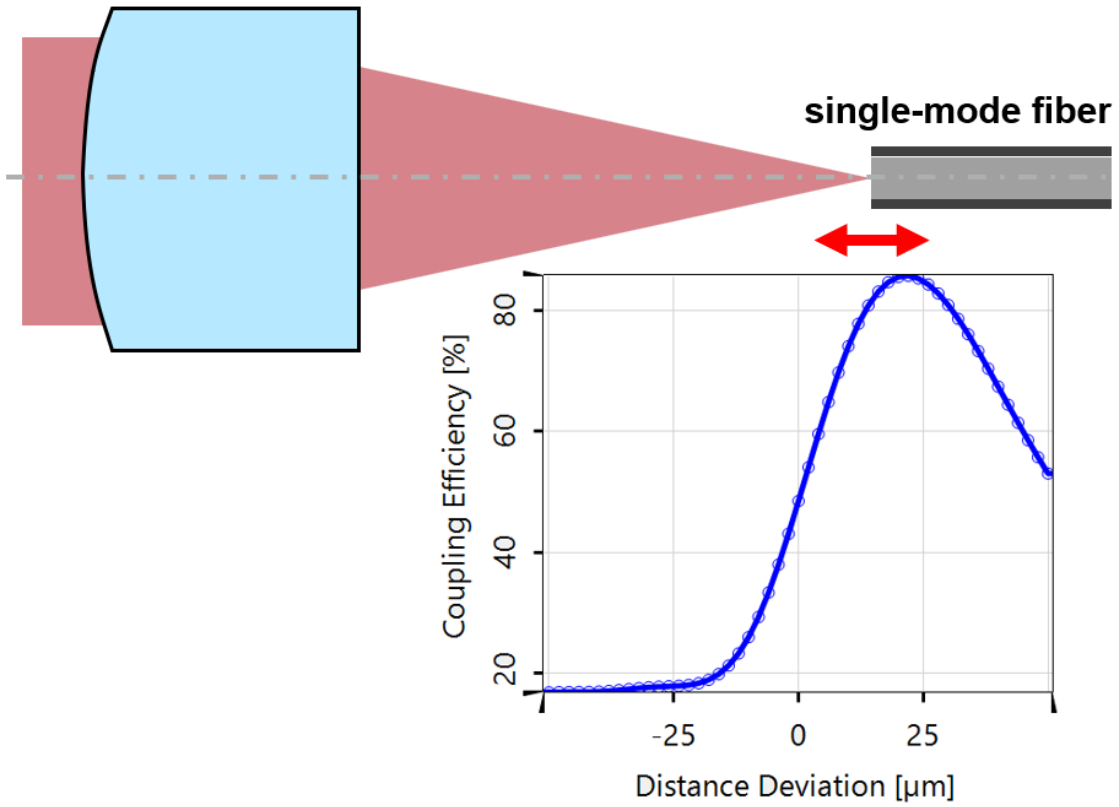
Optimal Working Distance for Coupling Light into Single-Mode Fibers

Abstract



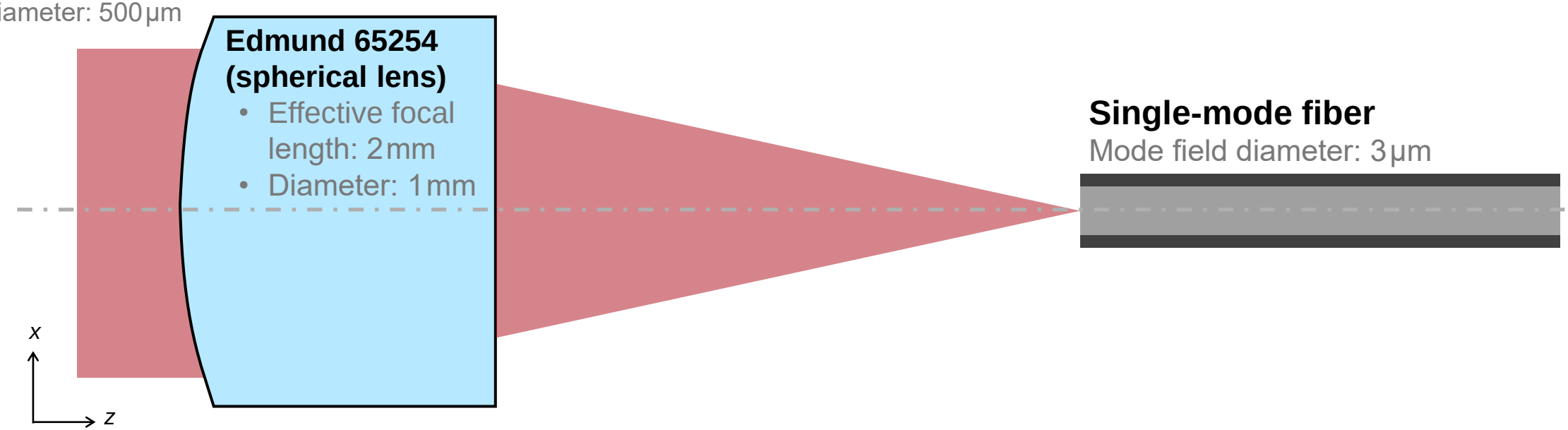
In this example, we select a commercially available lens and show how to find the optimal working distance to achieve maximum coupling efficiency. Starting from a geometrically found focus position, the optimal distance is evaluated using diffractive propagation methods.

Application Scenario

Application Scenario: System

Input field

- Fundamental Gaussian
- Wavelength: 780 nm
- Diameter: 500 µm



Application Scenario: System

Input field
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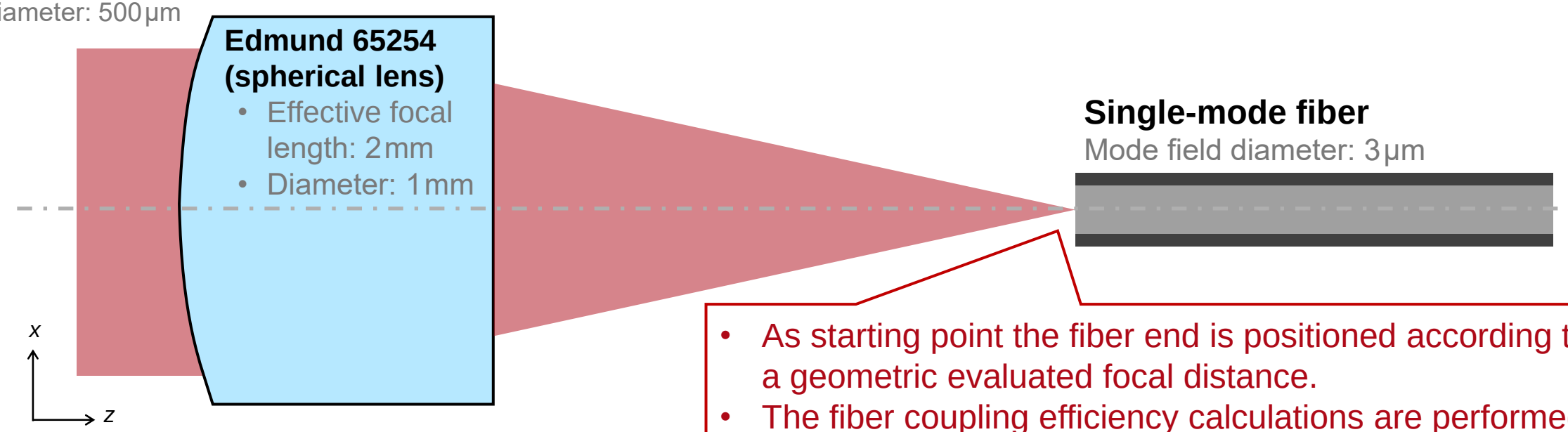
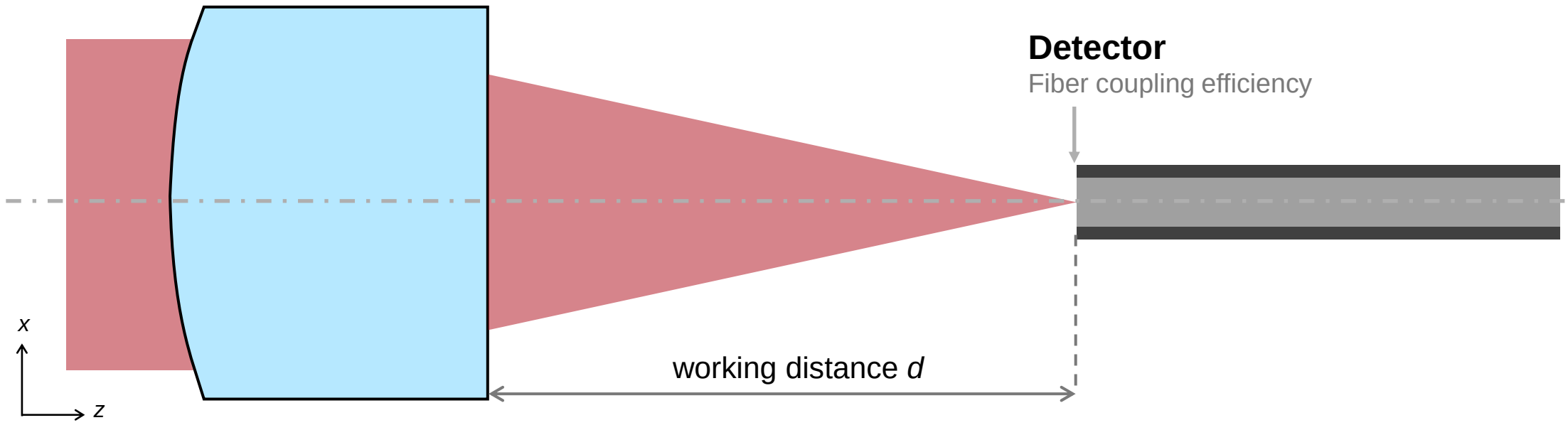


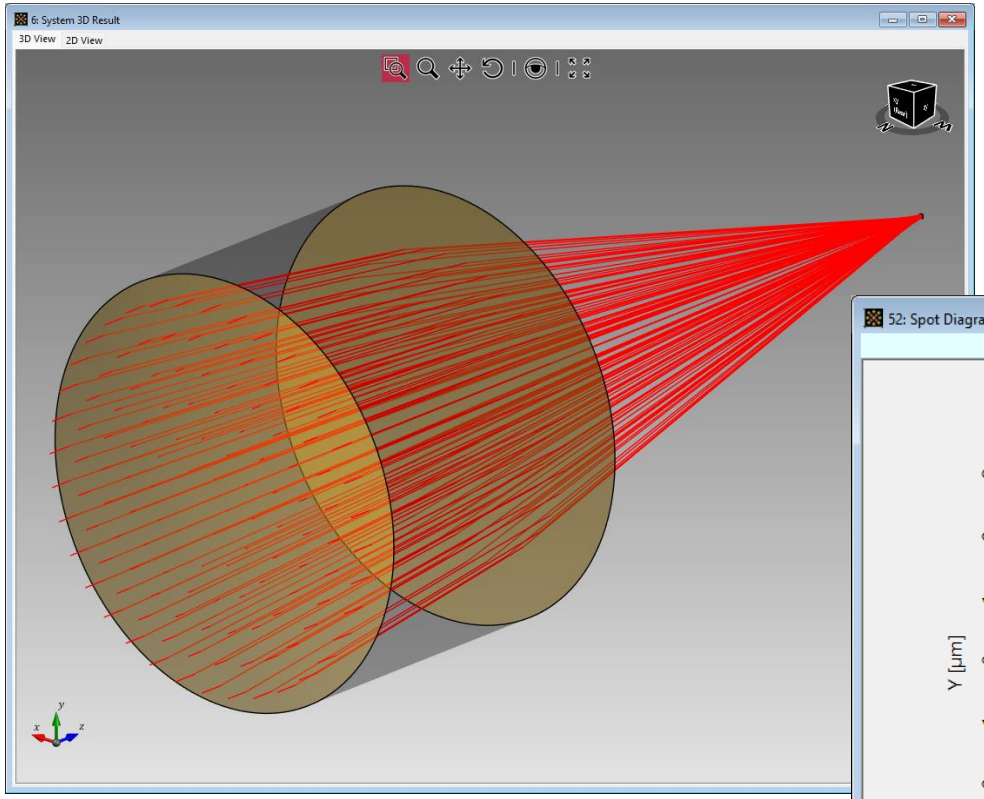
- As starting point the fiber end is positioned according to a geometric evaluated focal distance.
- The fiber coupling efficiency calculations are performed based on overlap integrals considering the diffractively calculated incident field and the fiber mode.

Application Scenario: Task

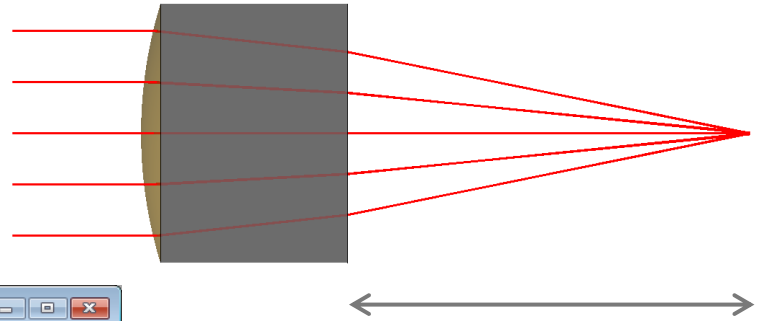
Find the optimal working distance *d* to maximize fiber coupling efficiency.



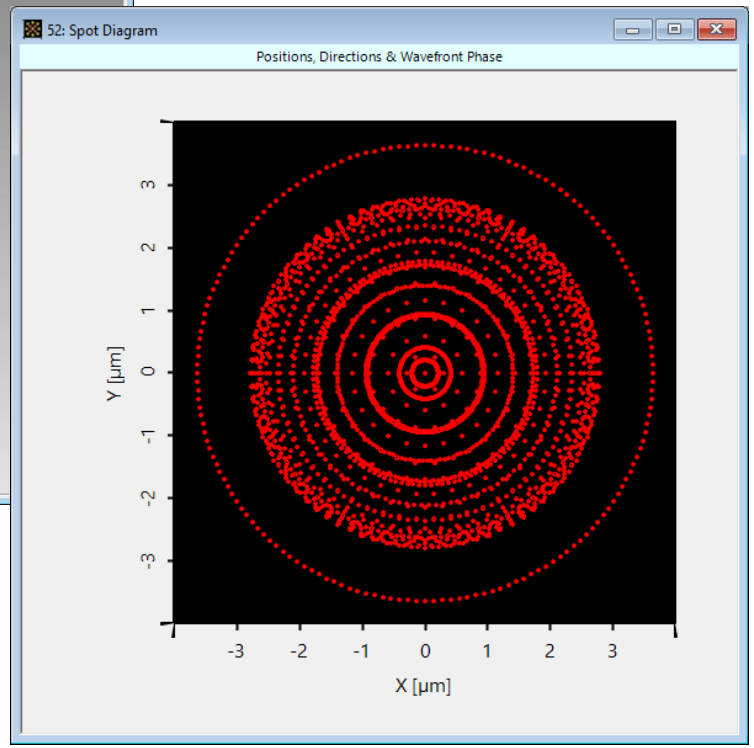
Initial Working Distance by Focal Spot Calculation



System 3D visualization



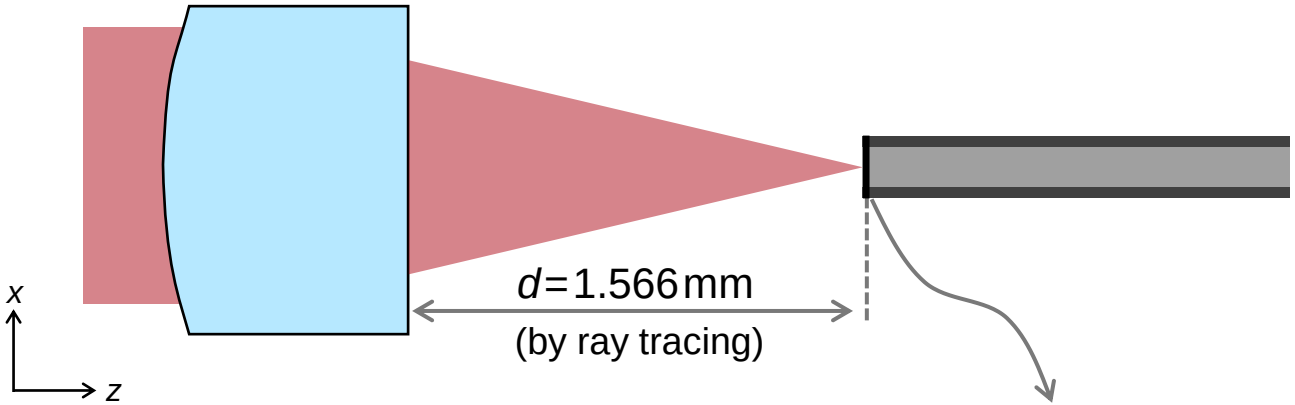
$d = 1.566\,\text{mm}$
Distance for minimum spot size



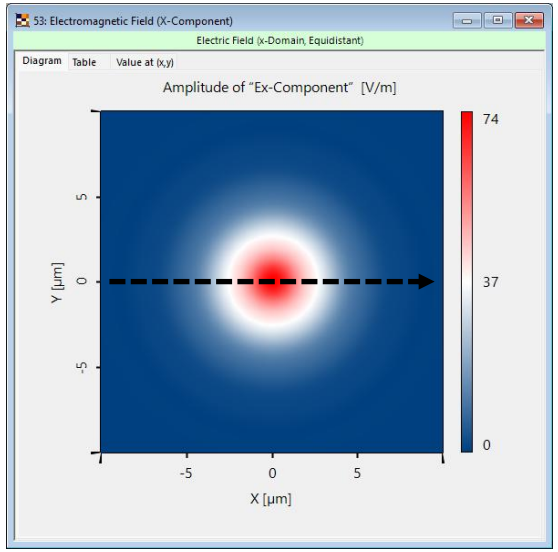
Spot diagram

file: USC.0072_FiberIncouplingDistance_01_At Focal Distance Found by Ray Tracing.os

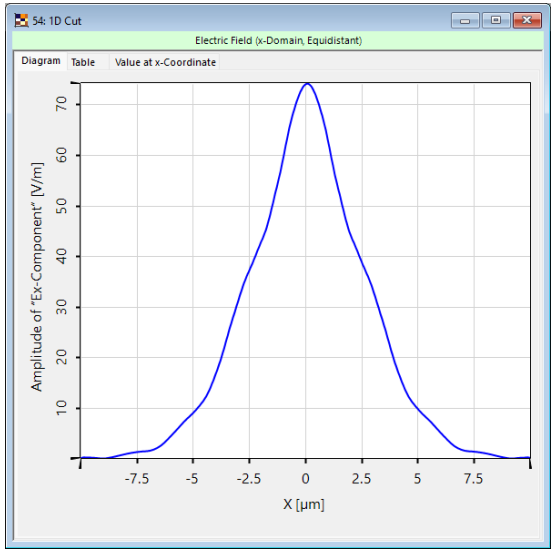
Field Evaluation at Ray-Optics' Focal Distance



coupling efficiency $\eta = 48.49\%$
(overlap integral calculation)



Amplitude (x-component)

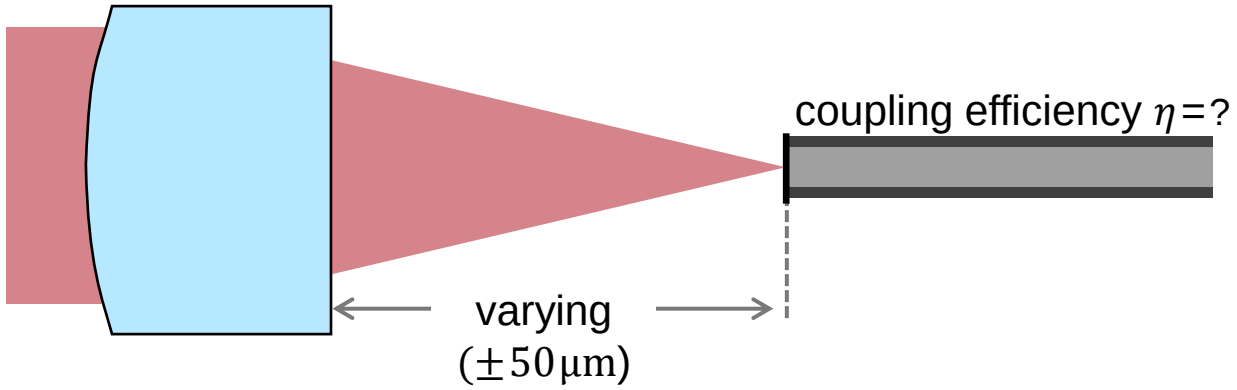


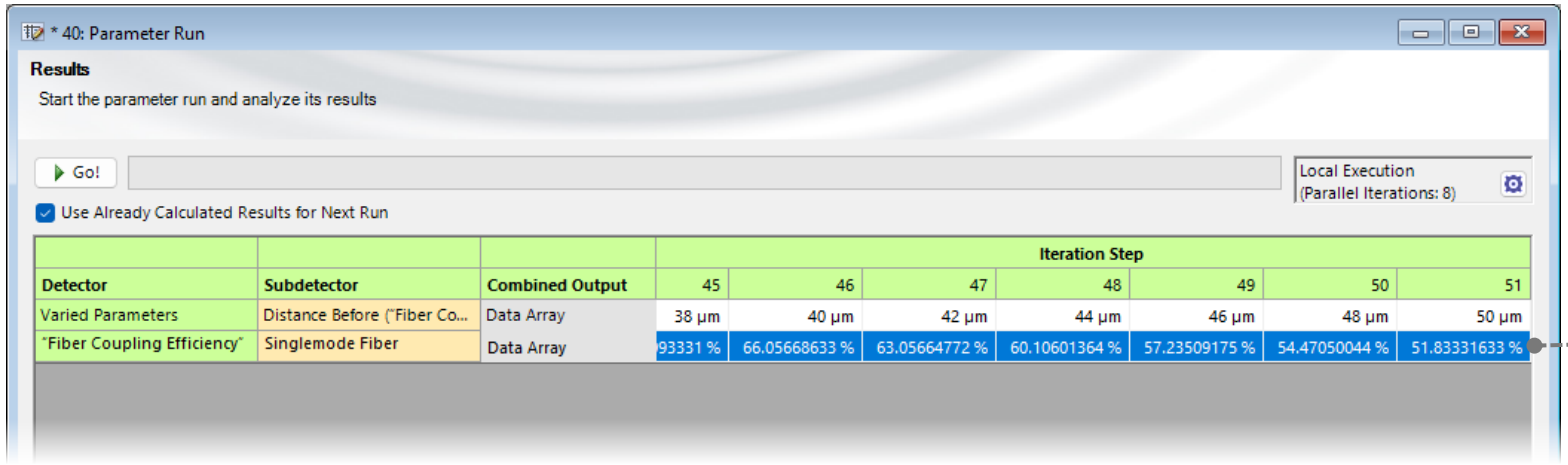
1D Cut

VirtualLab Fusion provides access to the full field information at any desired plane in the system.

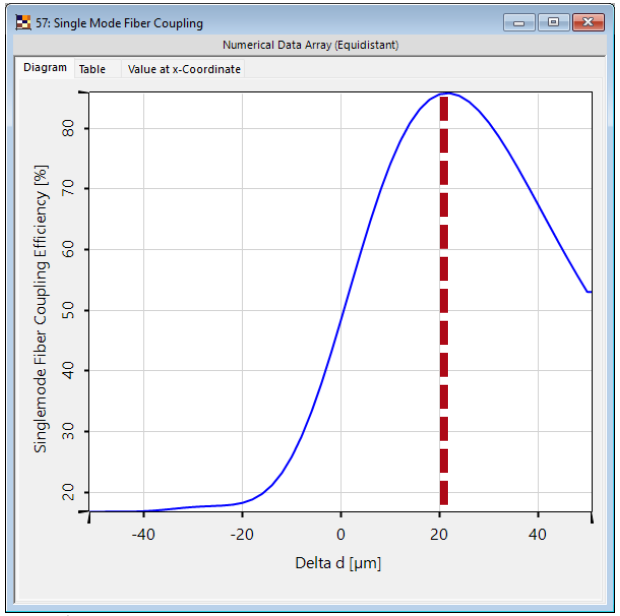
file: USC.0072_FiberIncouplingDistance_01_At Focal Distance Found by Ray Tracing.os

Optimal Working Distance by Parameter Run





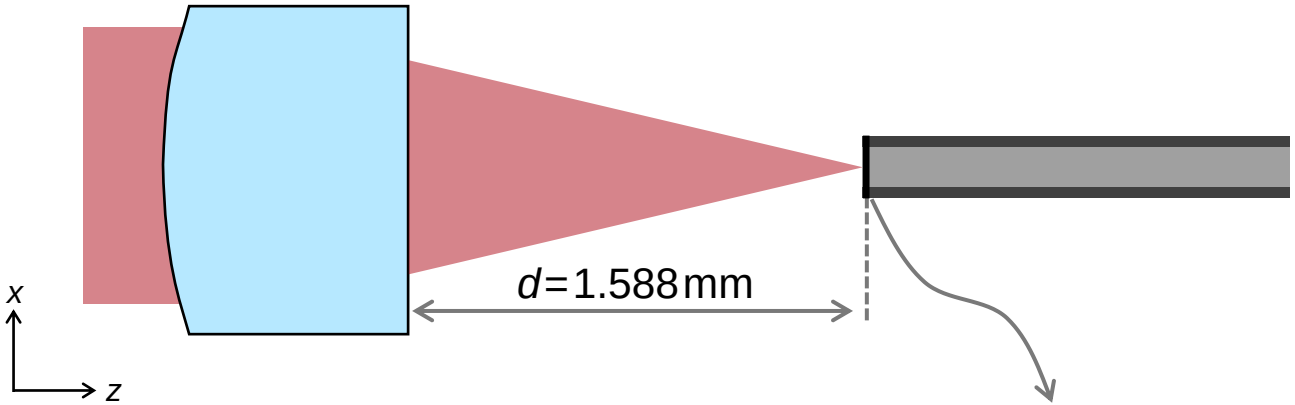
			Iteration Step						
Detector	Subdetector	Combined Output	45	46	47	48	49	50	51
Varied Parameters	Distance Before ("Fiber Co...	Data Array	38 µm	40 µm	42 µm	44 µm	46 µm	48 µm	50 µm
"Fiber Coupling Efficiency"	Singlemode Fiber	Data Array	93331 %	66.05668633 %	63.05664772 %	60.10601364 %	57.23509175 %	54.47050044 %	51.83331633 %



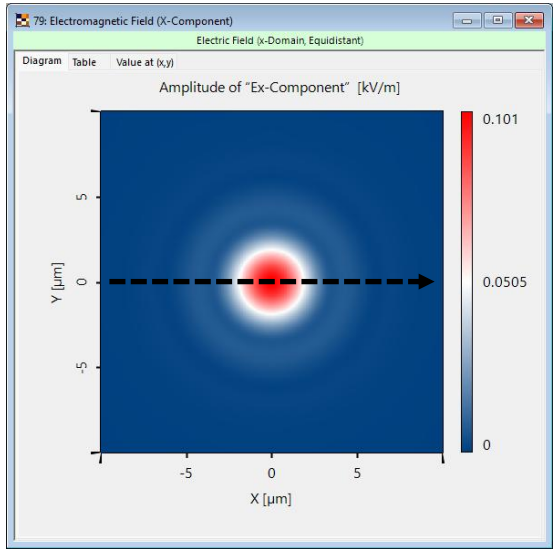
The optimal working distance found by evaluating the field is 1.588mm.

file: USC.0072_FiberIncouplingDistance_02_Searching Optimal Distance by Field Tracing.run

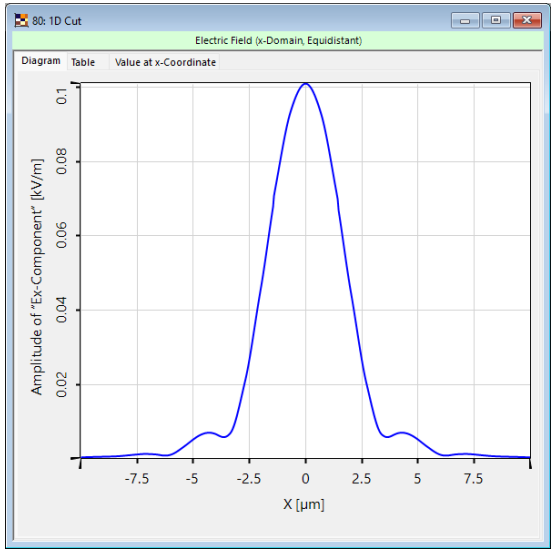
Field Evaluation at Ray-Optics Focal Distance



coupling efficiency $\eta = 85.82\,\%$
(overlap integral calculation)



Amplitude (x-component)



1D Cut

The focal spot with highest coupling efficiency has similar shape to the fiber mode.

file: USC.0072_FiberIncouplingDistance_03_At Optimal Distance Found by Field Tracing.os

Workflow Steps

Basic Workflow Steps

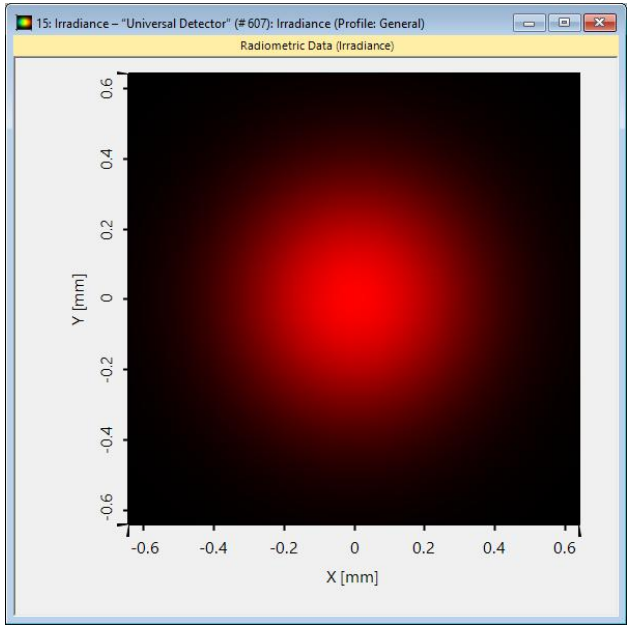
Source selection

System setup

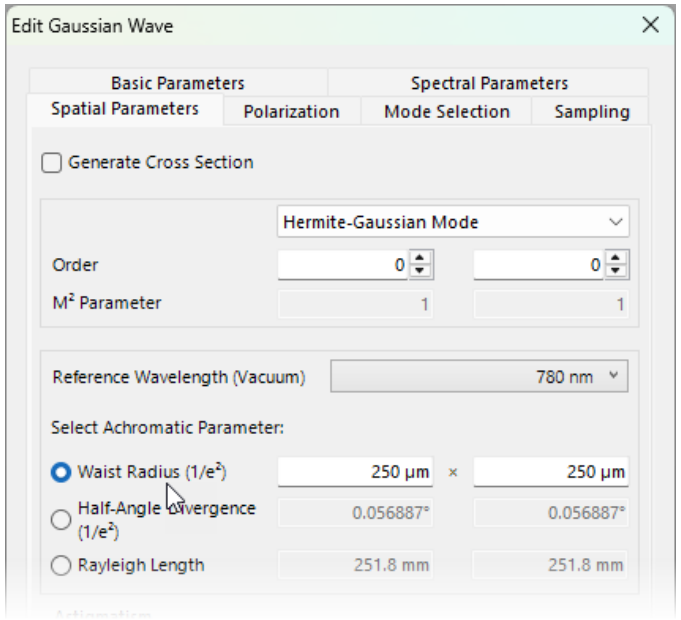
Detector selection

Getting it done in VirtualLab Fusion:

- Gaussian Wave



Irradiance of source



Source settings

Basic Workflow Steps

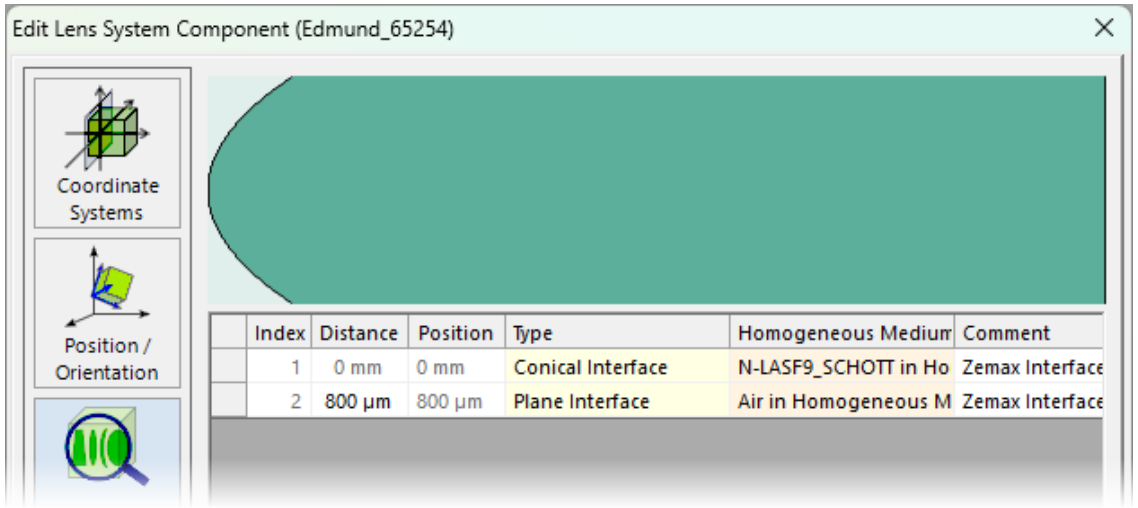
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Zemax import of lens group
- Position and orientation of elements in the optical setup



Imported Lens

Basic Workflow Steps

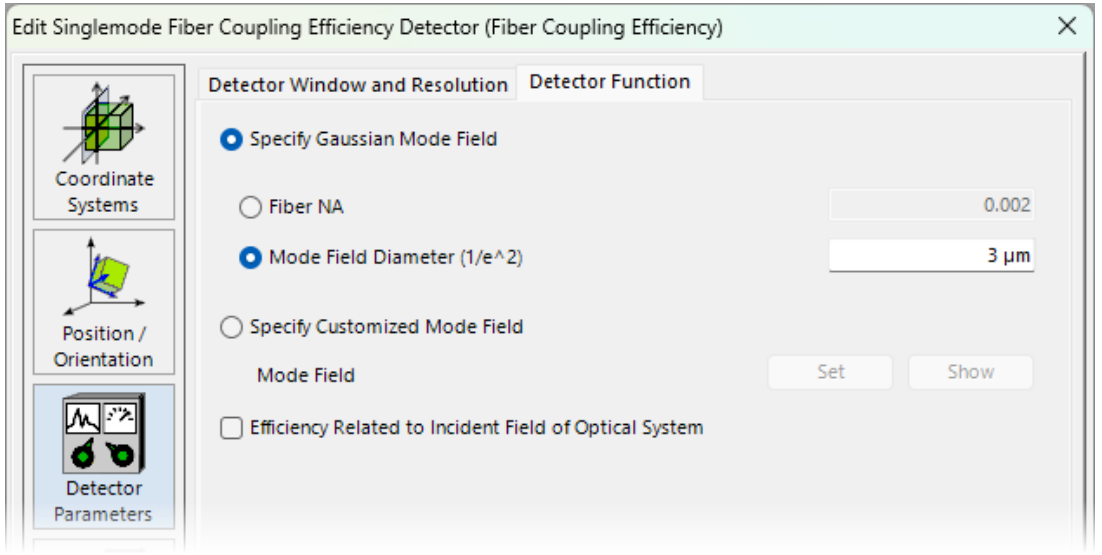
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Universal Detector
- Fiber Coupling Efficiency



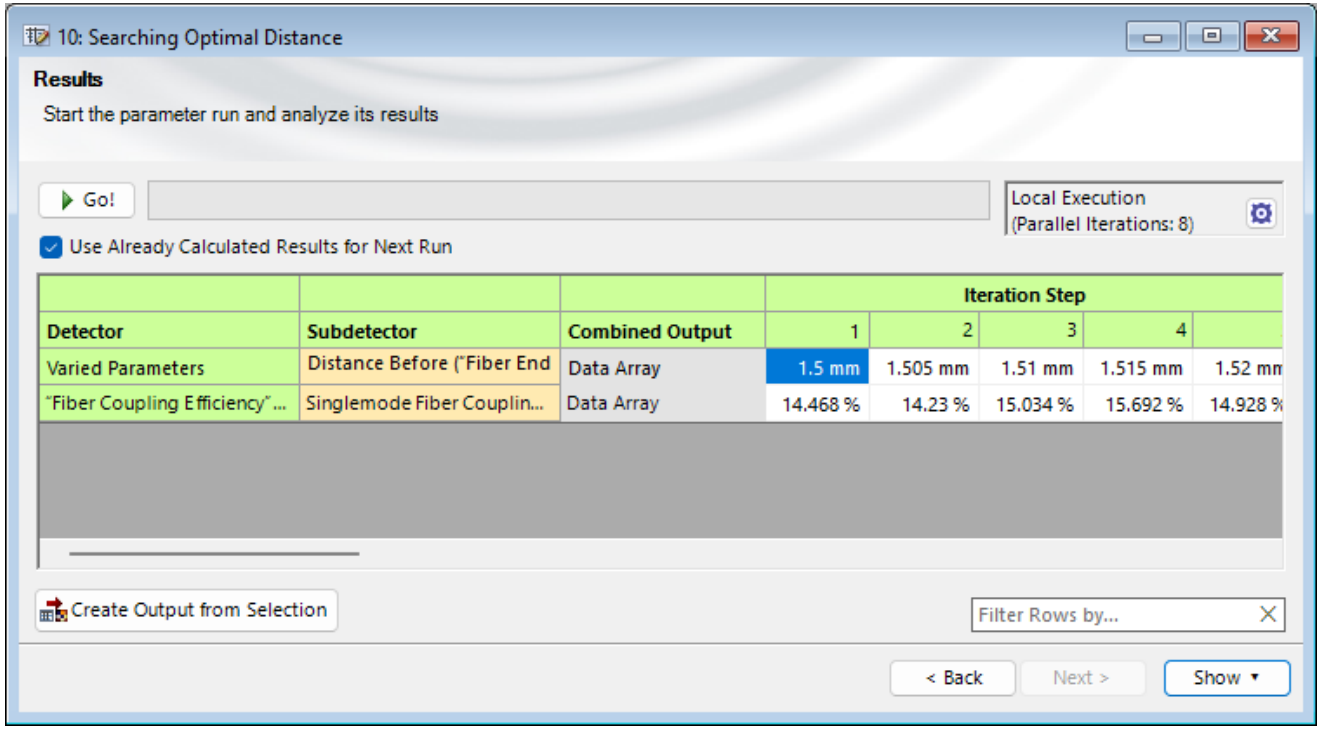
Singlemode Fiber Coupling Efficiency Detector

Specific Workflow Steps Related to Use Case

Perform parameter sweep

Getting it done in VirtualLab Fusion:

- Parameter Run document



Parameter Run document

Document Information

Title	Optimal Working Distance for Coupling Light into Single-Mode Fibers
Document code	USC.0072
Publication date	28.04.2025
Required packages	-
Software version	2024.1 (Build 2.74)*
Category	Use Case
Further reading	- Comparison of Different Lenses for Fiber Coupling - Parametric Optimization of Fiber Coupling Lens

* *The files attached to this document require the specific version or later.*