Parametric Optimization of Fiber Coupling Lenses
In modern optics, fibers can be found in various optical systems. To have an efficient use of light power, the fiber coupling lens must be well-designed, to ensure that the focal spot matches the propagating mode inside the fiber. With the fast-physical optics simulation and the parametric optimization in VirtualLab Fusion, we show the design of a lens with conical surface for the task of coupling light into a single-mode fiber.
Design Task

How to optimize the fiber coupling lens to achieve maximized efficiency, by proper selection of the lens parameters (radius of curvature $R$, conical constant $k$, and lens thickness $t$)?

**Input Field**
- Fundamental Gaussian
- Wavelength 780 nm
- Diameter 660 μm

**Coupling Lens**
(initial parameter from Edmund 65254)
- Effective focal length 2 mm

**Single-Mode Fiber**
- Mode field diameter = 3 μm

**Conical Surface**
- Radius of curvature $R$?
- Conical constant $k$?

**Diagram**

- $x$ axis
- $z$ axis
- $t$ = ?
- $d$ = 1.585 mm
- (fixed working distance)

**Design Parameters**
- $R = ?$
- $k = ?$
- $t = ?$
Evaluation of Initial Lens

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

The coupling efficiency obtained from the initial spherical lens is not optimal, due to mismatch to the mode inside the single-mode fiber.

Coupling efficiency $\eta=90.0\%$
(overlap integral calculation)
Parametric Optimization

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

\[ \eta = 90.0\% \]

parametric optimization of coupling efficiency with downhill simplex algorithm

\[ \eta = 99.1\% \]

optimized lens parameters
- radius of curvature $R=1.563\text{ mm}$
- conical constant $k=-0.7225$
- lens thickness $t=0.5328\text{ mm}$
Evaluation of Optimized Lens

optimized lens parameters
- radius of curvature \( R = 1.563 \text{ mm} \)
- conical constant \( k = -0.7225 \)
- lens thickness \( t = 0.5328 \text{ mm} \)

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

coupling efficiency \( \eta = 99.1\% \) (overlap integral calculation)
Peak into VirtualLab Fusion

parametric optimization with flexible variables and merit functions definition

result visualization in various formats
Workflow in VirtualLab Fusion

- Set up input Gaussian field
  - Basic Source Models [Tutorial Video]
- Import initial coupling lens from Zemax file
  - Import Optical Systems from Zemax [Use Case]
- Evaluate fiber coupling efficiency with initial lens
  - Optimal Working Distance for Coupling Light into Single-Mode Fibers [Use Case]
- Use Parametric Optimization to find proper values for selected lens parameters

\[ \eta = 99.1\% \] (overlap integral calculation)
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coupling lens
(conical surface)

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Field Solver

1. prisms, plates, cubes, ...
2. lenses & freeforms
3. apertures & boundaries

- free space
- crystals & anisotropic components
- waveguides & fibers
- scatterer
- diffusers
- diffractive beam splitters
- SLM & adaptive components
- micro lens & freeform arrays
- HOE, CGH, DOE
- diffractive, Fresnel, meta lenses
- gratings

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| further reading | - [Optimal Working Distance for Coupling Light into Single-Mode Fibers](#)  
- [Comparison of Different Lenses for Fiber Coupling](#) |