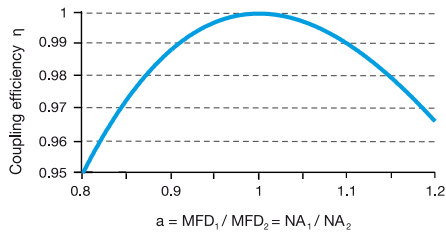


MISMATCH / NA MISMATCH



FIBER MISMATCH OR COMBINING FIBERS WITH DIFFERENT NAs

For both single-mode and polarization-maintaining fibers, the effective numerical aperture NAe^2 and mode field diameter MFD may vary by up to 10% from the specified values, simply arising from manufacturing tolerances. Selected fibers with characterized values are available on request.

The theoretical coupling efficiency η (overlap integral between two Gaussian intensity distributions) is still close to $\eta = 1$ even when mode field diameter of an actual fiber differs from the theoretical value.

The linear relationship between mode field diameter MFD and effective numerical aperture NAe^2 means that this is also valid for a mismatch in the values for NAe^2 .

EXAMPLE

For two fibers with exemplary effective numerical apertures NAe^2 of 0.07 and 0.08 respectively, the overlap is still $\eta = 0.982$

MISMATCH OF FOCAL LENGTHS

Since the mode field diameter is directly proportional to the calculated coupling focal length, the calculations concerning the overlap are also true for different focal lengths f_1 and f_2 and $a = f_1 / f_2$.

EXAMPLE

If the calculated coupling focal length ideally should be 22 mm, but the closest available optics has a focal length of 20 mm, the calculated overlap is still 0.991.

DETAILED CALCULATIONS: OVERLAP OF TWO SINGLE-MODE FIBERS

When coupling radiation from one fiber to another fiber with different numerical aperture NA, the maximum coupling efficiency η , which can be obtained for a physical contact theoretically, is reduced. The maximum coupling efficiency η (or overlap) for a fiber-to-fiber coupling with a symmetric optics is the same. The coupling (overlap) is

$$\eta = \frac{\left| \int \int U_1(x, y) \cdot U_2^*(x, y) dx dy \right|^2}{\int \int |U_1(x, y)|^2 dx dy \cdot \int \int |U_2(x, y)|^2 dx dy} \quad (1)$$

using the mode fields $U_i(x,y)$ of the two different fibers and (x,y) coordinates in the plane of the fiber end face.

Assuming that the mode field of a (weakly guiding) single-mode fiber can be approximated by a Gaussian, the mode fields are

$$U_i(x, y) = exp \left\{ - \frac{x^2 + y^2}{MFD_i^2} \right\} \quad (2),$$

with the mode field diameters MFD_i of the two fibers.

Assuming furthermore that the two mode fields are centered to each other, the coupling efficiency using equation (2) in integral (1) is:

$$\eta = \left[2 \frac{MFD_1 \cdot MFD_2}{MFD_1^2 + MFD_2^2} \right]^2 \quad (3).$$

When the mismatch of the two mode field diameters is defined as the ratio

$$a = \frac{MFD_1}{MFD_2} \quad (4)$$

equation (3) can be expressed as

$$\eta = 4 \frac{a^2}{(1 + a^2)^2} \quad (5)$$

Since the numerical aperture NA of a single-mode fiber is inversely proportional to its mode field diameter MFD and since

$$\eta(a) = \eta(1/a)$$

equation (5) is valid even when using the numerical apertures NA_i in (4) instead of the mode field diameters,

$$a = \frac{NA_1}{NA_2}$$

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