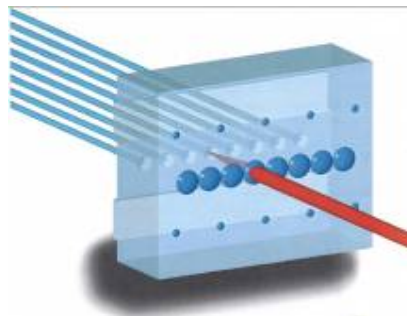


SMO TECHINFO SHEET 07 - FIBER COUPLING



Introduction

This data sheet summarizes optical and physical properties of Fiber-To-Fiber Coupling for standard **Single Mode Optical Fibers** and refractive, plano-convex **Microlenses** as supplied by SUSS MicroOptics. All data given for coupling efficiency and tolerances is based on simulations using Zemax¹ Optical Design Program.

Specifications

As an example, the specifications of a **Corning SMF-28 Single Mode Fiber** are used. However, any other fiber from any other supplier could be used as well.

Single Mode Fiber, Corning SMF-28²

Coating Diameter	245 ± 5 μm	Numerical Aperture	0.14
Cladding Diameter	125 ± 1 μm	Effective Group Index of Refraction	1.4675 @1310nm
Core Diameter	8.3 μm	Effective Group Index of Refraction	1.4681 @1550nm
Core-Clad Concentricity	≤ 0.5 μm	Refractive Index Difference	0.36%
Cladding Non-Circularity	≤ 1%	Mode Field Diameter @1310nm	9.2 ± 0.4 μm
Zero Dispersion Wavelength	1312 nm	Mode Field Diameter @1550nm	10.4 ± 0.8 μm

As an primary example, the specifications of a **SUSS MicroOptics Microlens Array** is used. Simulation results for different microlens configurations are found in the attachment.

Microlens Array, SUSS MicroOptics³ (Quartz)

Substrate Material	Fused Silica	Lens Arrangement	Linear array
Substrate Thickness*	0.9 mm	Lens Diameter*	240 μm
Index of Refraction	1.444 @1550 nm	Lens Pitch*	250 μm
Transmission excl. FR	>0.99 [1350 – 1600 nm]	Pitch Accuracy	± 0.25 μm
AR Coating Reflectivity	1250 nm to 1650 nm	Radius of Curvature*	330 μm
Outer Dimensions	14.0 mm x 4 mm	Conic Constant*	K = 0
Standard values – to be modified upon customer's request.		Numerical Aperture	0.17

Definition of Numerical Aperture

The optical design program Zemax¹ defines the numerical aperture of a single mode optical fiber as “the sin of the half angle to the 1/e² intensity” (= 13.5%). The definition of Corning² for the numerical aperture is the sin of the half angle to 1% of the peak center intensity. Thus a numerical aperture of NA = 0.09 is to be used with Zemax fiber coupling calculations to represent correctly a Corning SMF-28 single mode fiber.

¹ ZEMAX-EE Optical Design Program, Focus Software Incorporated

² Specifications from SMF-28™ Corning Incorporated, datasheet PI-1036, March 2001

³ SUSS MicroOptics Microlens Array 15-9920-105-119: Circular lenses, linear array - 1x48 lenses

ZEMAX¹ Calculation of Coupling Efficiency

ZEMAX offers two different possibilities to compute the coupling efficiency for single mode fiber-to-fiber coupling:

A) FICL – Ray Based Fiber Coupling Efficiency Calculation

Ray based method to compute the fiber coupling efficiency. Light emerges from a source fiber to fill or partially overfill the entrance pupil of an optical system. Energy not collected by the entrance pupil is lost, reducing the overall efficiency. The coupling efficiency is the fraction of energy radiated by the source that couples into the receiver. The fiber coupling receiver efficiency is defined as a normalized overlap integral between the fiber and beam complex amplitude. The total coupling efficiency into the fiber is the system efficiency multiplied by the receiver efficiency.

B) FICP – Wave Based Fiber Coupling Efficiency Calculation

This feature calculates the fiber coupling efficiency of a coherent optical Gauss beam through the optical system using a Physical Optics Propagation (POP) algorithm. Physical Optics Propagation models the optical system by propagating wavefronts. The physical optics model is generally more accurate at predicting the detailed amplitude and phase structure of the beam away from focus than conventional ray tracing as it takes into e.g. account diffraction effects of the finite lens apertures.

Discussion: For a short sender-to-receiver distance both methods deliver equal coupling efficiencies. As the ray based method does not take into account diffraction effects, the ray based FICL method does not work accurately for longer sender-to-receiver distances.

Fresnel Reflection

A standard Anti-Reflection Coating reduces the FR loss to less than -0.025 dB [0.6%] for a microlens coupling element (two surfaces).

How to Simulate FICP Correctly

The calculation of the fiber coupling efficiency by using the ZEMAX Physical Optics Propagation (POP) algorithm is only available in the full version ZEMAX EE.

The POP analysis tool is found in “Analysis” → “Physical Optics” → “Physical Optics Propagation”.

POP Settings

Beam Definition | Display | Fiber Data

X-Sampling: 128 Wavelength: 1
 Y-Sampling: 128 Field: 1
 X-Width: 0.0922439205 Start Surface: 1
 Y-Width: 0.0922439205 End Surface: Image
 Type: Gaussian Waist Surf To Beam: -1.22

File:
 Use Polarization Peak Irradiance: 1
 Total Power: 1

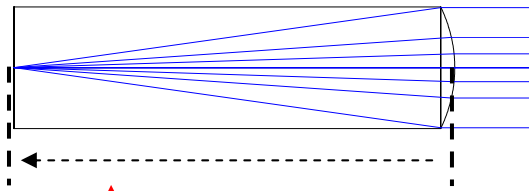
Waist x: 0.0046 Decenter X: 0
 Waist y: 0.0046 Decenter Y: 0

Save Load Reset

OK Cancel Apply Help

Fiber Core
(Object)

Microlens
(Surface 1)



Surface To Beam: The distance from surface 1 (NOT the object surface) to the beam waist location. Negative if the waist lies to the left of surface 1.

Gaussian Waist: The radial size of the embedded beam waist in object space in lens units.
 Mode Field Diameter SMF-28 @1310 nm = 9.2µm

POP Settings

Beam Definition | Display | Fiber Data

Compute Fiber Coupling Integral

Tilt About X (deg): 0 Tilt About Y (deg): 0

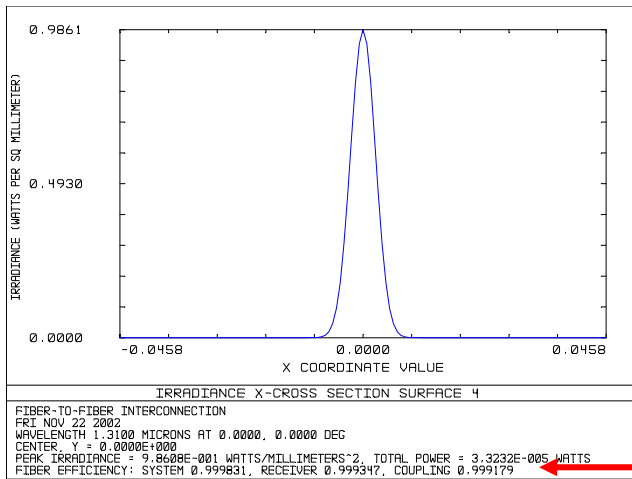
Fiber Type: Gaussian Waist
 File:
 Waist x: 0.0046 Decenter X: 0
 Waist y: 0.0046 Decenter Y: 0

Fiber Position: Chief Ray

Save Load Reset

OK Cancel Apply Help

POP-Window



Coupling Efficiency calculated by POP is noted here.