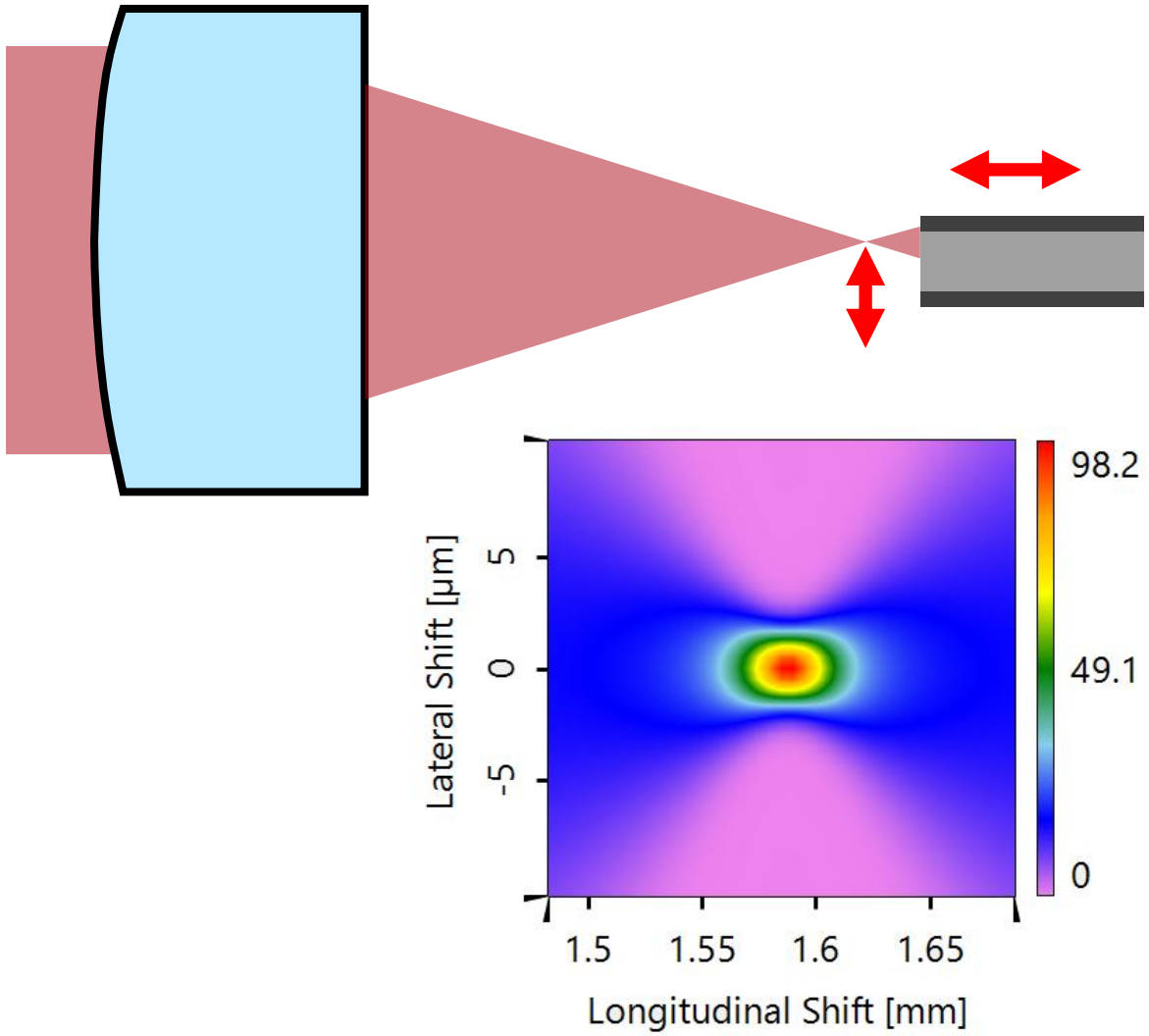
Tolerance Analysis of a Fiber Coupling Setup

Abstract



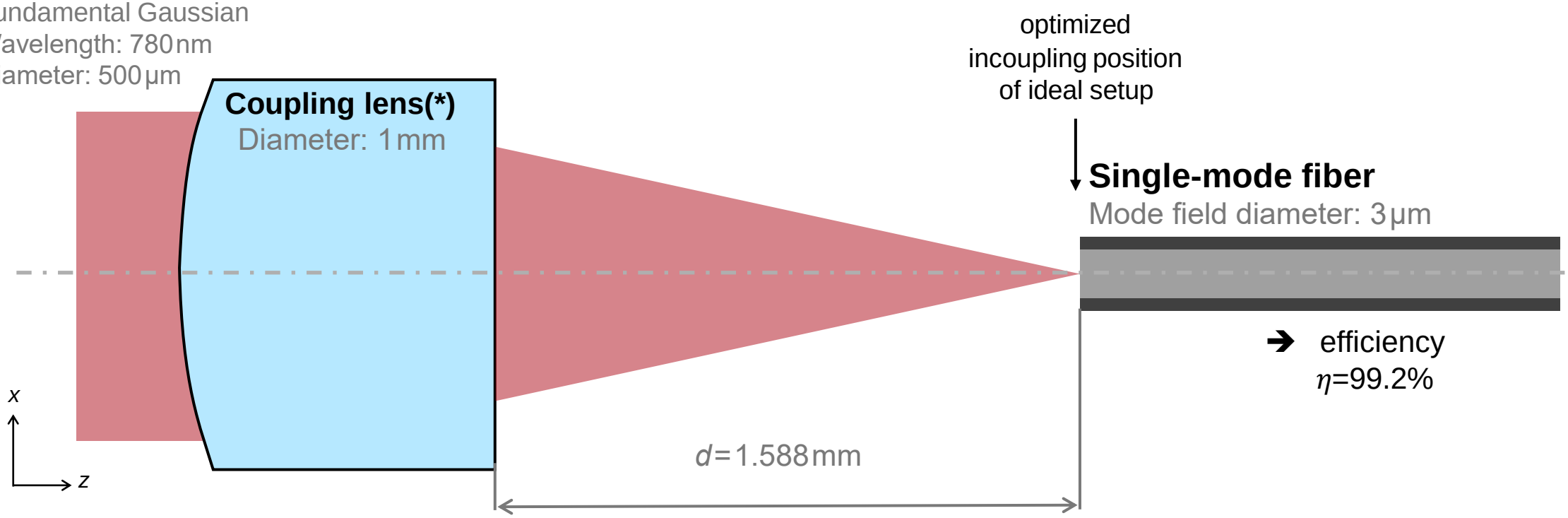
In this example, a well-designed fiber-coupling lens is selected, and the coupling efficiency is evaluated with respect to different tolerance factors, such as the shift of the fiber end position and the tilt of the coupling lens.

Application Scenario

Application Scenario: System

Input field

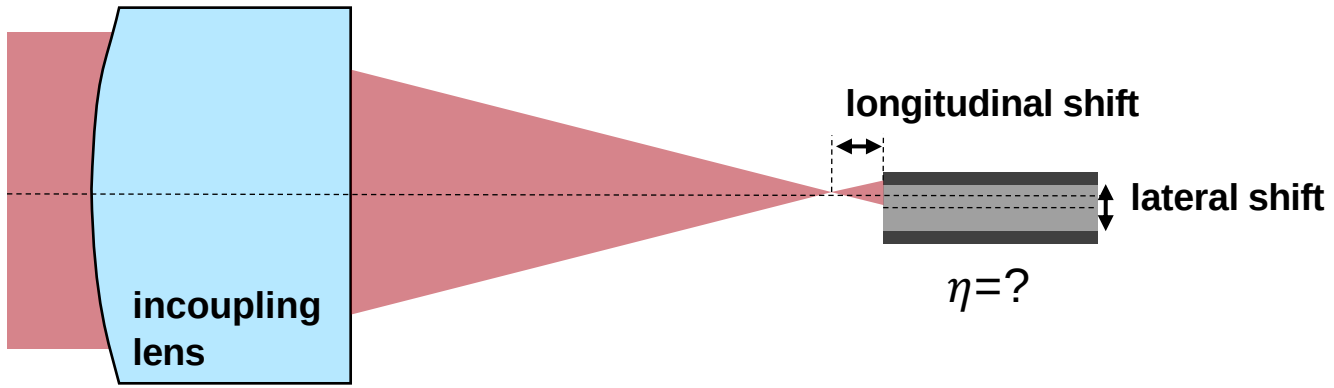
- Fundamental Gaussian
- Wavelength: 780 nm
- Diameter: 500 µm



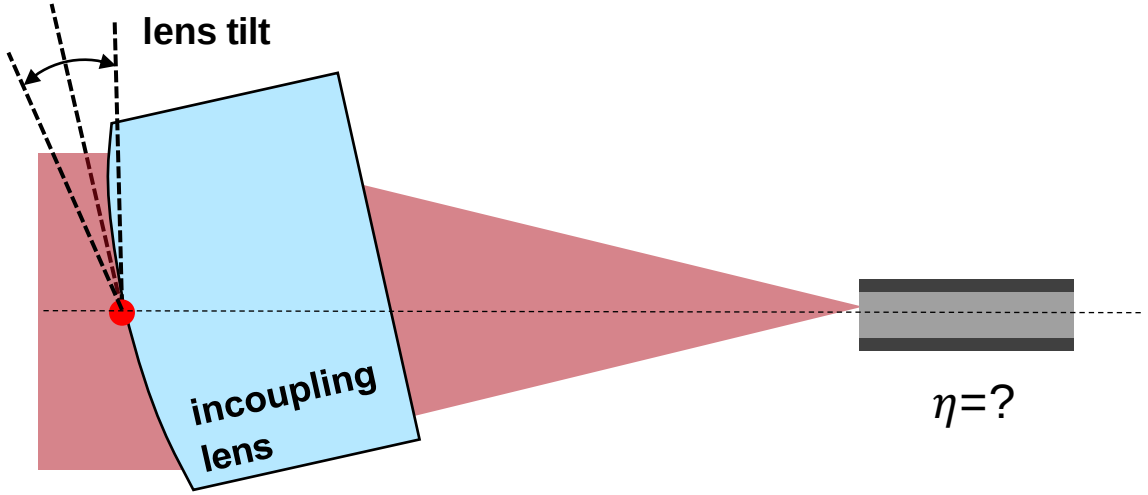
(*) For design of lens, please see: Parameteric Optimization of Fiber Coupling Lens

Application Scenario: Task

Task 1: Investigate coupling efficiency while shifting the fiber end position.



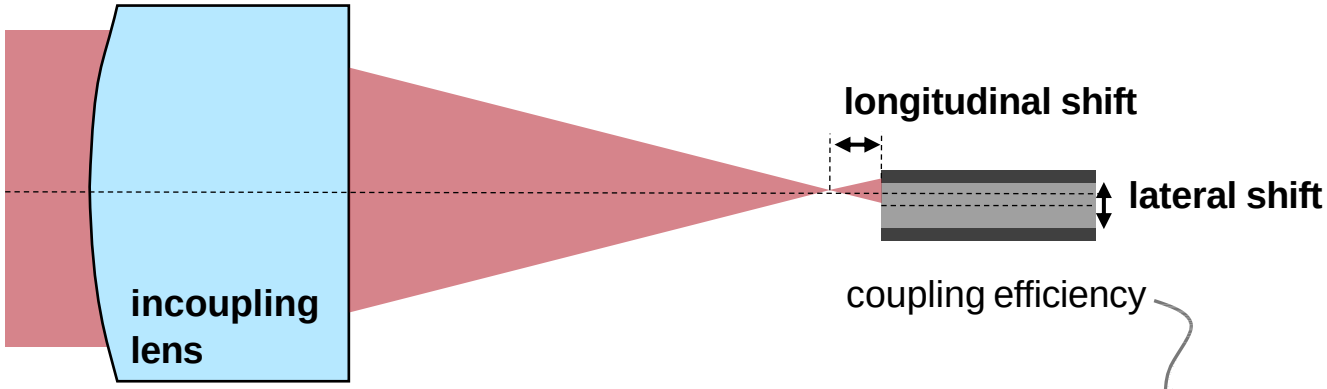
Task 2: Investigate coupling efficiency while tilting the coupling lens.



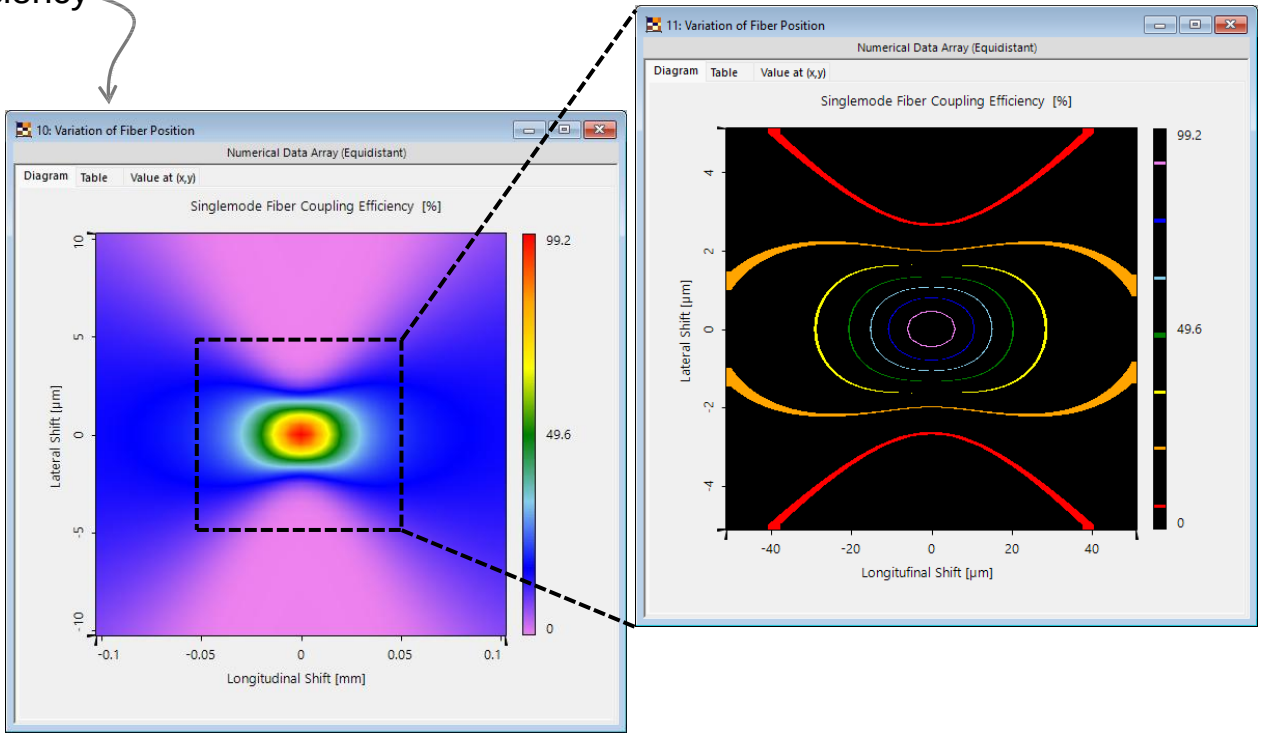
Task 3: Exemplary robustness tolerance analysis considering both shift and tilt deviations.

Simulation Results

Coupling Efficiency vs. Fiber End Position Shift



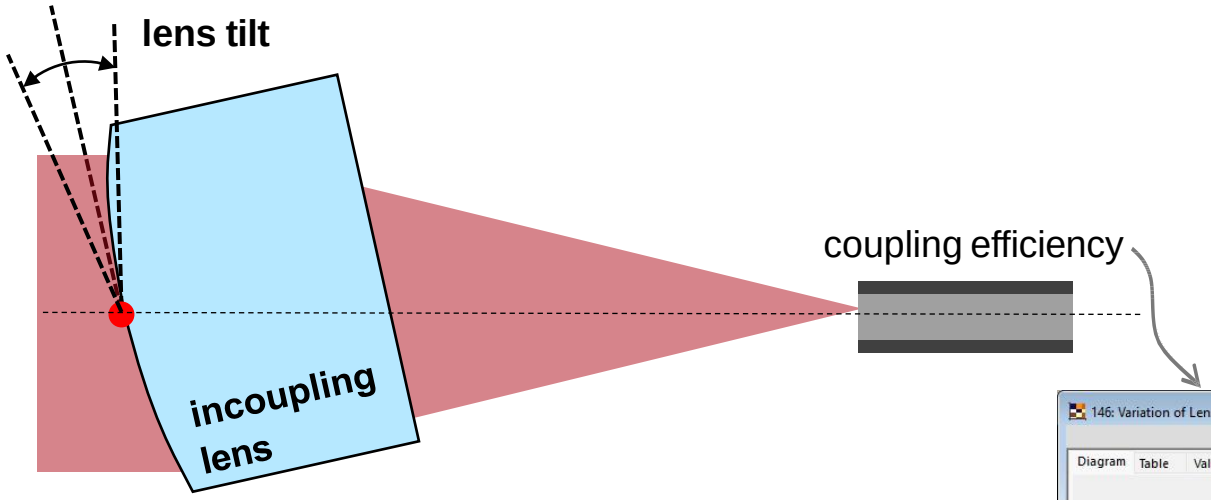
Contour plots help with the identification of the parameter range that provides the desired coupling efficiency threshold.



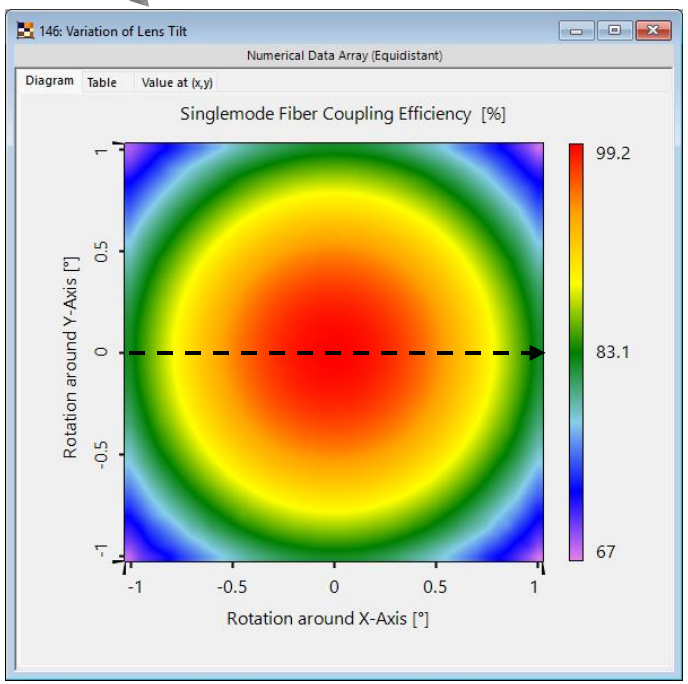
The coupling efficiency is scanned with respect to the fiber position shifts along both longitudinal and lateral directions.

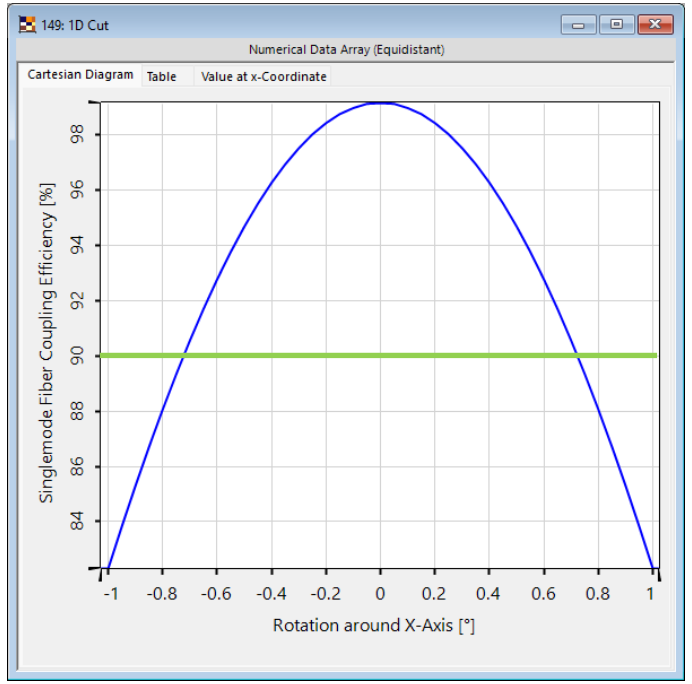
file: USC.0073_FiberCouplingTolerancing_02_Lateral and longitudinal shifts.run

Coupling Efficiency vs. Coupling Lens Tilt



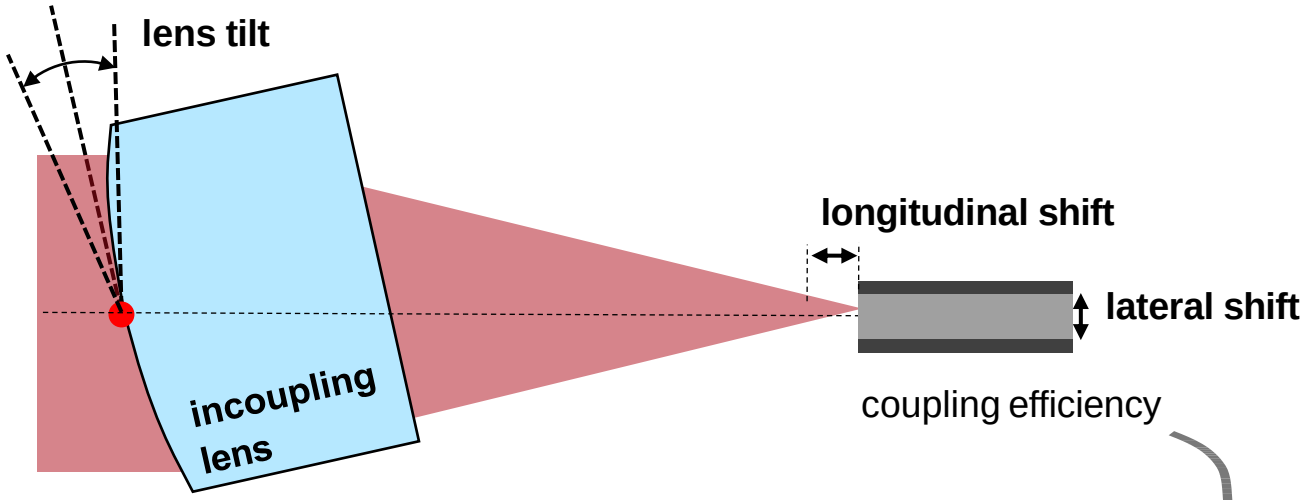
Physical-optics analysis of the coupling efficiency with respect to lens tilt. As long as the lens tilt angle is within ±0.7°, the coupling efficiency remains higher than 90%.





file: USC.0073_FiberCouplingTolerancing_03_Coupling lens tilt.run

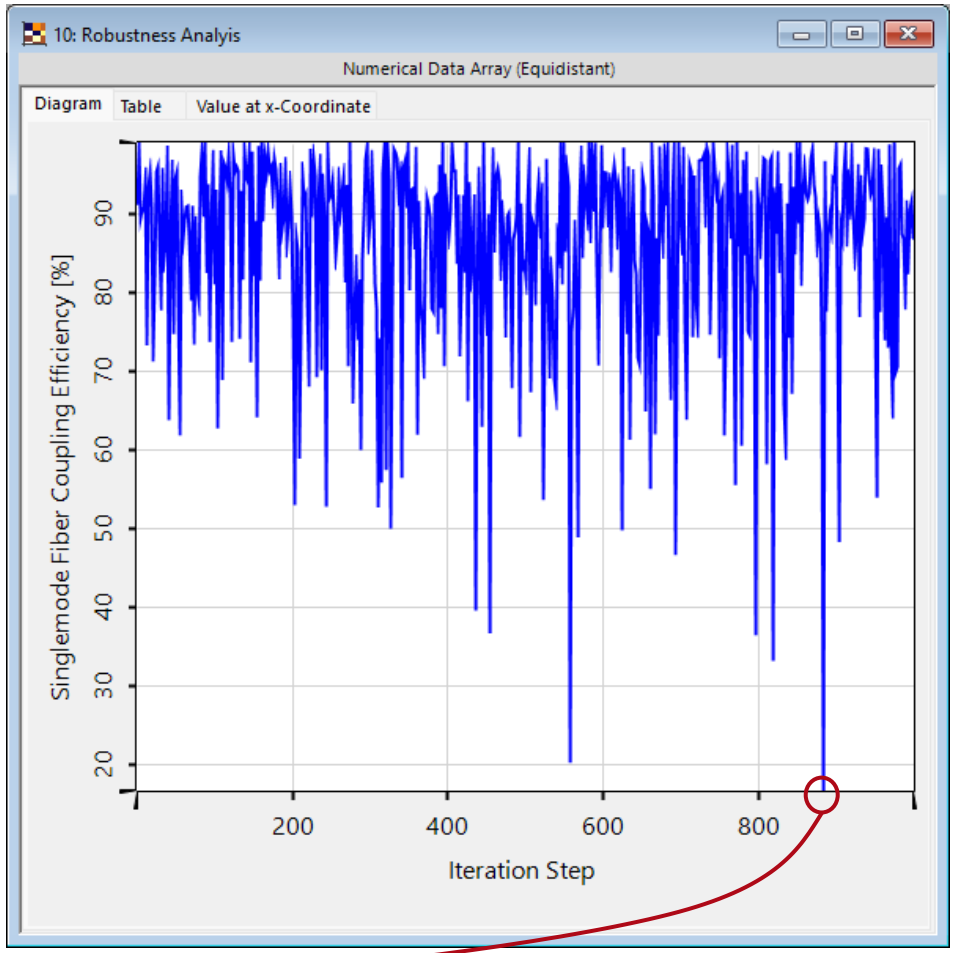
Robustness Tolerancing of Fiber Coupling Setup



For an exemplary robustness analysis we vary all (shift and tilt) parameter in the following ranges(*):

- longitudinal shift: ±1 µm
- lateral shift: ±0.5 µm
- tilt (x/y-axis): ±0.7°

Fiber Coupling Efficiency for mixed tolerance simulations.



With these deviation ranges outlier under 20% are to be expected.

Minimum: 16.53%

(*) Values refer to 2 times the standard deviation.

file: USC.0073_FiberCouplingTolerancing_04_Robustness Analysis.run

Workflow Steps

Basic Workflow Steps

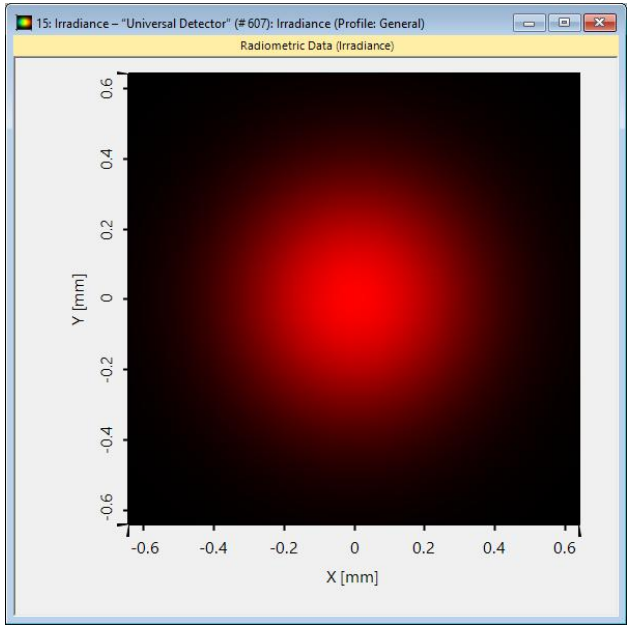
Source selection

System setup

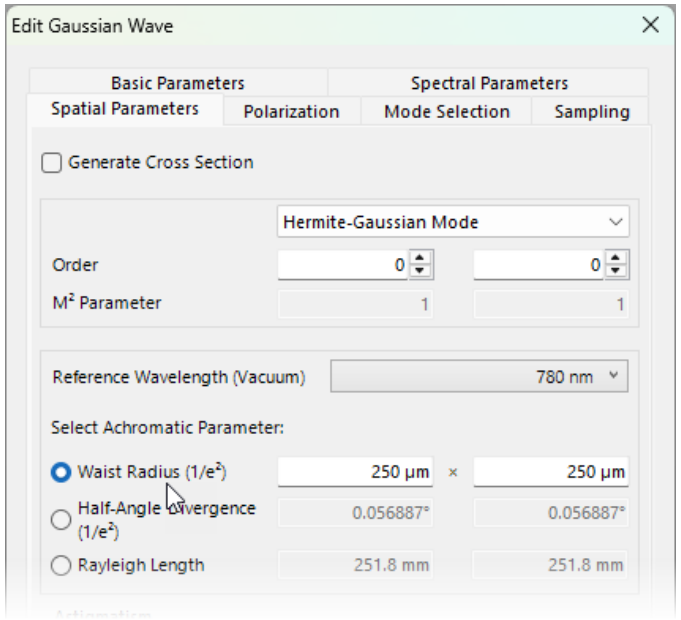
Detector selection

Getting it done in VirtualLab Fusion:

- Gaussian Wave



Irradiance of source



Source settings

Basic Workflow Steps

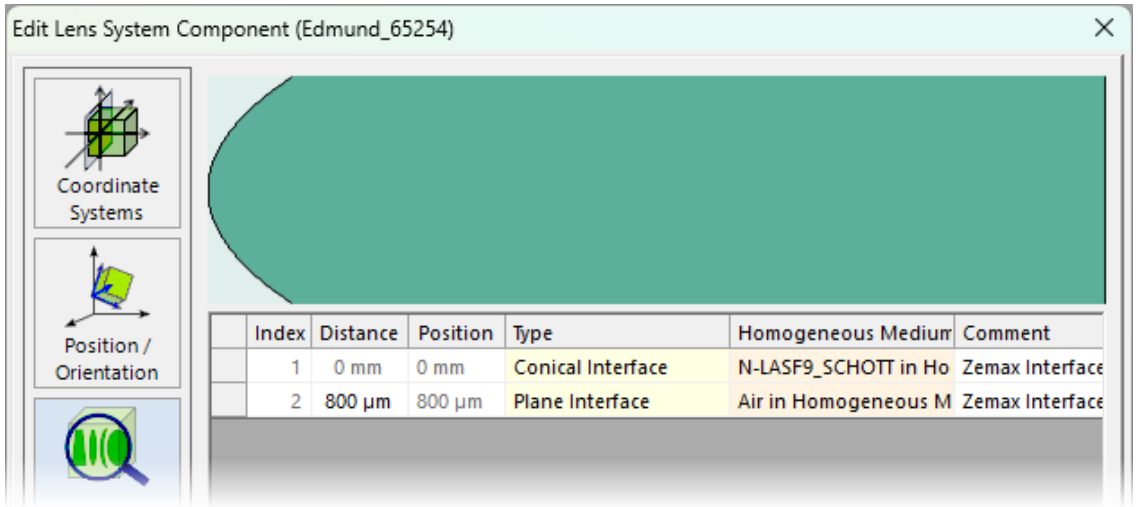
Source selection

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
- Optimize lens parameters for highest efficiency



Imported Lens

Basic Workflow Steps

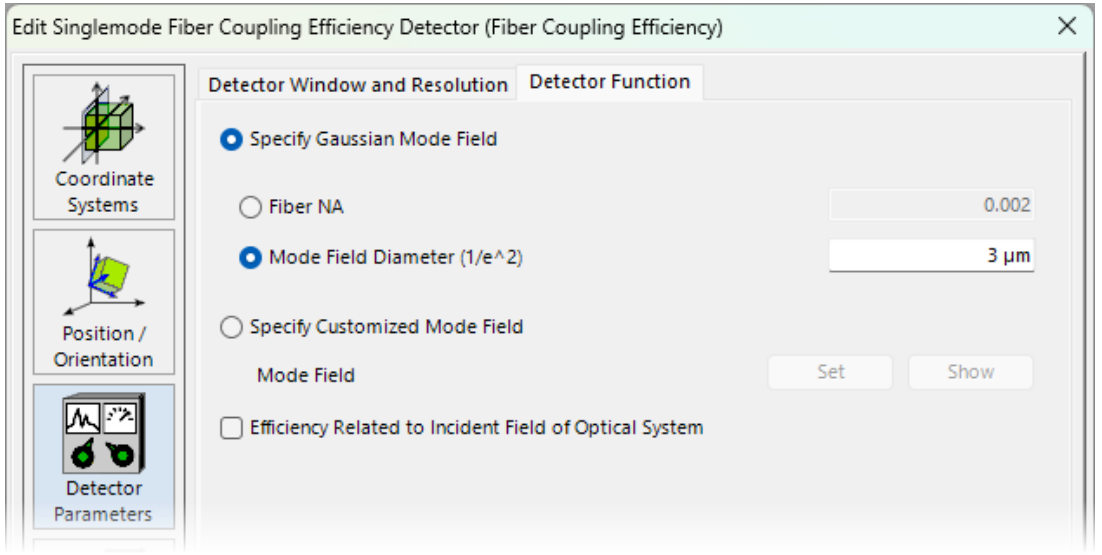
Source selection

System setup

Detector selection

Getting it done in VirtualLab Fusion:

- Universal Detector
- Fiber Coupling Efficiency



Singlemode Fiber Coupling Efficiency Detector

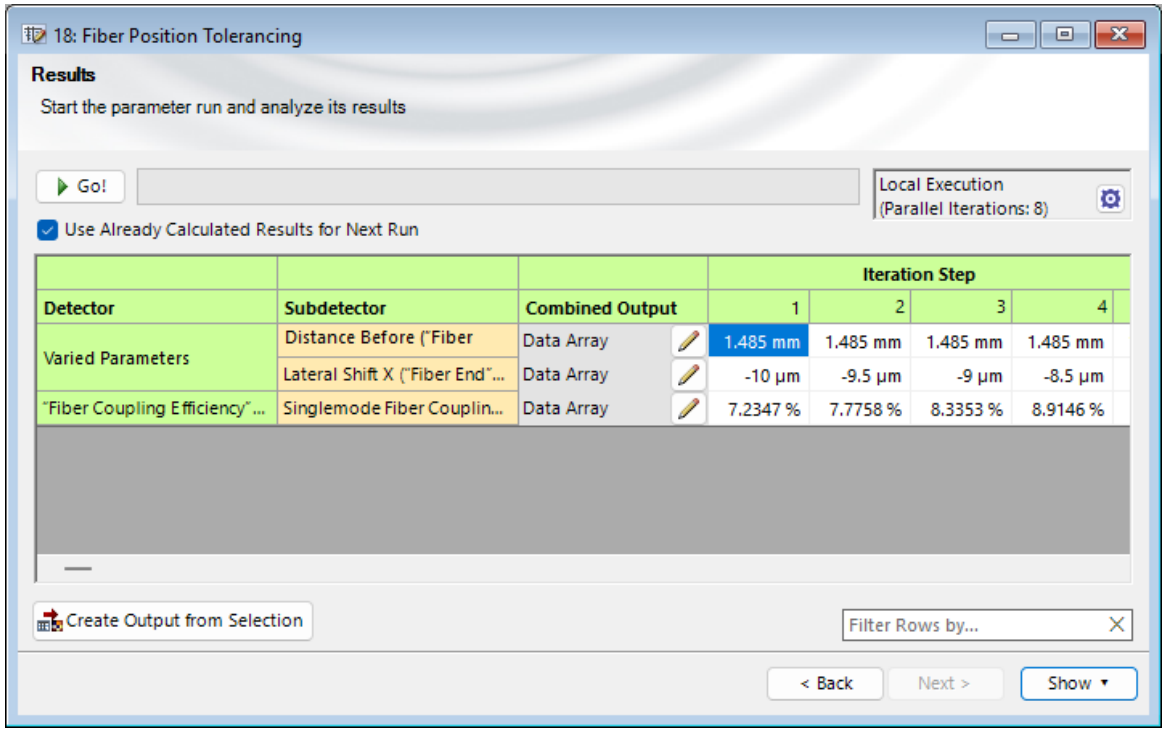
Specific Workflow Steps Related to Use Case

Perform parameter sweep

Adjust result visualization

Getting it done in VirtualLab Fusion:

- Parameter Run document
- Random Distribution for robustness tolerancing analysis



Parameter Run document

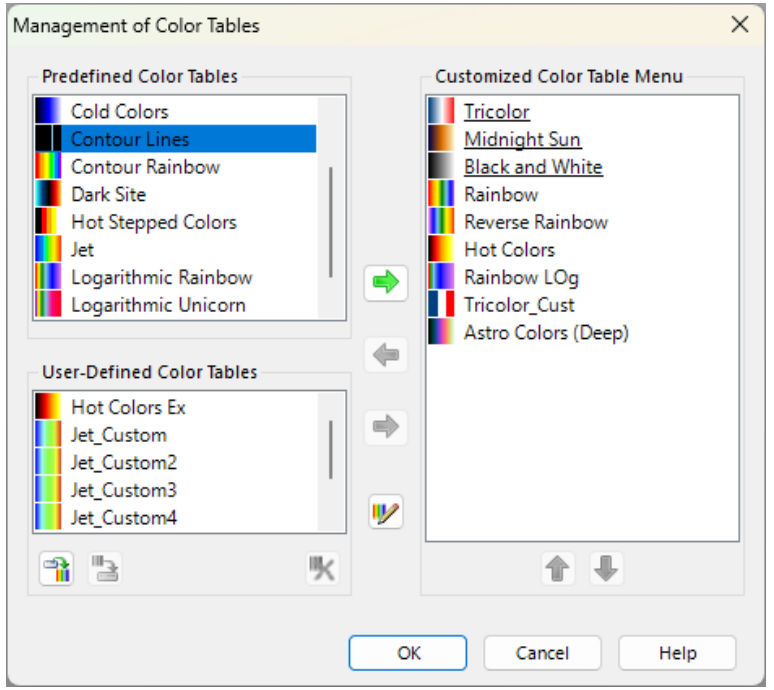
Specific Workflow Steps Related to Use Case

Perform parameter sweep

Adjust result visualization

Getting it done in VirtualLab Fusion:

- Change Color Scheme for detector result documents



Contour Lines in the list of available color tables

Document Information

Title	Tolerance Analysis of a Fiber Coupling Setup
Document code	USC.0073
Publication date	25.04.2025
Required packages	-
Software version	2024.1 (Build 2.74)*
Category	Use Case
Further reading	- Comparision of Different Lenses for Fiber Coupling - Parametric Optimization of Fiber Coupling Lens

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