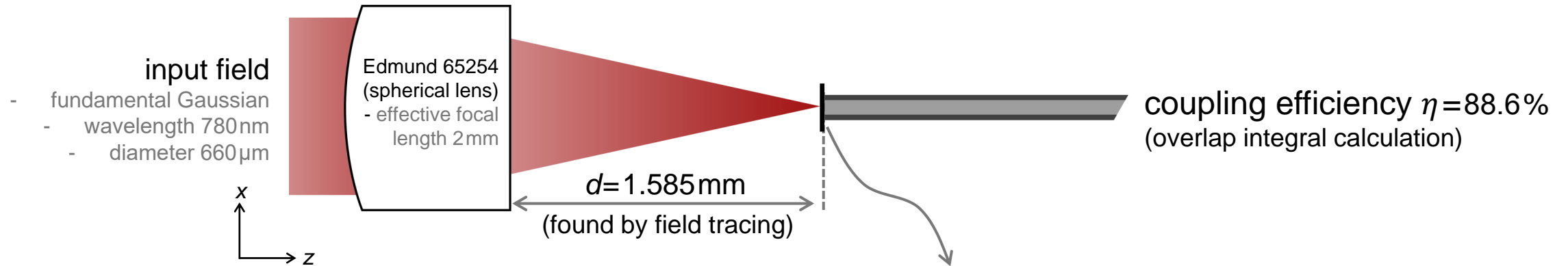**Results**

Start the parameter run and analyze its results

▶ Go!

☑ Use Cached Results for Next Run

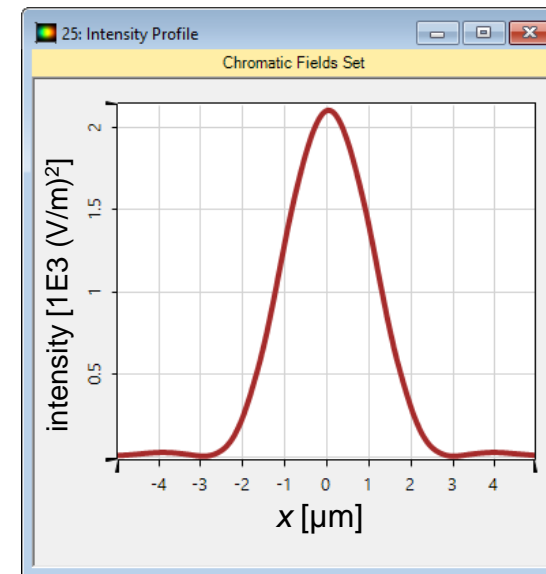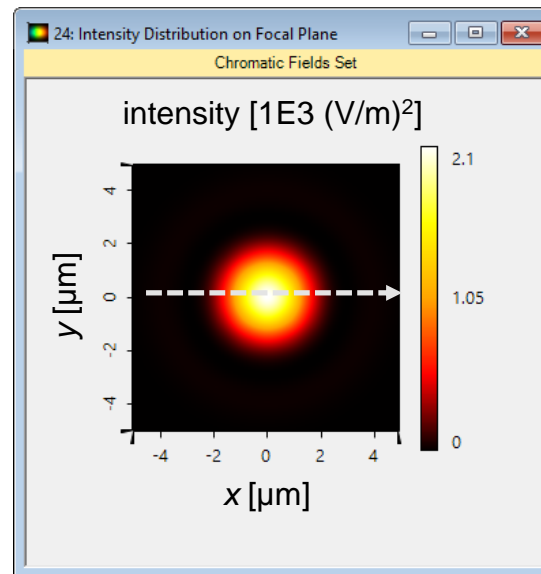|			Iteration Step				
Detector	**Subdetector**	**Combined Output**	196	197	198	199	200
Varied Parameters	Distance Before (Identity O…	Data Array	.695 mm	1.696 mm	1.697 mm	1.698 mm	1.699 mm	1.7
Fiber Coupling Efficiency #…	Fiber Coupling Efficiency	Data Array	3.7805 %	3.7067 %	3.6351 %	3.5657 %	3.4982 %	3.432
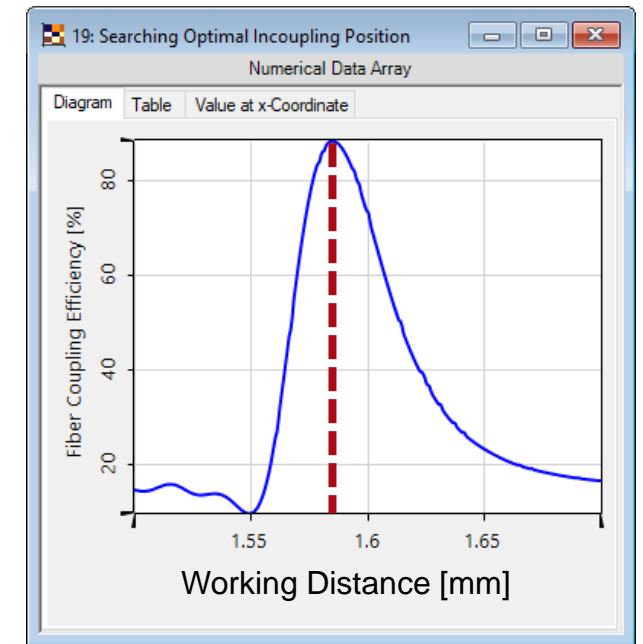
The optimal working distance found by field tracing is 1.585 mm.
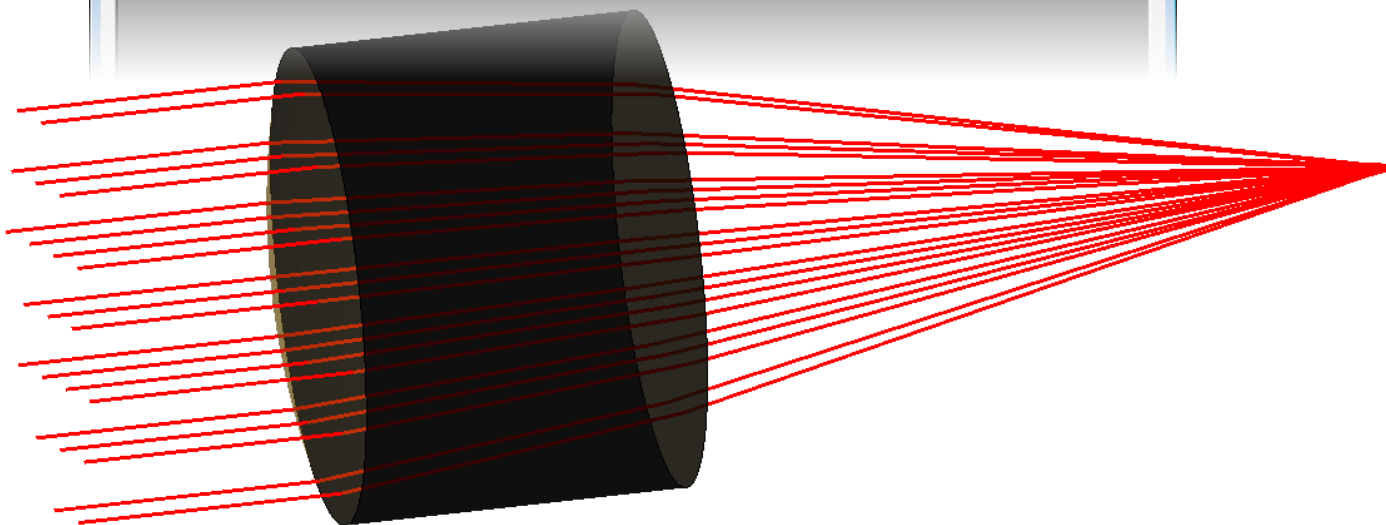
Evaluation at Optimal Working Distance

input field
- fundamental Gaussian
- wavelength 780 nm
- diameter 660 μm

Edmund 65254
(spherical lens)
- effective focal length 2 mm

x

z

$d = 1.585$ mm
(found by field tracing)

coupling efficiency $\eta = 88.6\%$
(overlap integral calculation)

The calculation of the focal spot and the evaluation of the coupling efficiency takes only 2 seconds!

24: Intensity Distribution on Focal Plane
Chromatic Fields Set
intensity [1E3 (V/m)^2]

y [μm]

x [μm]

25: Intensity Profile
Chromatic Fields Set
intensity [1E3 (V/m)^2]

x [μm]

Peek into VirtualLab Fusion

Parameter Run for selected variables in system

intensity [1E3 (V/m)^2]

visualization and analysis

ray tracing system analysis

Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Import coupling lens from Zemax file
  - Import Optical Systems from Zemax [Use Case]
- Find focal distance using ray optics

- Evaluate fiber coupling efficiency for initial working distance with field tracing

- Use Parameter Run to find optimal working distance
  - Usage of the Parameter Run Document [Use Case]
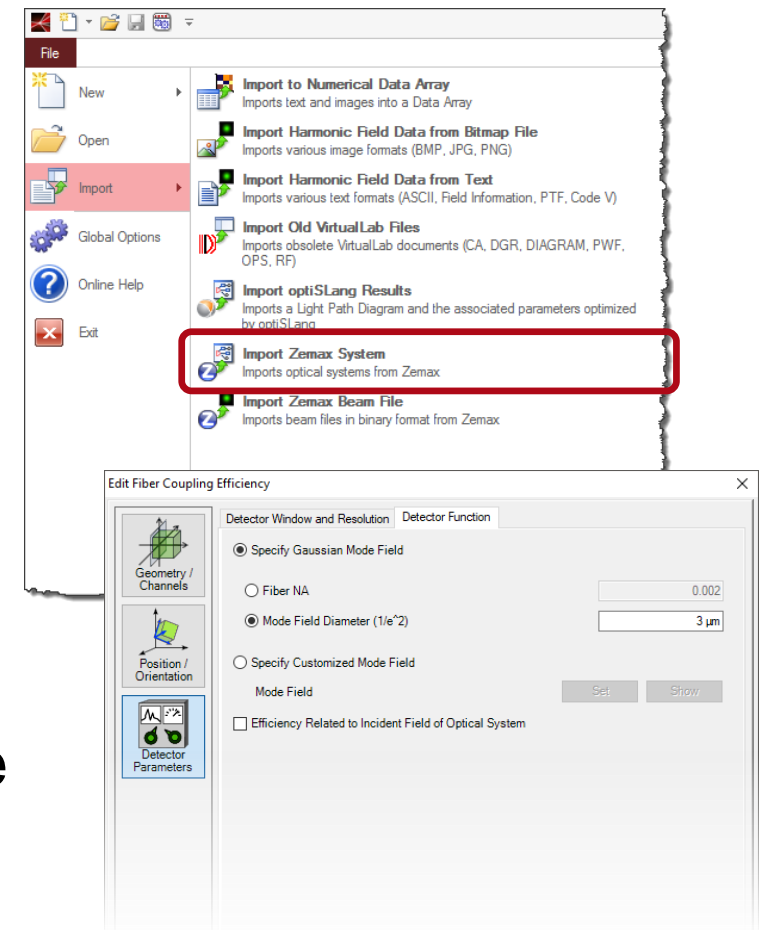
VirtualLab Fusion Technologies
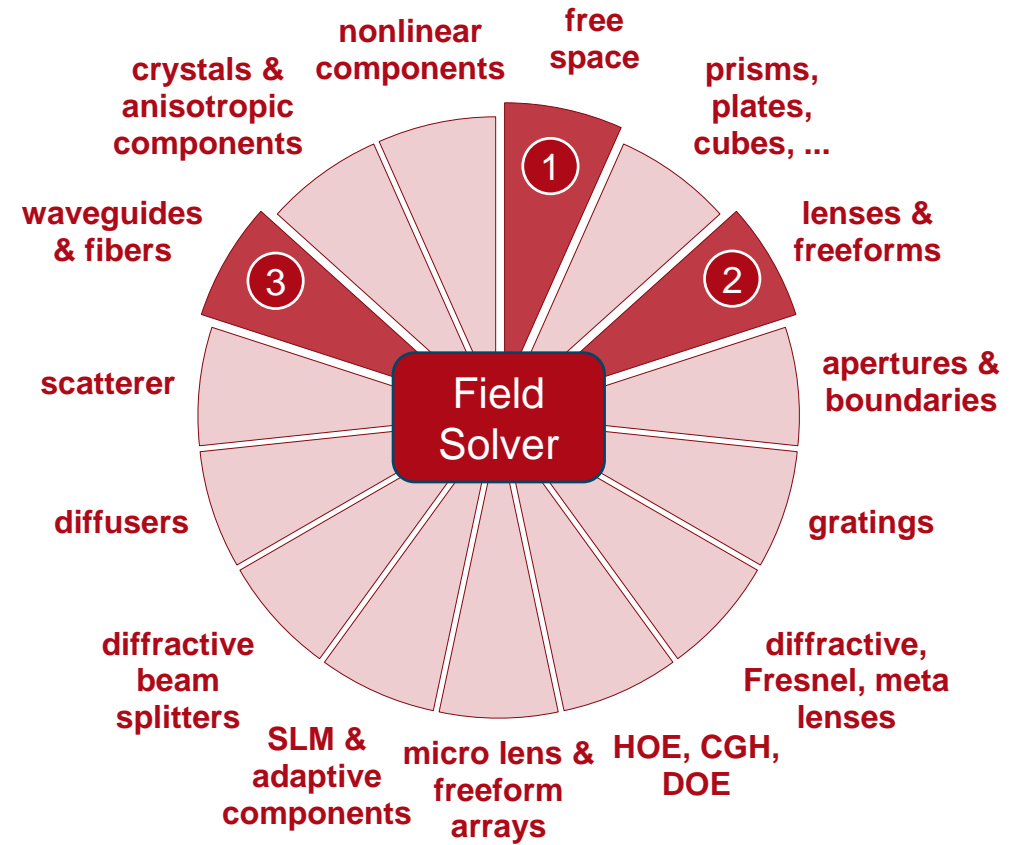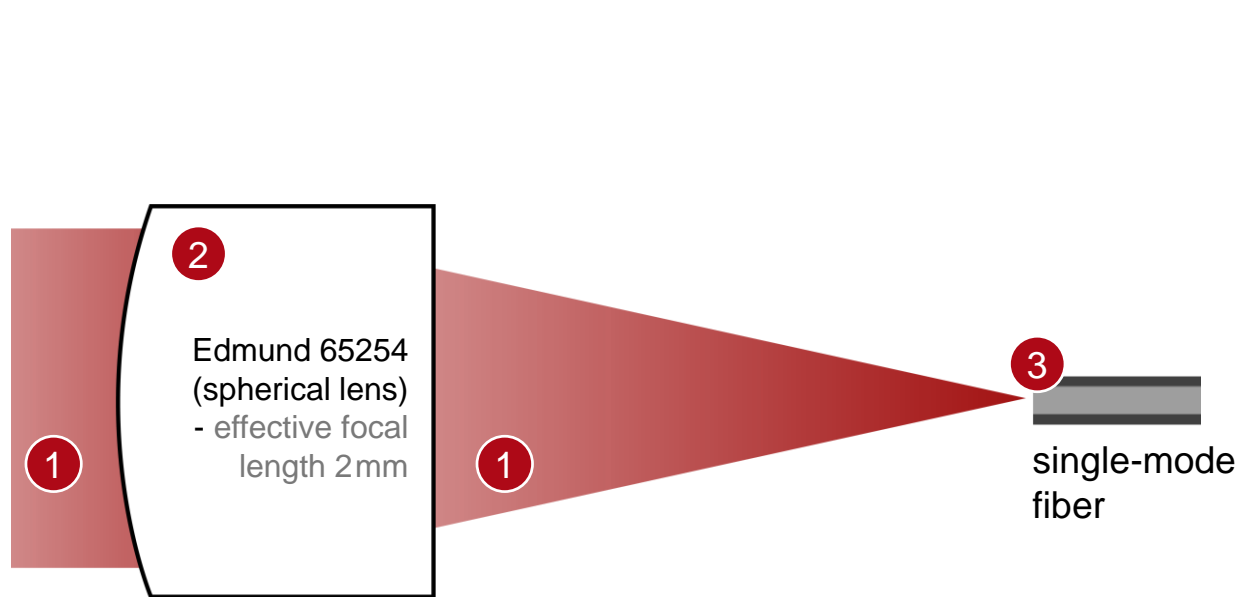
Document Information

title	Optimal Working Distance for Coupling Light into Single-Mode Fibers
document code	FCP.0001
version	1.0
toolbox(es)	Starter Toolbox
VL version used for simulations	7.4.0.49
category	Application Use Case
further reading	- Comparison of Different Lenses for Fiber Coupling - Parametric Optimization of Fiber Coupling Lens