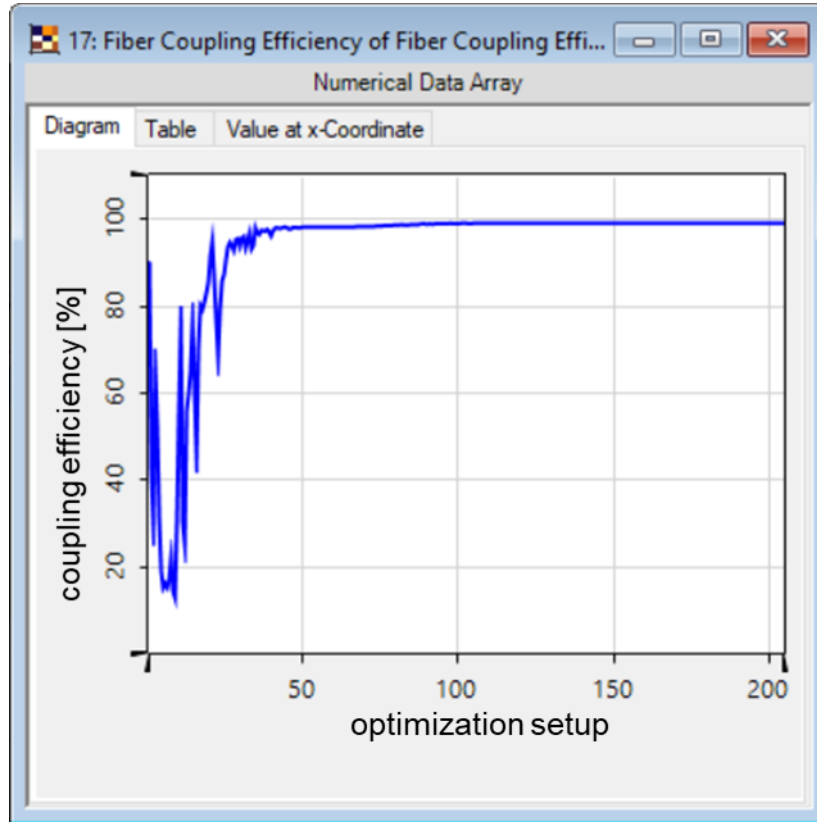


Parametric Optimization of Fiber Coupling Lenses

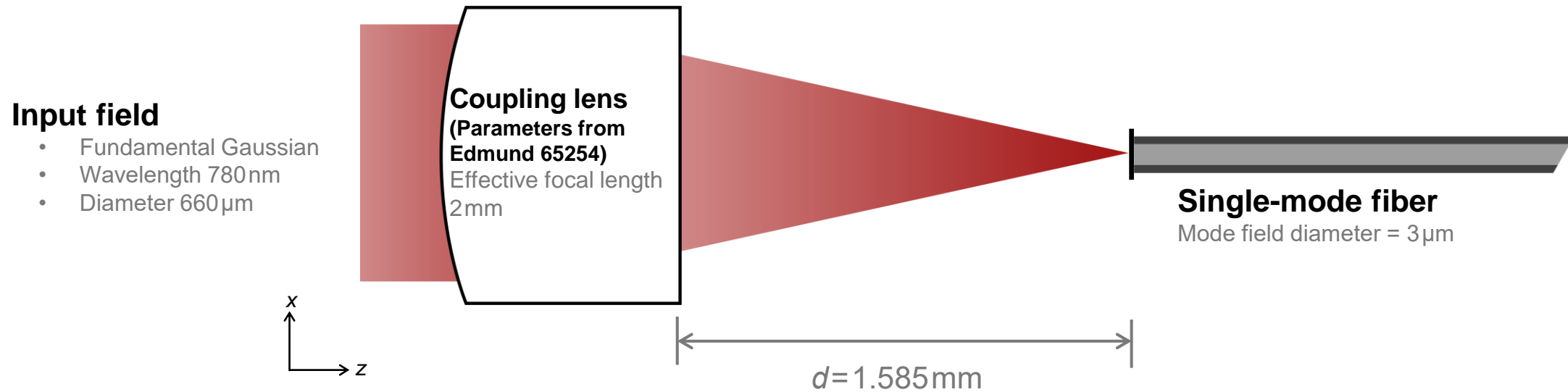
Abstract



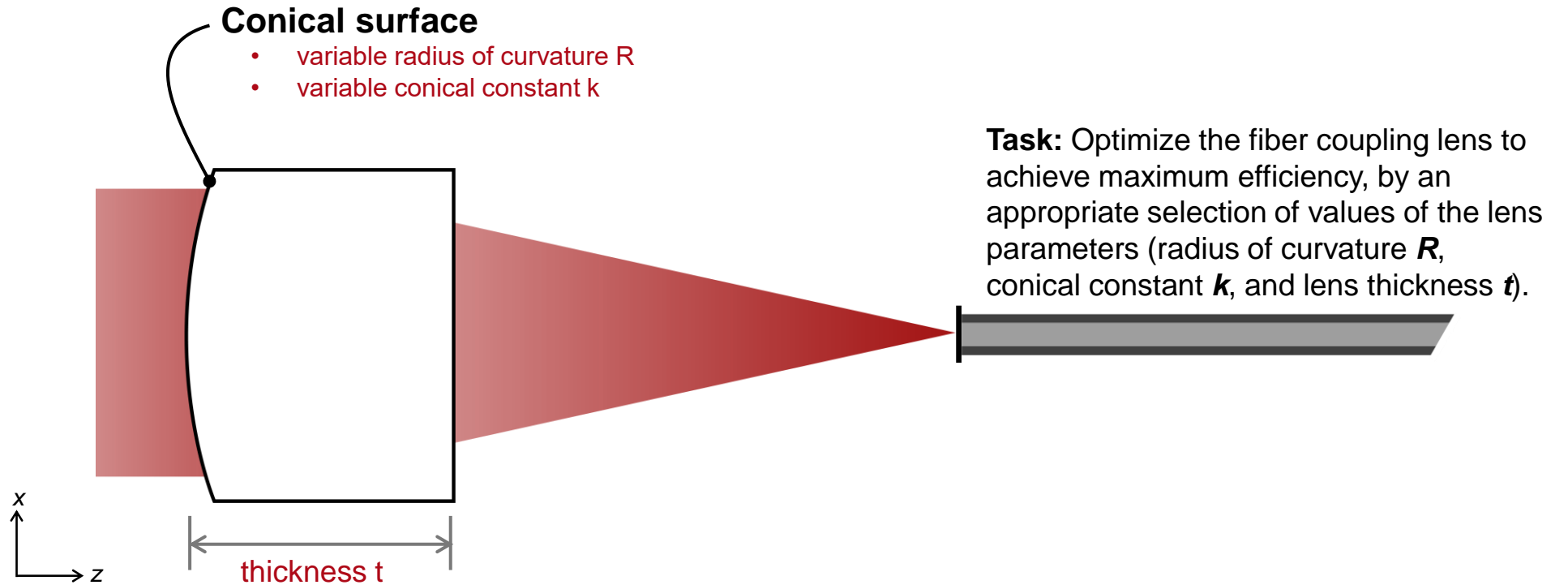
Fibers are some of the most versatile components in modern optics. One of their most valued characteristics is their capacity to transport optical energy with very low losses across vast distances (even several kilometers). On the flip side, coupling light into a fiber in a way that achieves as high 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



Application Scenario: Design Task

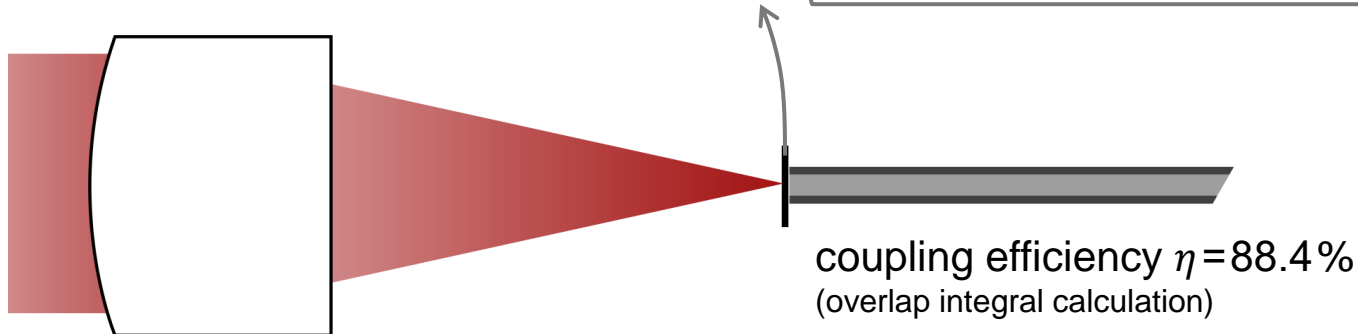


Simulation Results

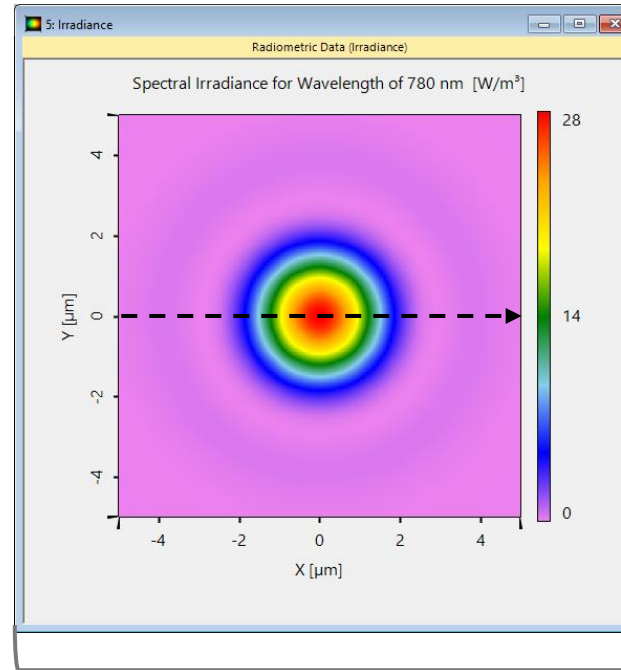
Evaluation of Initial Lens

Initial lens parameters

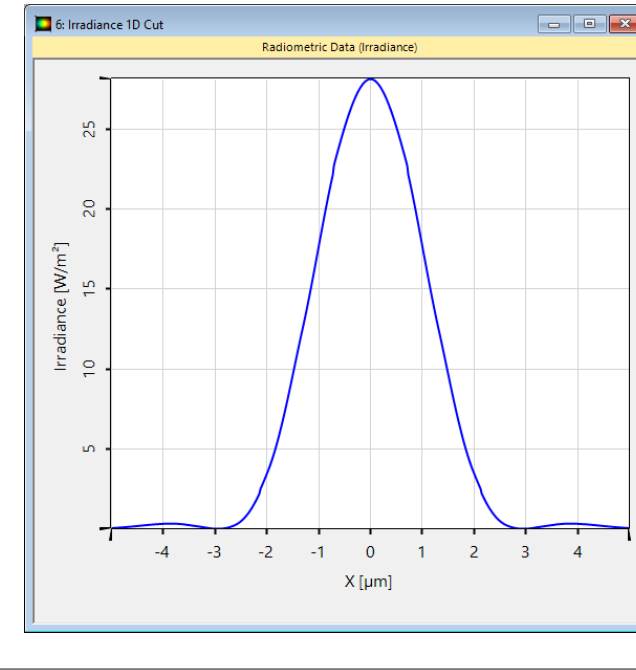
- radius of curvature $R=1.7\text{ mm}$
- conical constant $k=0$
- lens thickness $t=0.8\text{ mm}$



Irradiance



Irradiance 1D cut

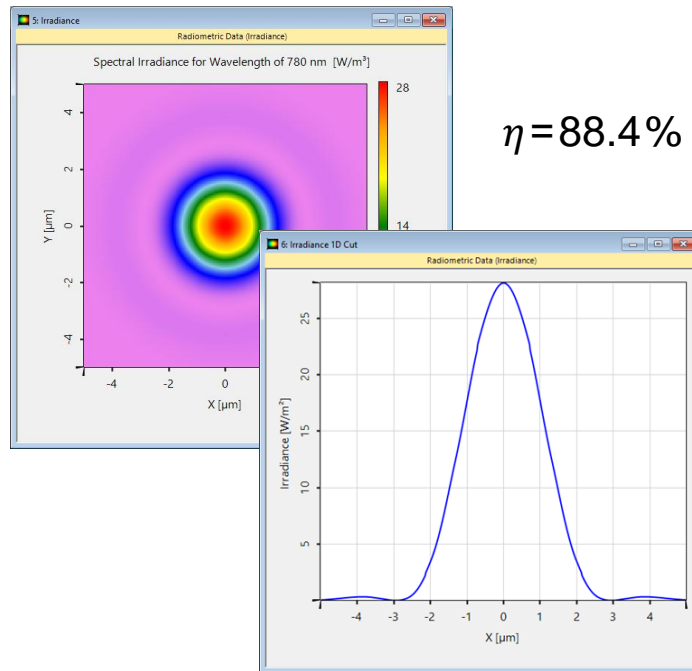


The coupling efficiency obtained from the initial spherical lens is not optimal, due to mismatch between the focal spot of the lens and the propagating mode of the fiber.

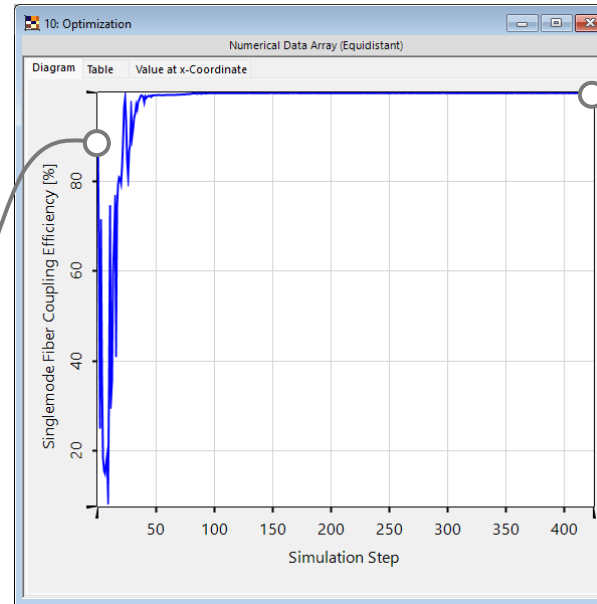
Parametric Optimization

Initial lens parameters

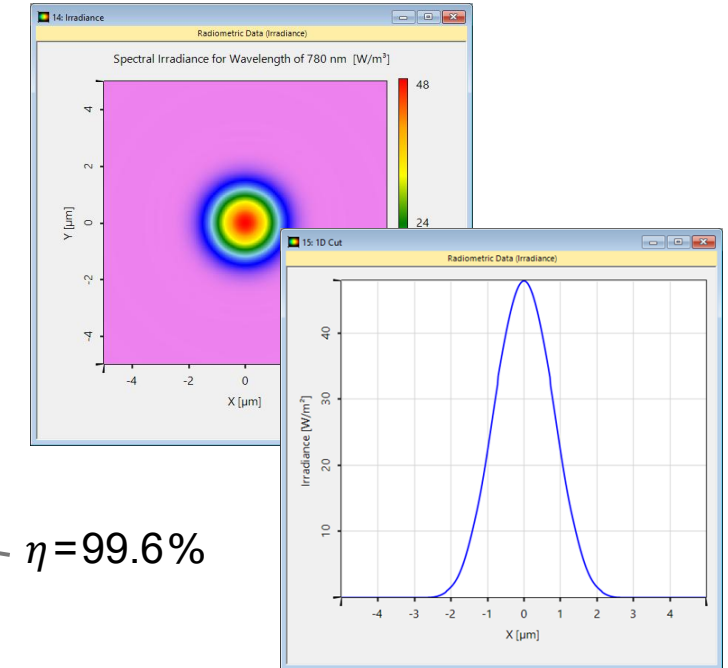
- radius of curvature $R=1.7$ mm
- conical constant $k=0$
- lens thickness $t=0.8$ mm



$\eta=88.4\%$



parametric optimization of coupling efficiency with downhill simplex algorithm



$\eta=99.6\%$

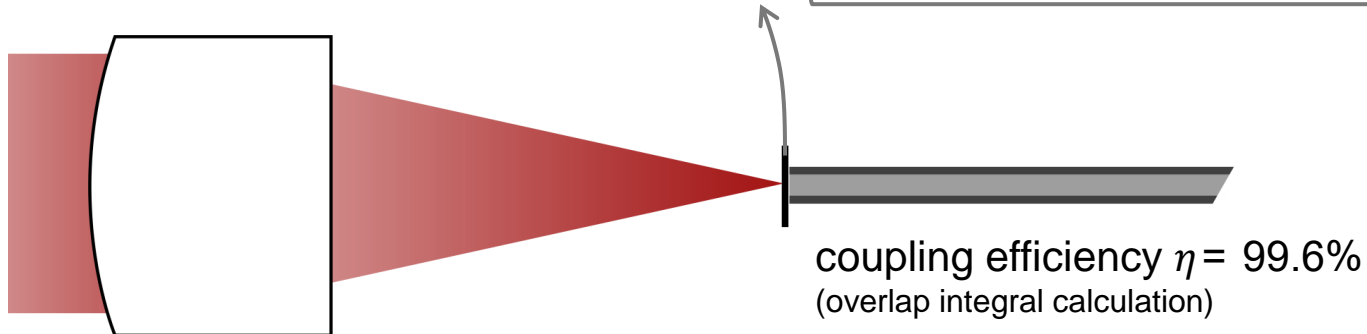
optimized lens parameters

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

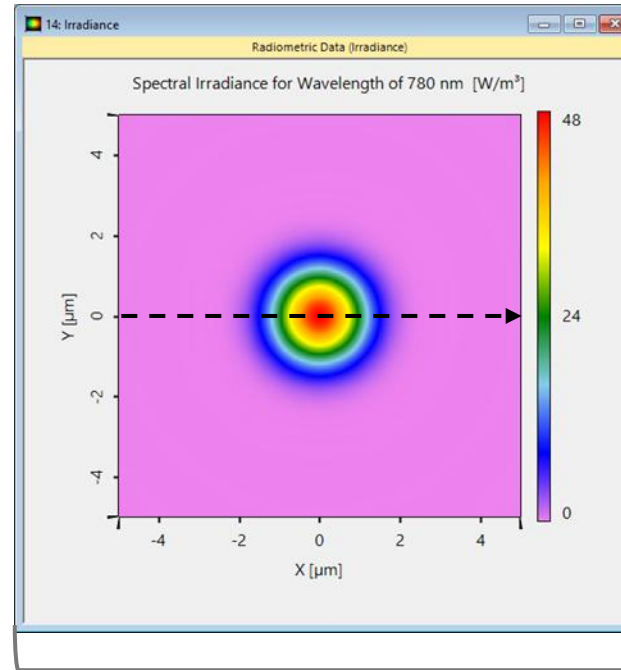
Evaluation of Optimized Lens

Optimized lens parameters

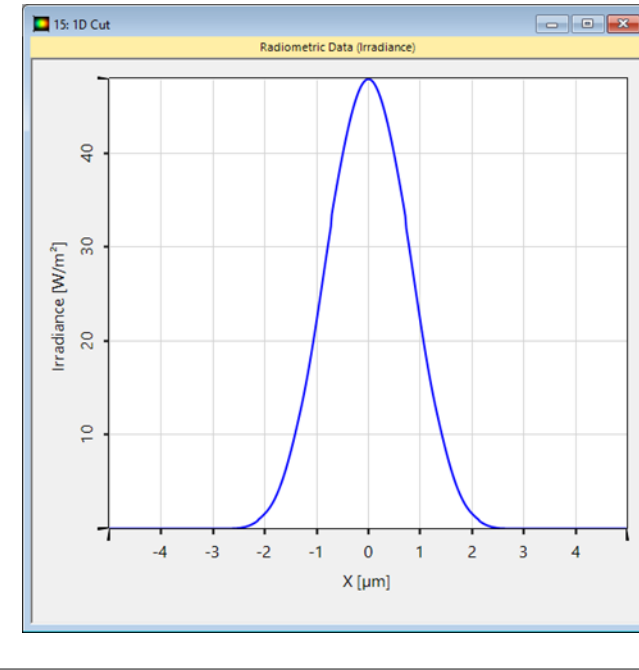
- radius of curvature $R=1.608\text{mm}$
- conical constant $k=-0.7139$
- lens thickness $t=0.6311\text{mm}$



Irradiance



Irradiance 1D cut



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

Workflow Steps

Basic Workflow Steps

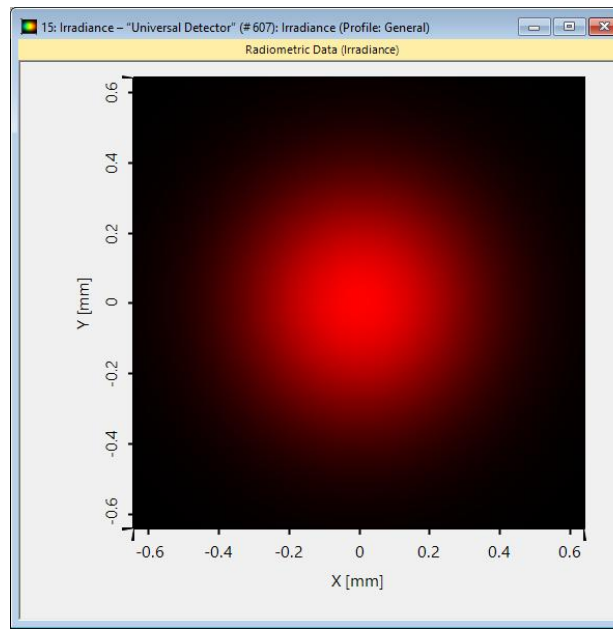
Source selection

System setup

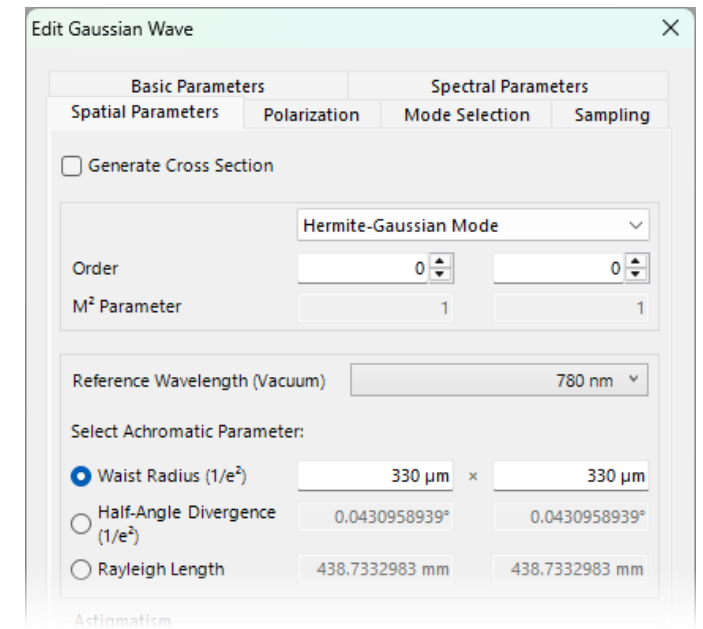
Detector selection

Getting it done in VirtualLab Fusion:

➤ Gaussian Wave



Irradiance of source



The 'Edit Gaussian Wave' window shows various parameters for a Gaussian wave. It has tabs for 'Basic Parameters', 'Spectral Parameters', 'Spatial Parameters', 'Polarization', 'Mode Selection', and 'Sampling'. The 'Basic Parameters' tab is active. It includes a 'Generate Cross Section' checkbox, a 'Hermite-Gaussian Mode' dropdown, and input fields for 'Order' (0) and 'M² Parameter' (1). The 'Reference Wavelength (Vacuum)' is set to 780 nm. Under 'Select Achromatic Parameter:', the 'Waist Radius (1/e²)' is selected with values of 330 μm for both x and y. Other options include 'Half-Angle Divergence (1/e²)' and 'Rayleigh Length'.

Source settings

Basic Workflow Steps

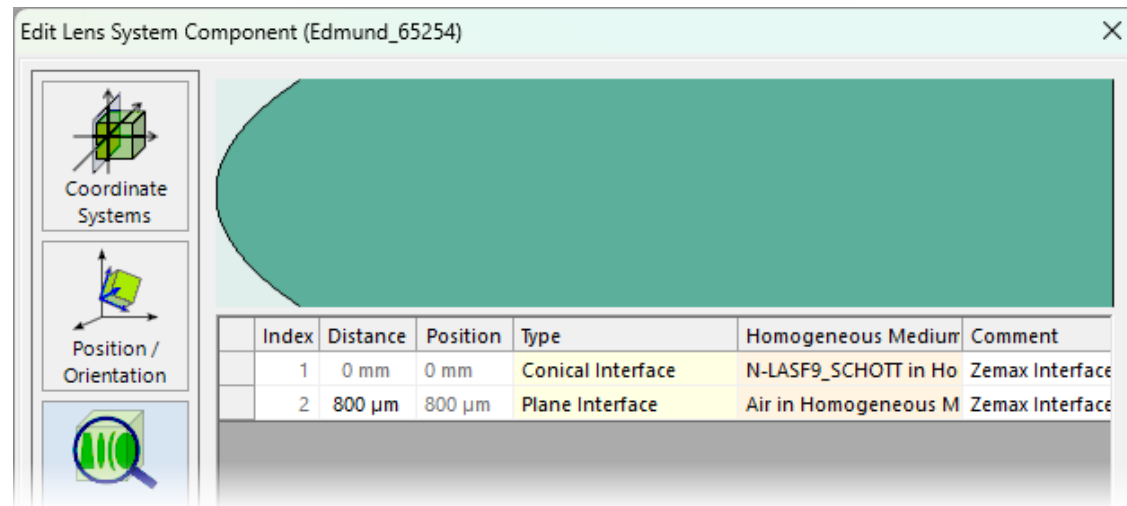
Source selection

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

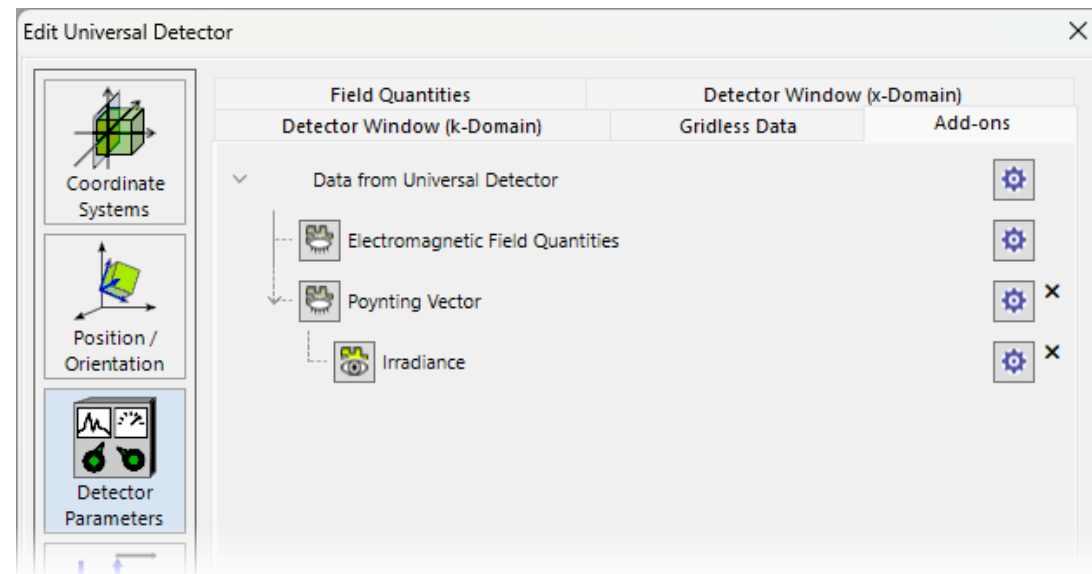
Source selection

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

9: Parametric Optimization

Optimization Results
Start or stop the optimization routine. The results are shown in the table.

Go!

| Detector | Subdetector | Simulation Step | | | | | | | |
|-----------------------------|---------------------------------|-----------------|----------|----------|----------|-----------|----------|-----------|-----------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Optimizer Logging | Target Function Value | 0.013368 | 0.73185 | 0.076235 | 0.43008 | 0.73065 | 0.70186 | 0.74112 | 0.60081 |
| | Conical Constant ("Initial L... | 0 | 0 | 1 | 0 | 0.66667 | 0.5 | 0.16667 | 0.41667 |
| Parameter Constraints | Distance ("Initial Lens (Edm... | 800 µm | 800 µm | 800 µm | 880 µm | 853.33 µm | 840 µm | 813.33 µm | 833.33 µm |
| | Radius of Curvature ("Initia... | 1.7 mm | 1.87 mm | 1.7 mm | 1.7 mm | 1.53 mm | 1.615 mm | 1.785 mm | 1.6575 mm |
| "Fiber Coupling Efficiency" | Singlemode Fiber | 88.438 % | 14.452 % | 72.389 % | 34.419 % | 14.522 % | 16.223 % | 13.912 % | 22.488 % |

Create Output from Selection

Filter Rows by...

< Back Next > Show ▾

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 | <ul style="list-style-type: none">• <u>Optimal Working Distance for Coupling Light into Single-Mode Fibers</u>• <u>Comparison of Different Lenses for Fiber Coupling</u>• <u>Introduction to the Parametric Optimization Document</u> |

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