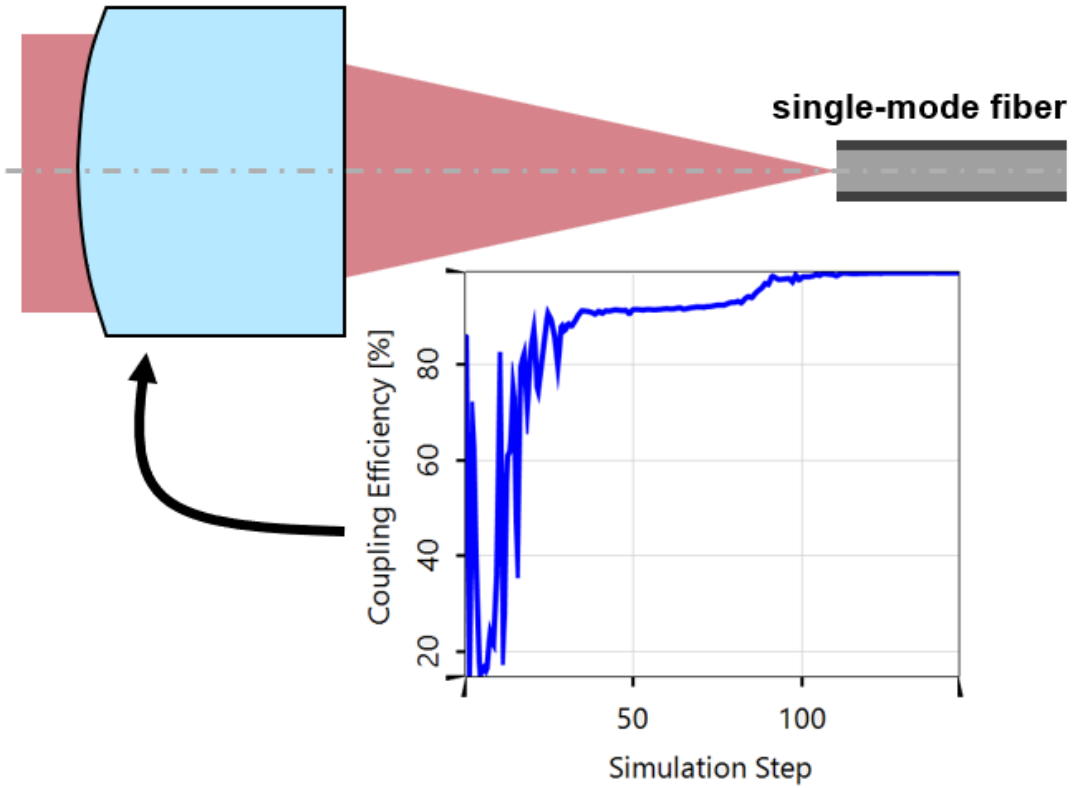
Parametric Optimization of Fiber Coupling Lens

Abstract



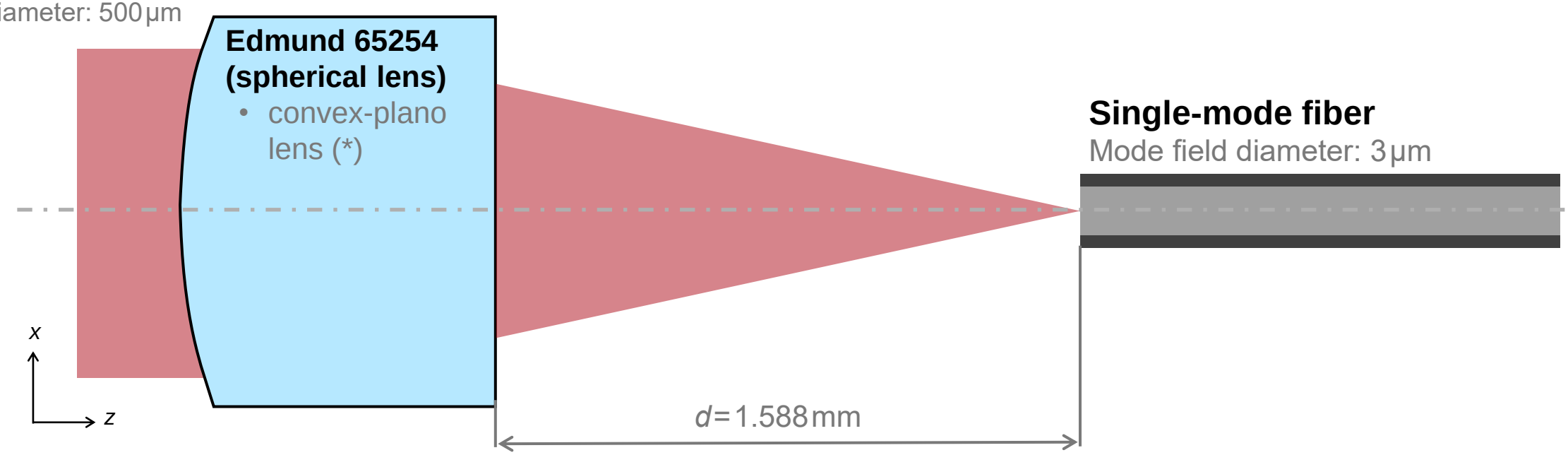
Using the simulation and optimization capabilities of VirtualLab Fusion, we present the design of a convex-plano lens with a conical surface for efficient light coupling into a single-mode fiber. To evaluate the performance, the fiber incoupling efficiency—quantified by the overlap integral—is compared between a commercially available spherical lens and the optimized conical lens.

Application Scenario

Application Scenario: Initial System

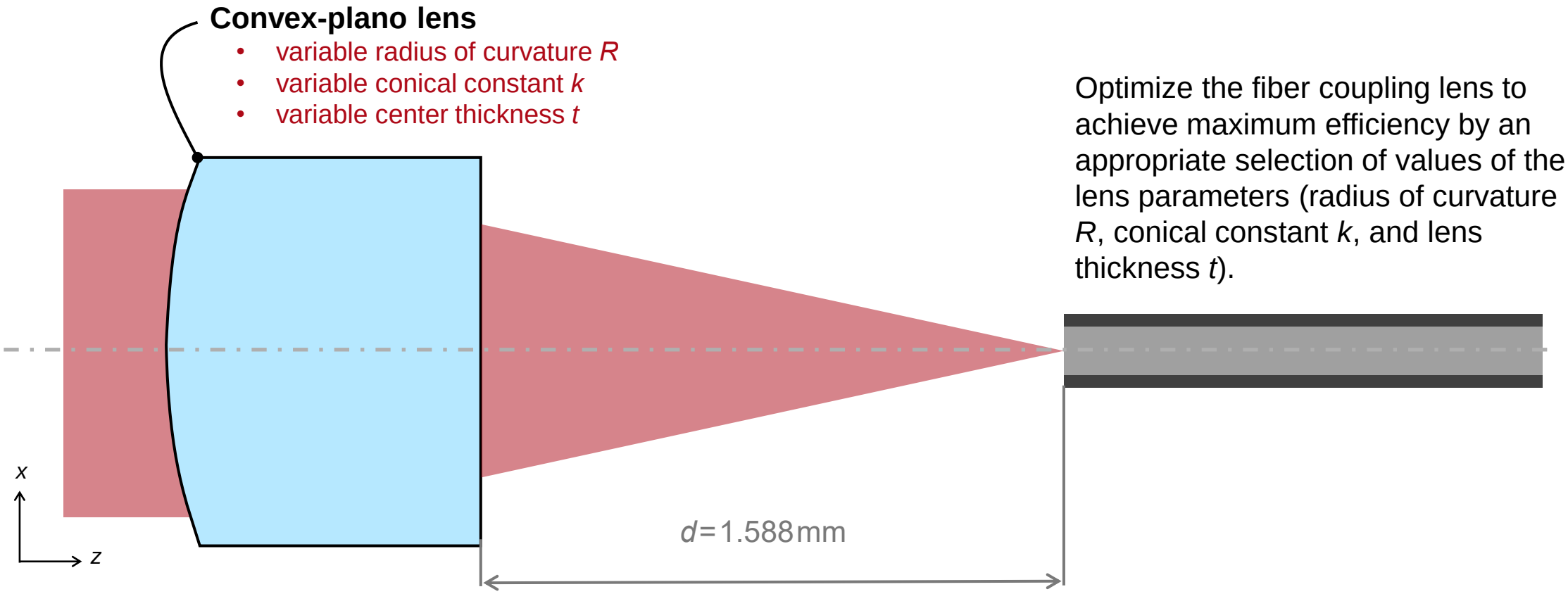
Input field

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



(*) For the design of the coupling lens, please see: Parametric Optimization of Fiber Coupling Lens

Application Scenario: Task

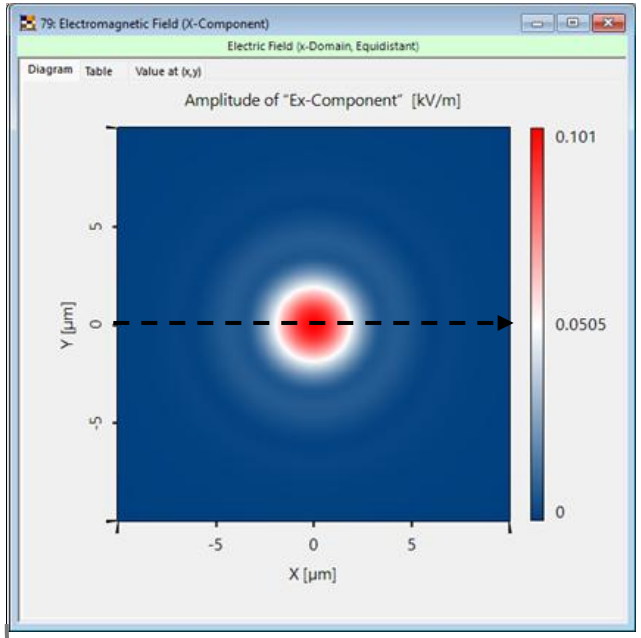


Optimize the fiber coupling lens to achieve maximum efficiency by an appropriate selection of values of the lens parameters (radius of curvature *R*, conical constant *k*, and lens thickness *t*).

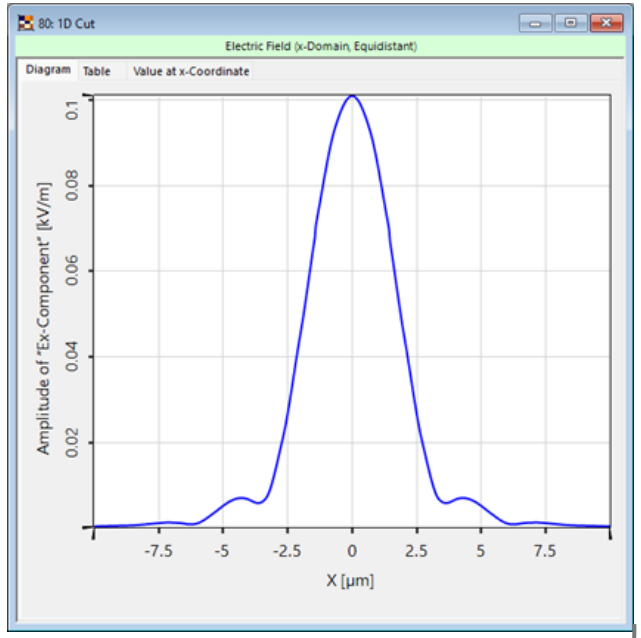
Simulation Results

Evaluation of Initial Lens

Amplitude (x-component)

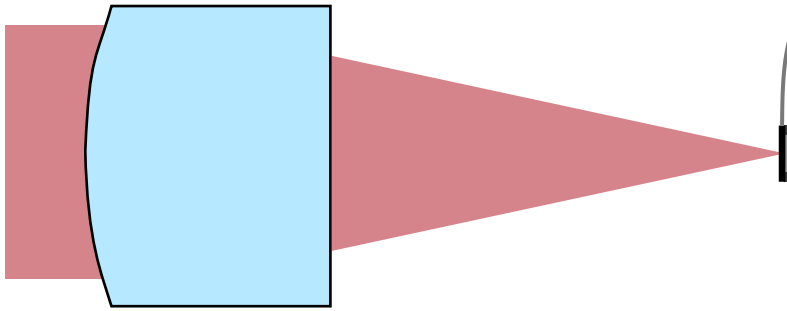


1D cut



Initial lens parameters

- radius of curvature $R = 1.7\text{mm}$
- conical constant $k = 0$
- lens thickness $t = 0.8\text{mm}$



coupling efficiency $\eta = 85.8\%$
(overlap integral calculation)

The coupling efficiency obtained from the initial spherical lens is not optimal, due to mismatch between the focal spot of the lens and the propagating mode of the fiber.

file: USC.0051_FiberLensOptimization_01_Initial lens.os

Parametric Optimization

Initial lens parameters

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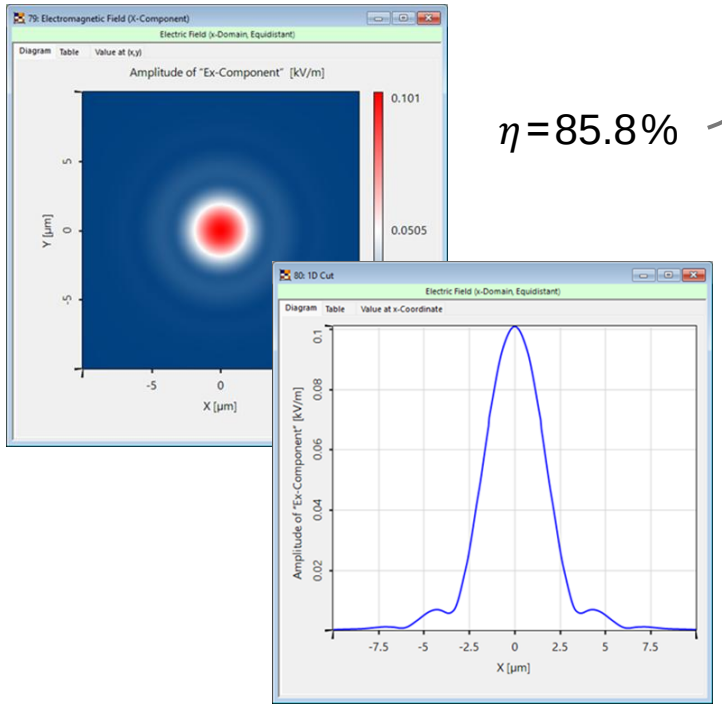
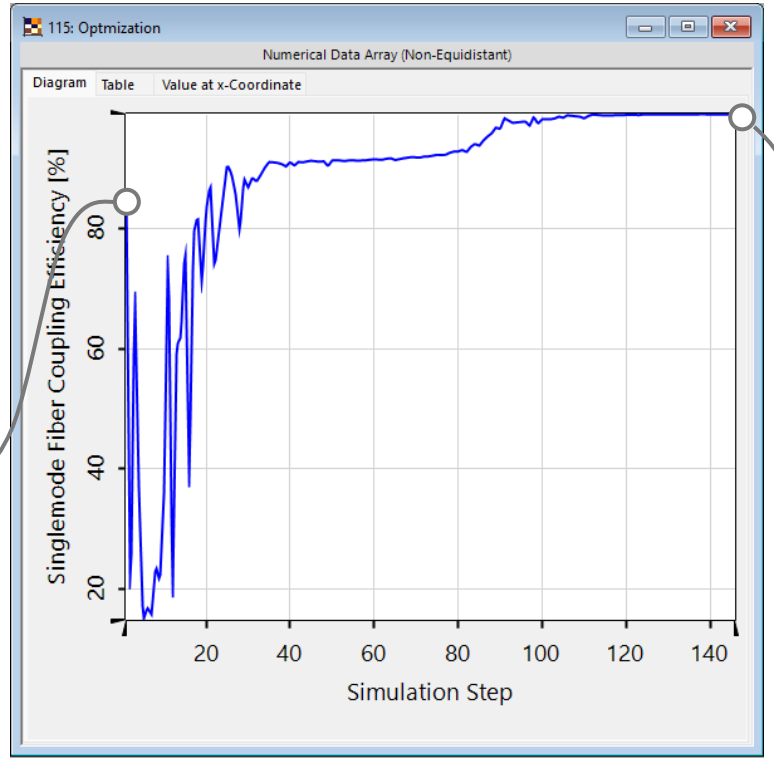
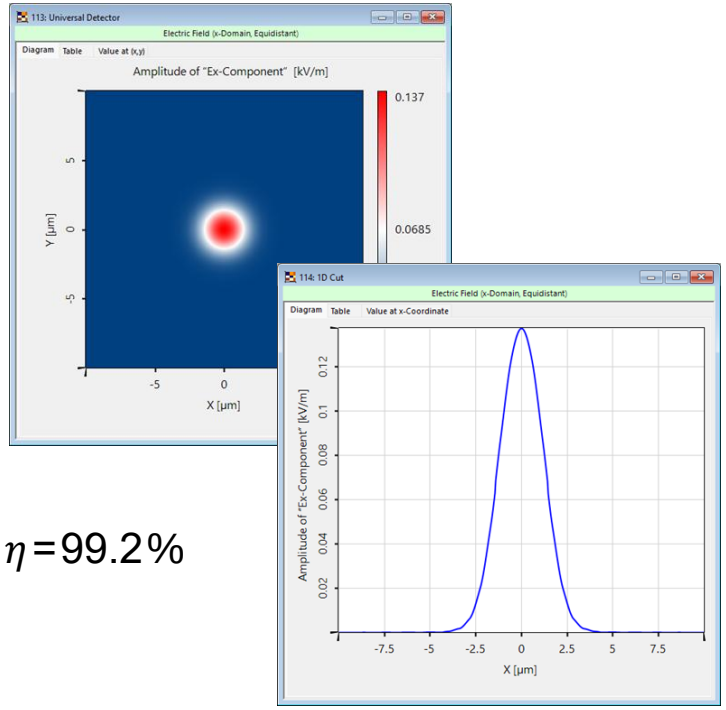


$\eta = 85.8\%$



Parametric optimization of coupling efficiency with downhill simplex algorithm

$\eta = 99.2\%$



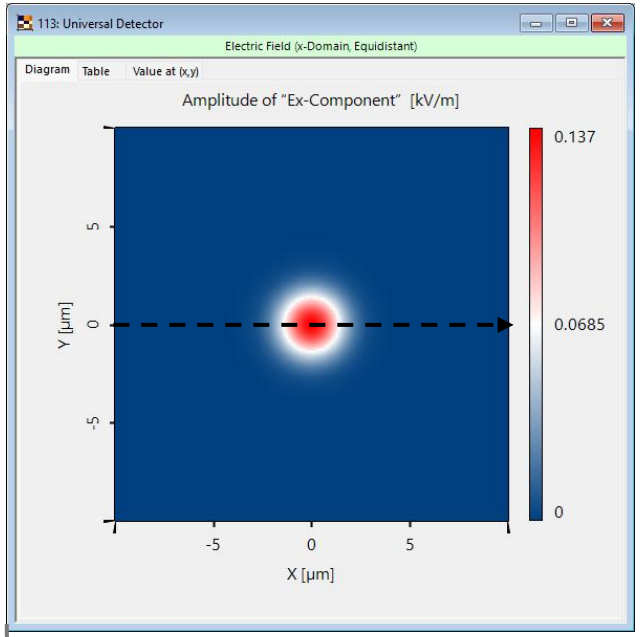
Optimized lens parameters

- radius of curvature $R = 1.608\text{mm}$
- conical constant $k = -0.7139$
- lens thickness $t = 0.6311\text{mm}$

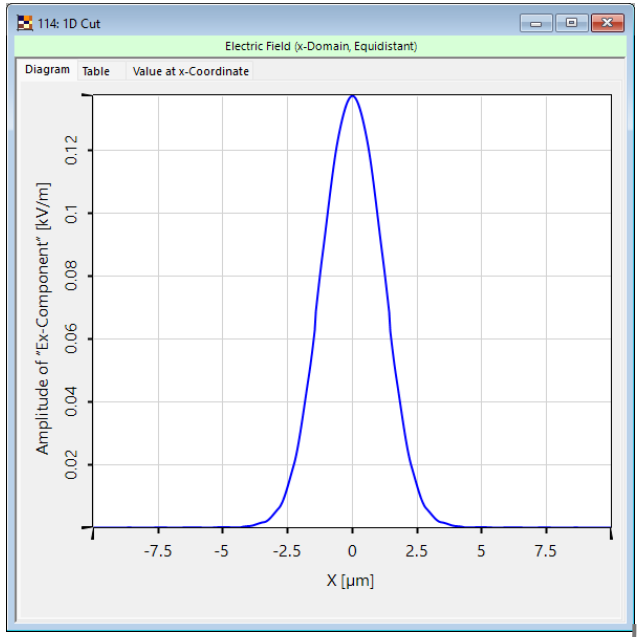
file: USC.0051_FiberLensOptimization_02_Parametric optimization.opt

Evaluation of Optimized Lens

Amplitude (x-component)



1D cut



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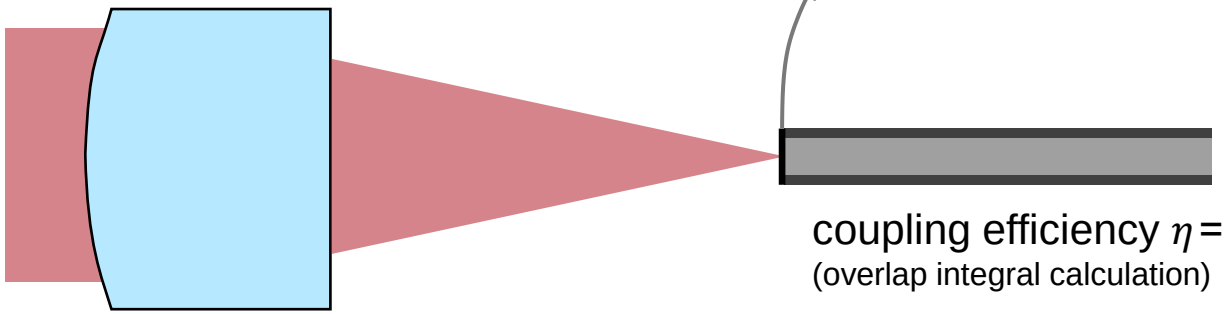


coupling efficiency η = 99.2%
(overlap integral calculation)

The coupling efficiency increases to almost the ideal theoretical value after optimization of the lens.

file: USC.0051_FiberLensOptimization_03_Optimized Lens.os

Workflow Steps

Basic Workflow Steps

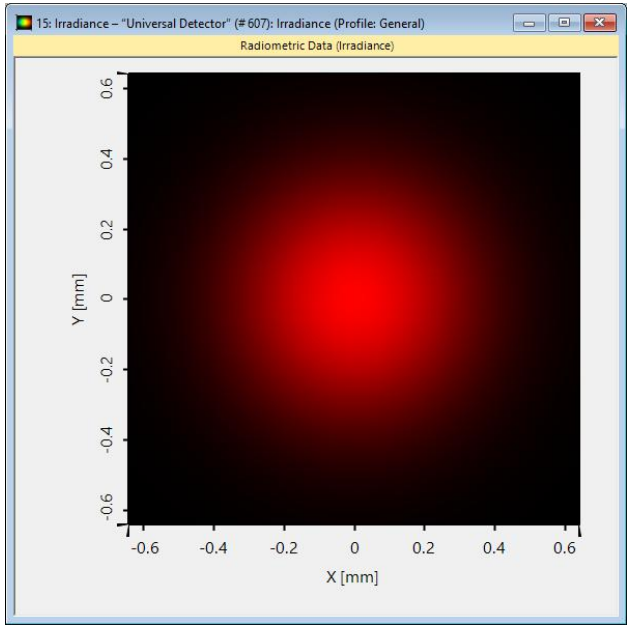
Source selection

System setup

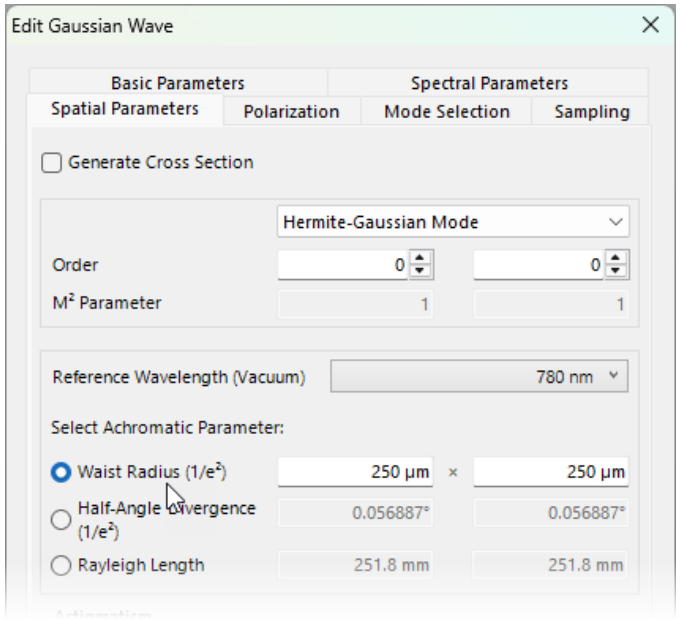
Detector selection

Getting it done in VirtualLab Fusion:

- Gaussian Wave



Irradiance of source



Source settings

Basic Workflow Steps

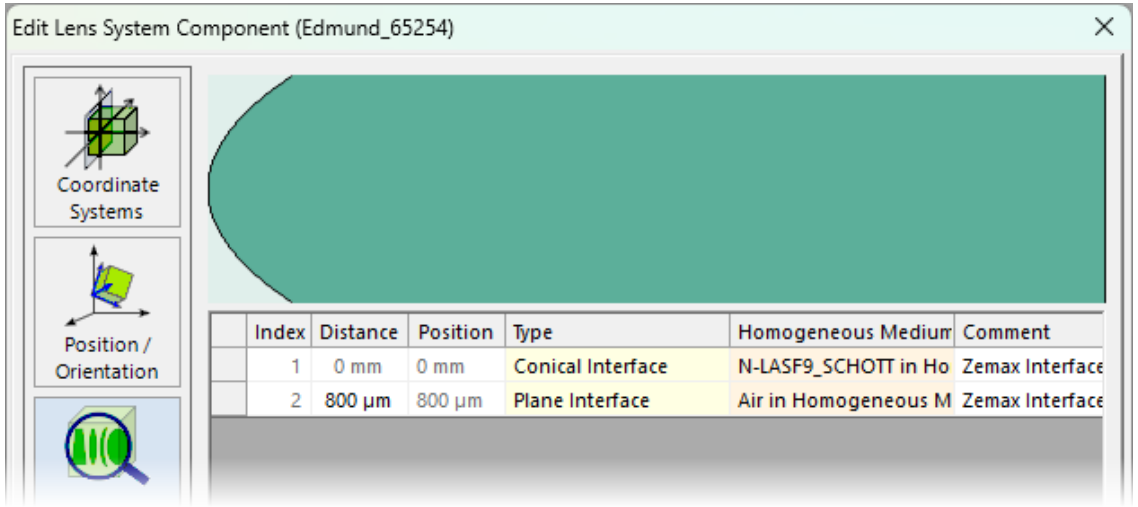
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Zemax import of lens group
- Position and orientation of elements in the optical setup
- Find optimal working distance for fiber



Imported Lens

Basic Workflow Steps

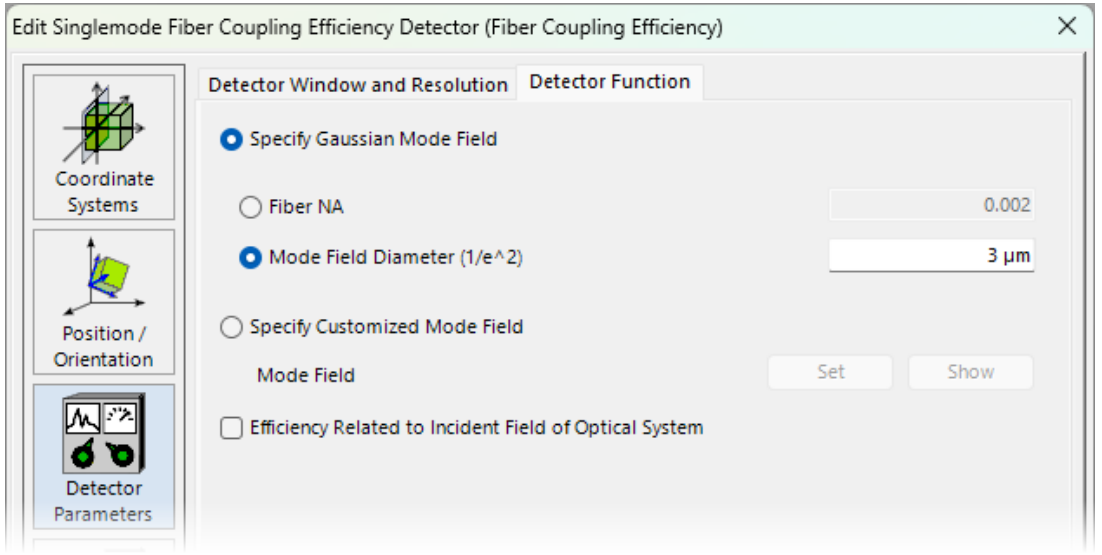
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Universal Detector
- Fiber Coupling Efficiency



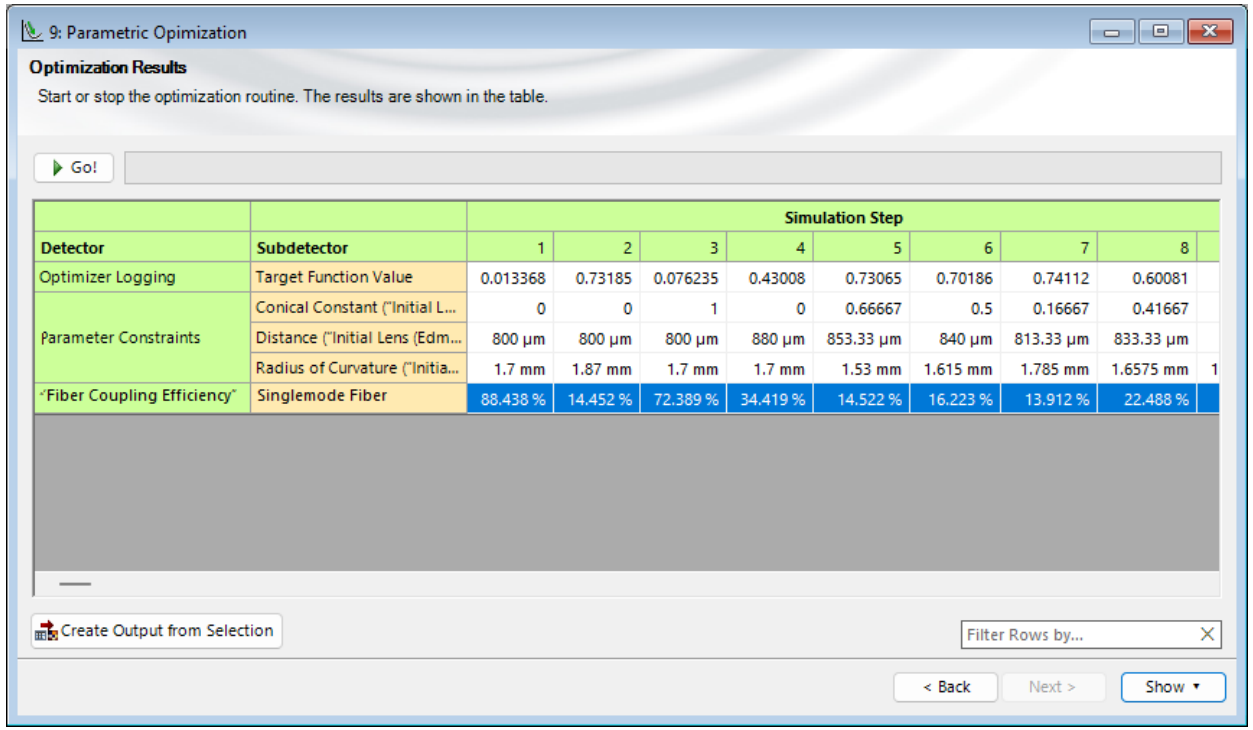
Singlemode Fiber Coupling Efficiency Detector

Specific Workflow Steps Related to Use Case

Perform parameter sweep

Getting it done in VirtualLab Fusion:

- Parametric Optimization document



Parametric Optimization document

Document Information

Title	Parameteric Optimization of Fiber Coupling Lens
Document code	USC.0051
Publication date	25.04.2025
Required packages	-
Software version	2024.1 (Build 2.74)*
Category	Use Case
Further reading	• Optimal Working Distance for Coupling Light into Single-Mode Fibers • Comparison of Different Lenses for Fiber Coupling • Introduction to the Parametric Optimization Document

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