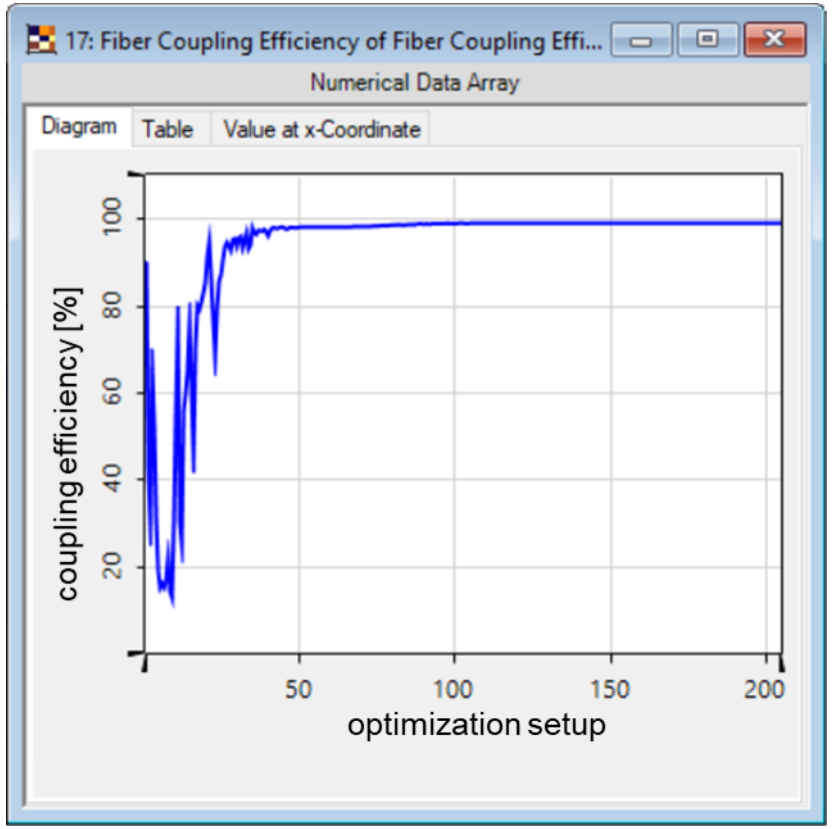
Parametric Optimization of Fiber Coupling Lenses

Abstract



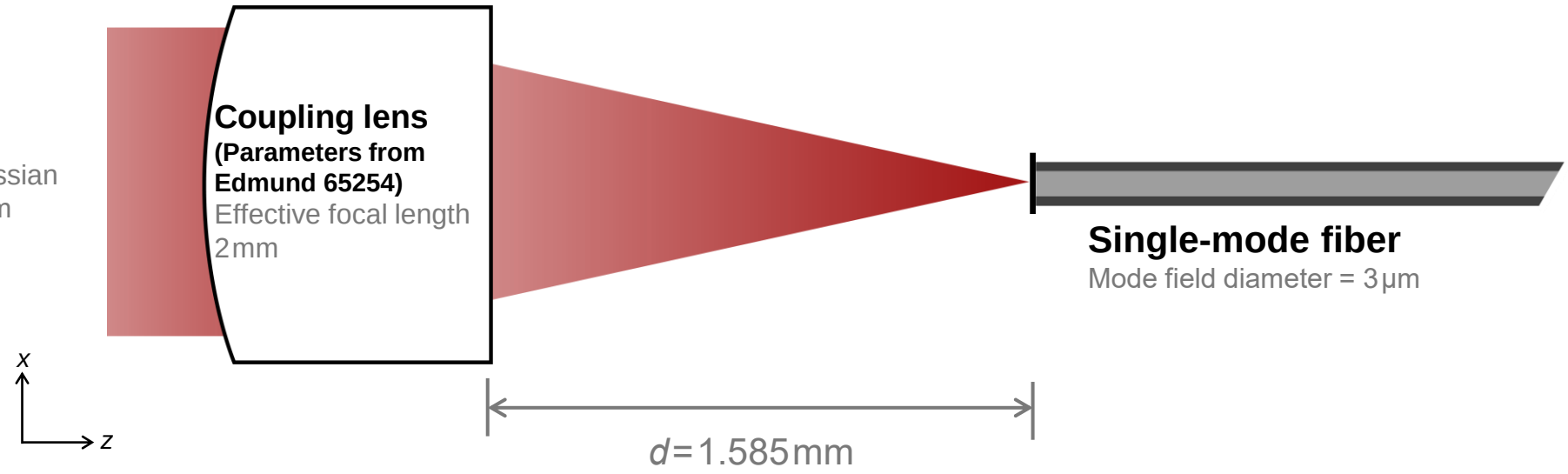
Fibers are some of the most versatile components in modern optics. One of their most valued characteristics is their capacity to transport optical energy with very low losses across vast distances (even several kilometers). On the flip side, coupling light into a fiber in a way that achieves as high an efficiency as possible is often a very delicate endeavor: among other things, the fiber coupling lens must be well designed to ensure that the focal spot matches the propagating modes of the fiber as closely as possible. With the fast physical optics simulation and the parametric optimization in VirtualLab Fusion, we show the design of a plano-convex lens with a conical surface for the task of coupling light into a single-mode fiber.

Application Scenario

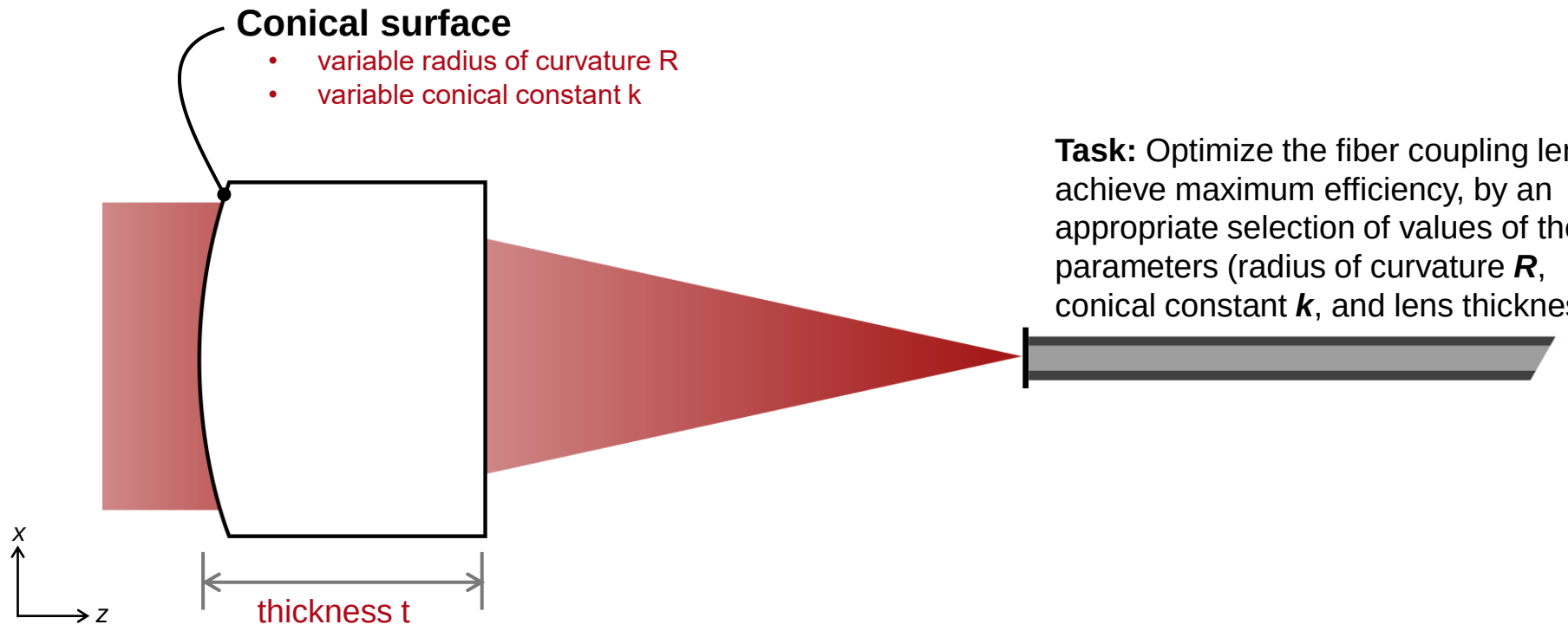
Application Scenario: System

Input field

- Fundamental Gaussian
- Wavelength 780 nm
- Diameter 660 µm



Application Scenario: Design Task

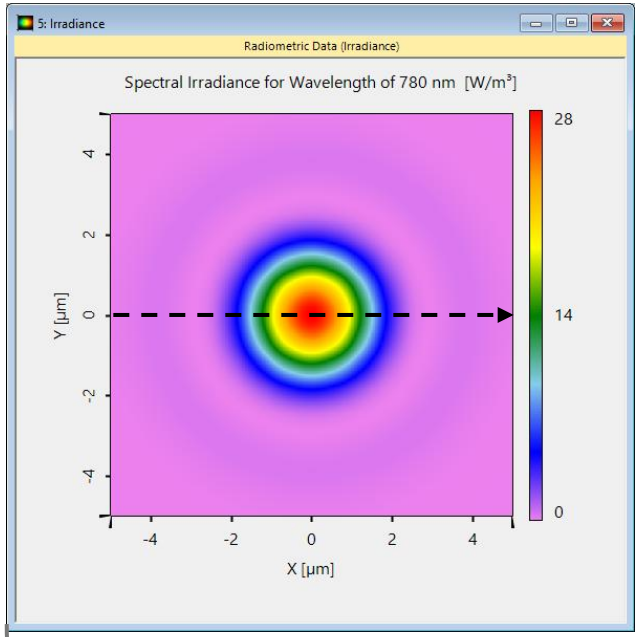


Task: Optimize the fiber coupling lens to achieve maximum efficiency, by an appropriate selection of values of the lens parameters (radius of curvature ***R***, conical constant ***k***, and lens thickness ***t***).

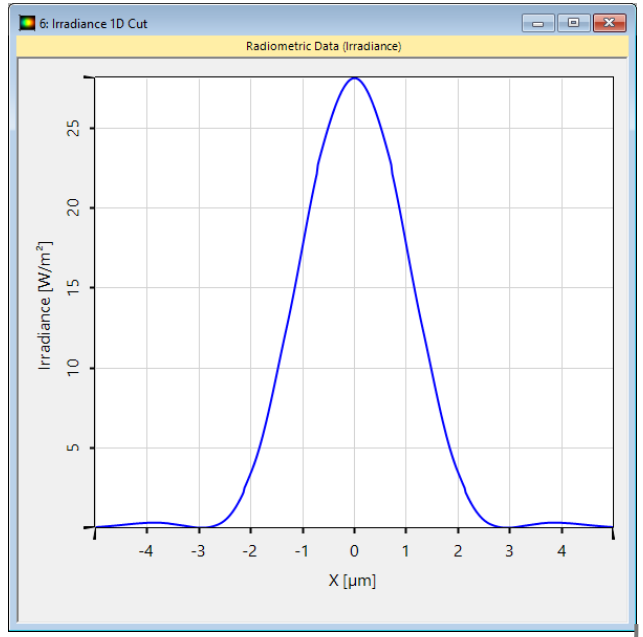
Simulation Results

Evaluation of Initial Lens

Irradiance

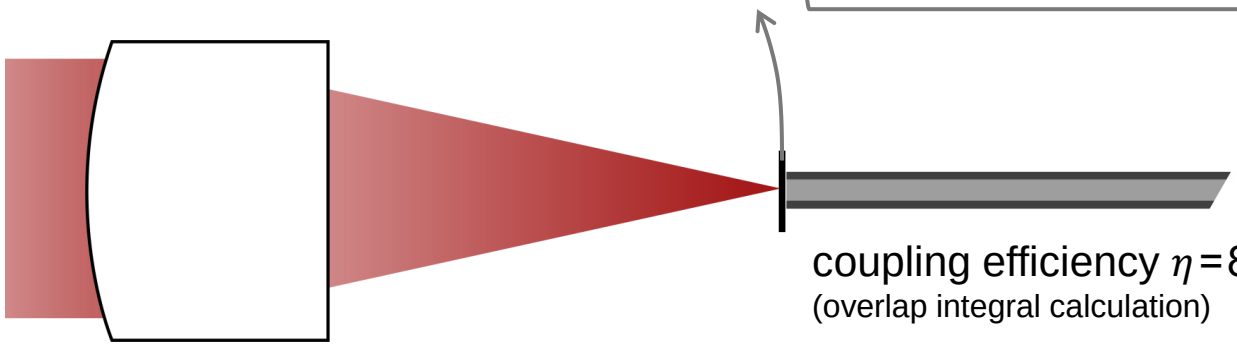


Irradiance 1D cut



Initial lens parameters

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



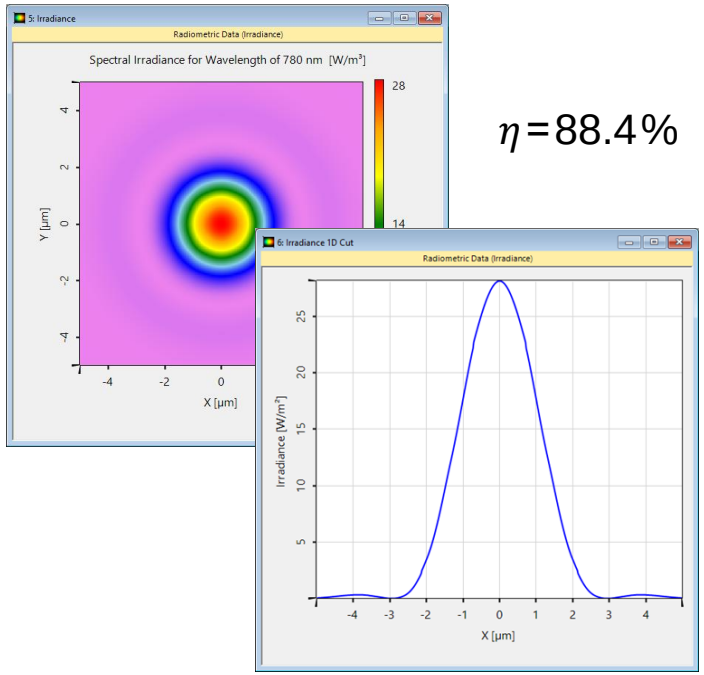
coupling efficiency $\eta = 88.4\%$
(overlap integral calculation)

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.

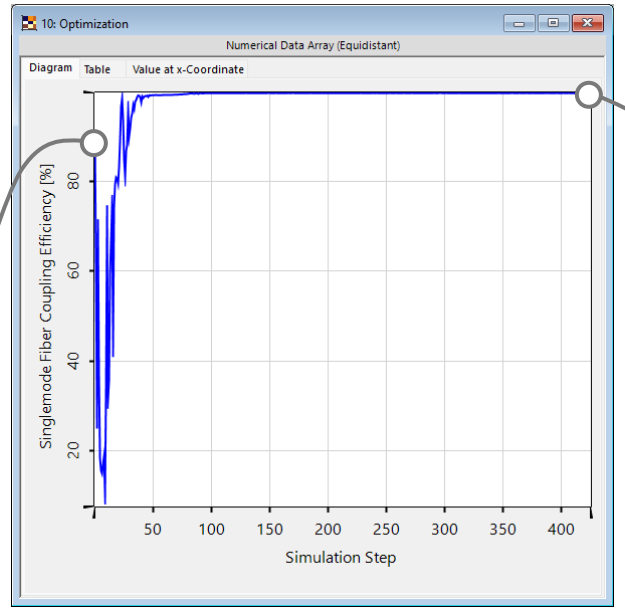
Parametric Optimization

Initial lens parameters

- radius of curvature R=1.7mm
- conical constant k=0
- lens thickness t=0.8mm

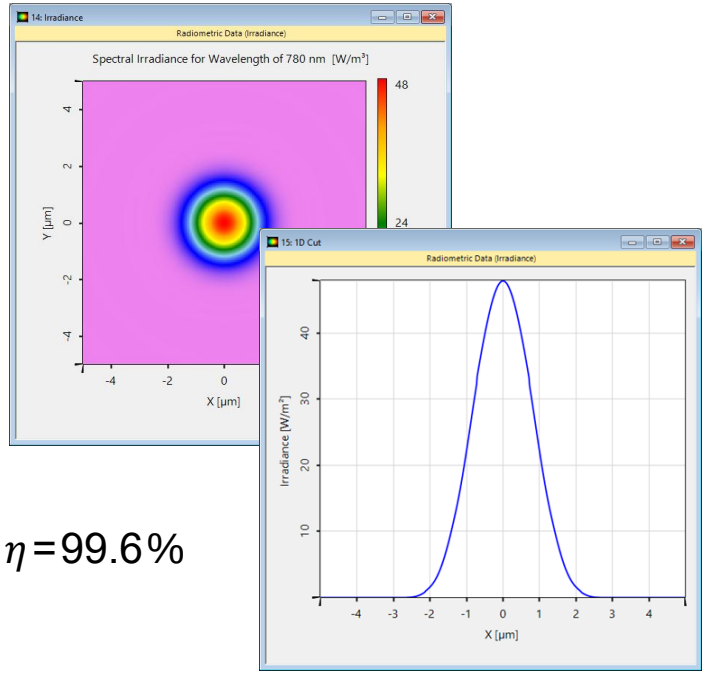


η=88.4%



parametric optimization of coupling efficiency with downhill simplex algorithm

η=99.6%

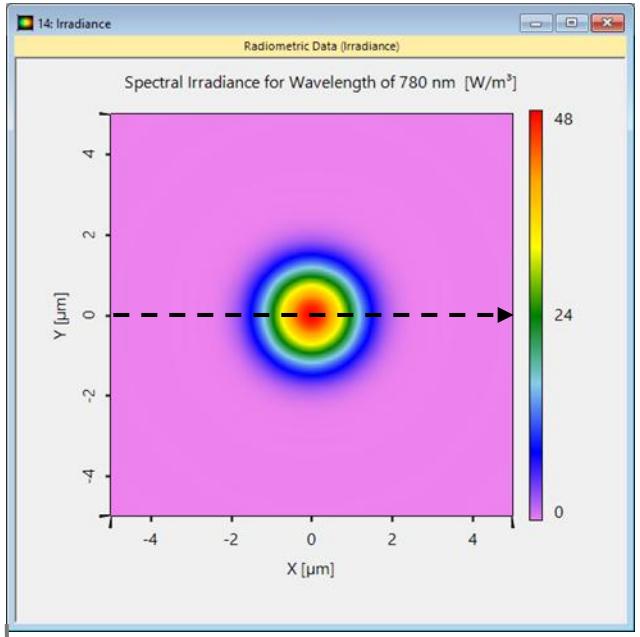


optimized lens parameters

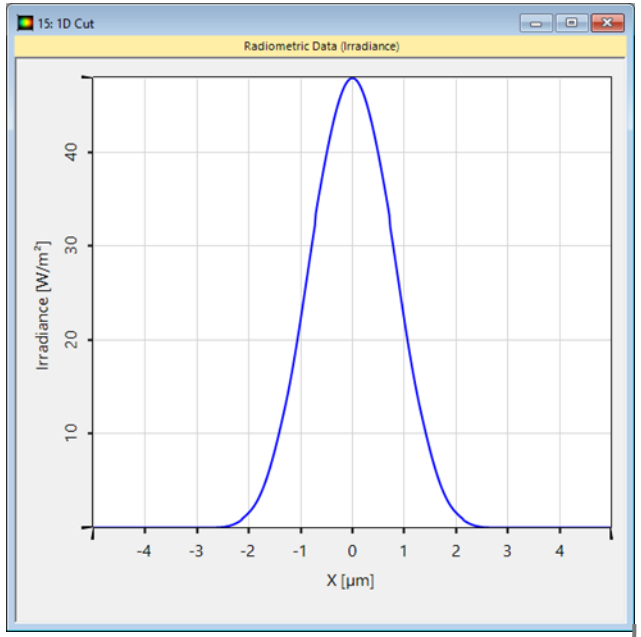
- radius of curvature R=1.608mm
- conical constant k=-0.7139
- lens thickness t=0.6311mm

Evaluation of Optimized Lens

Irradiance

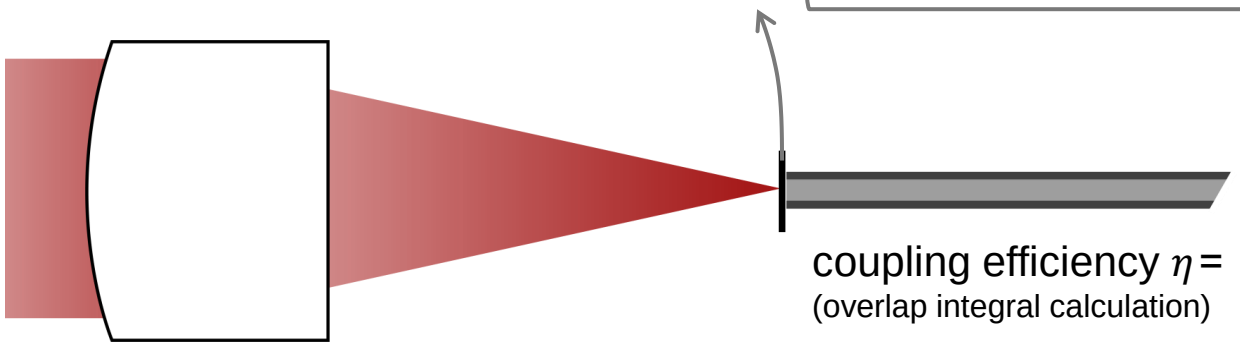


Irradiance 1D cut



Optimized lens parameters

- radius of curvature ***R***=1.608mm
- conical constant ***k***=-0.7139
- lens thickness ***t***=0.6311mm



coupling efficiency η = 99.6%
(overlap integral calculation)

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

Workflow Steps

Basic Workflow Steps

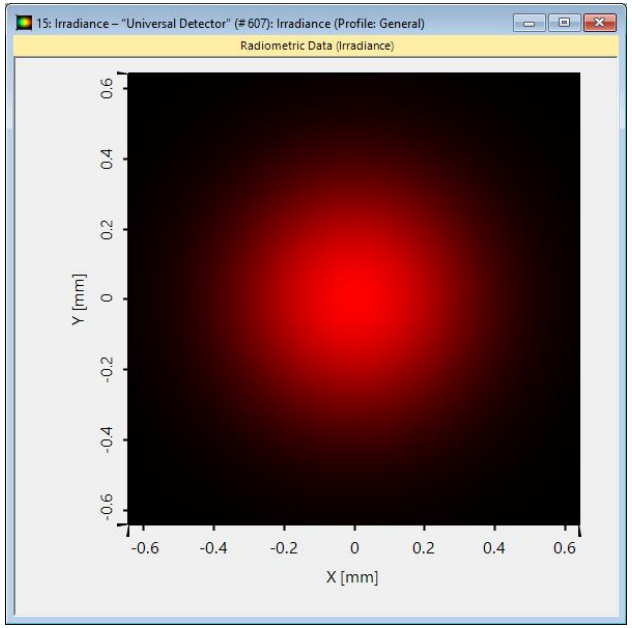
Source selection

System setup

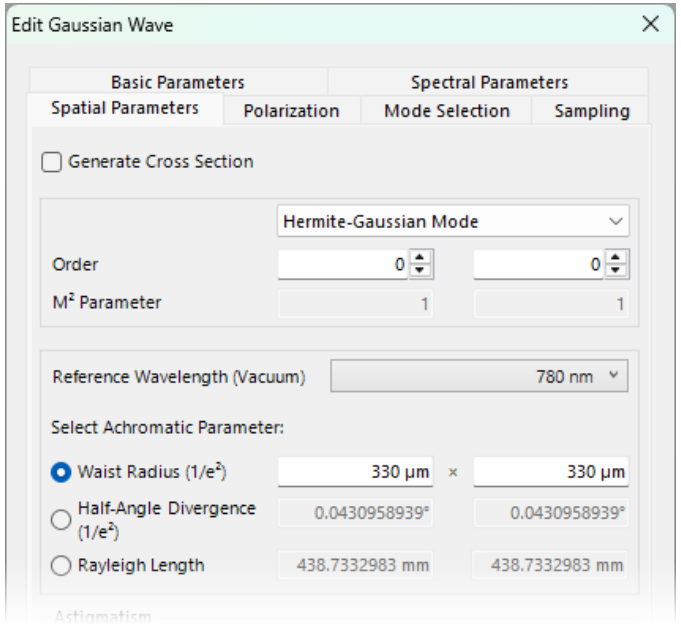
Detector selection

Getting it done in VirtualLab Fusion:

- Gaussian Wave



Irradiance of source



Source settings

Basic Workflow Steps

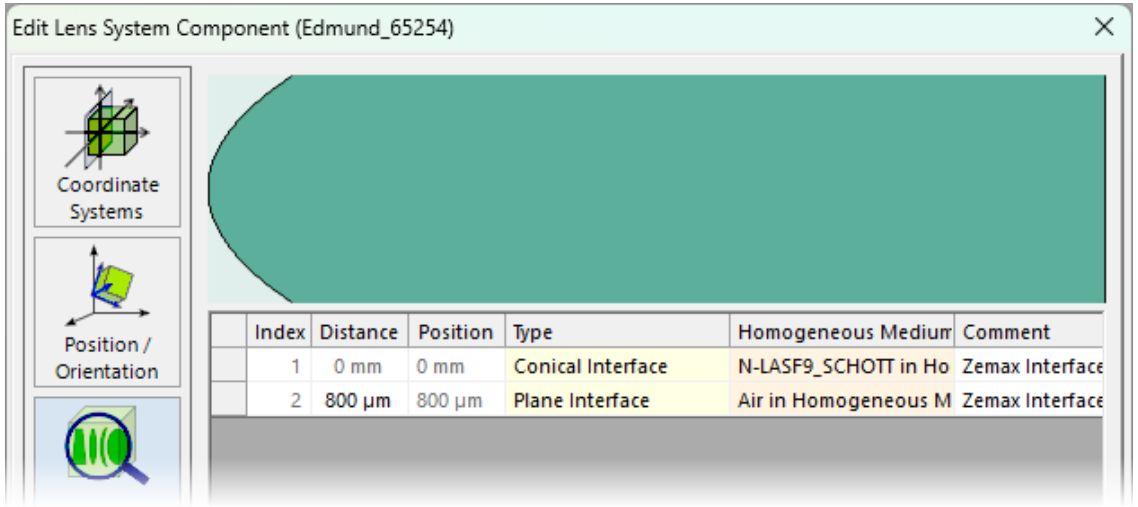
Source selection

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

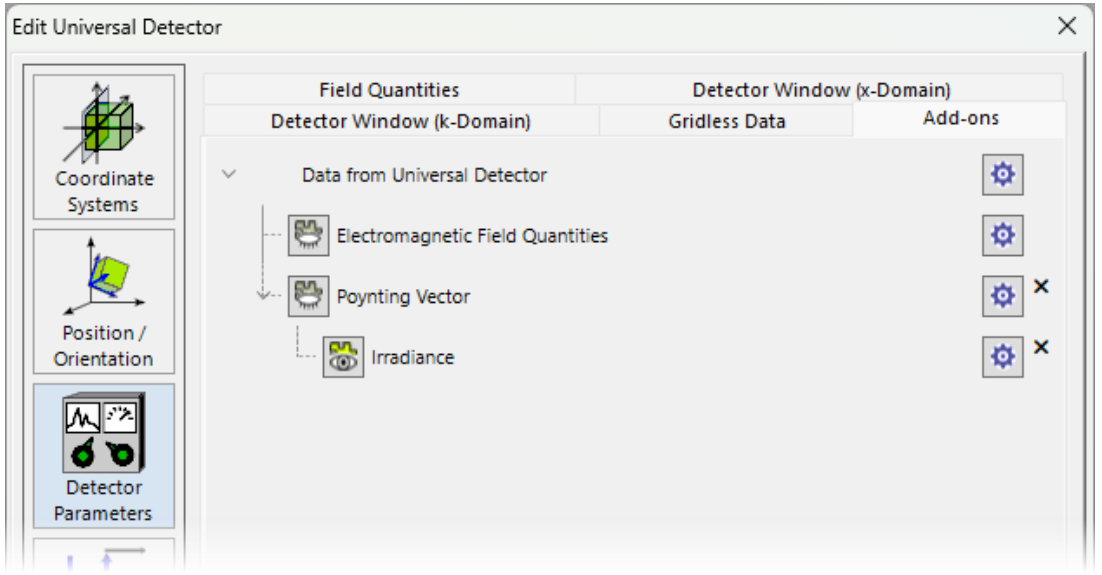
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Universal Detector
- Single Mode Fiber Coupling Efficiency



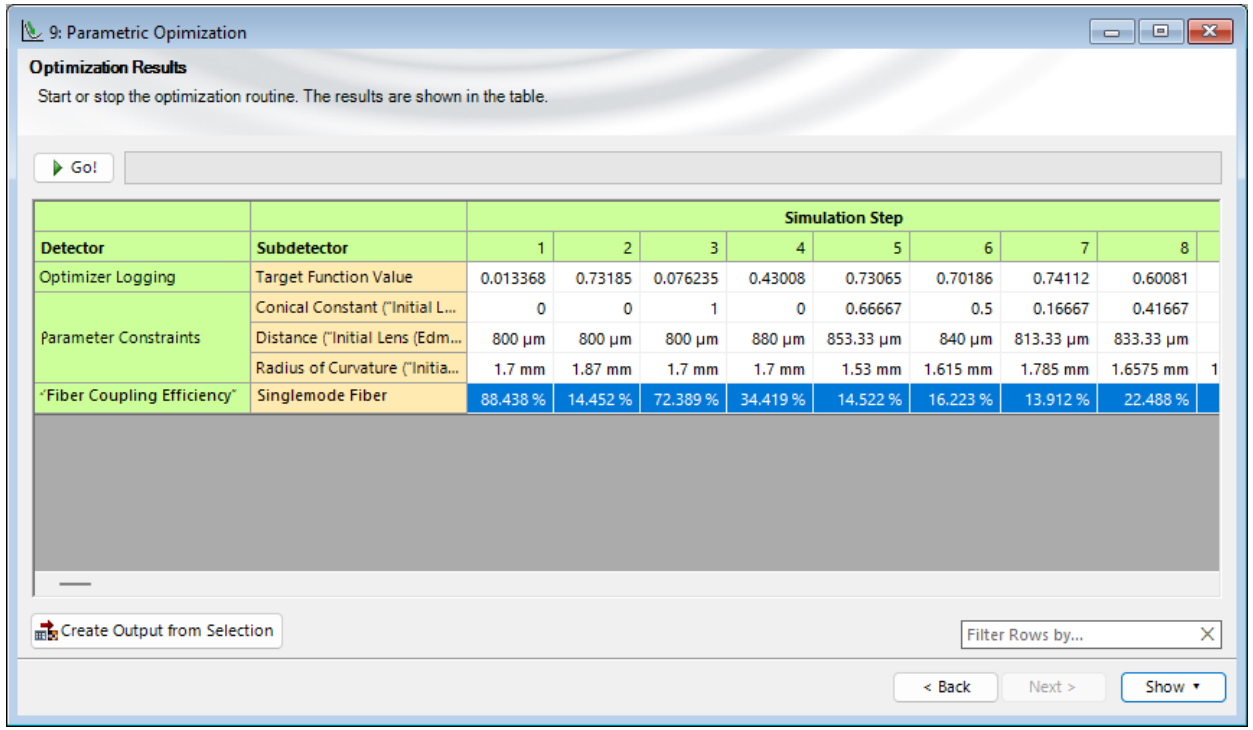
Detector add-on selection

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.*