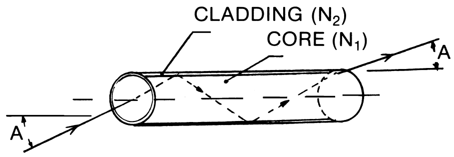
Fiber Characteristics



Fiber Composition

Most optical fibers consist of two different types of optically conductive materials. The Core, which is about 85% of the total fiber and carries the light, has a higher refractive index than the Cladding, which creates the reflecting interface.

Most optical fibers are made from glass, plastic or synthetic fused silica (often called “quartz”). Each fiber has different properties producing various advantages and disadvantages. Silica fibers are usually used for data communication, but Glass is still the best choice for illumination and sensing applications. Plastic fibers can be used for assemblies not requiring heat above 175°F. Because single plastic fibers are usually larger in diameter than glass fibers, they are not as flexible and can’t be used when bending radii are tight.

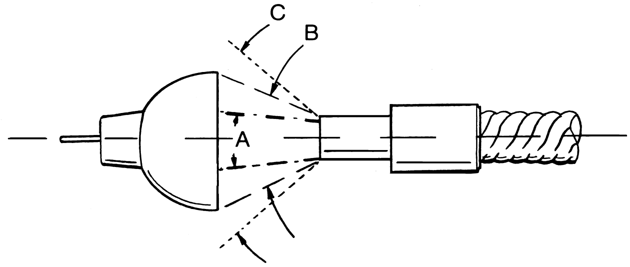
Numerical Aperture

The sketch above shows a typical fiber. The Core has a refractive index of N_1 and the Cladding an index of N_2. Light enters the fiber at angle A and is transmitted through the fiber. If angle A is too large, the light will go out the side of the fiber and will not be transmitted. We call the angle beyond which the light cannot be carried through the fiber the Critical Angle. This is calculated using the two refraction indices. The sine of the Critical Angle is the Numerical Aperture or N.A. The Acceptance Angle of the fiber is two times the Critical Angle.

$$N.A. = \sqrt{(N_1)^2 - (N_2)^2} \qquad f_{\#} = 1/2\ N.A.$$

EXAMPLE: If N_1 is 1.62 and N_2 is 1.52, the N.A. will be .56 which equals a Critical Angle of 34° and an Acceptance Angle of 68°. The f number/equivalent will be f/0.89.

Optical fiber tends to preserve the Angle of Incidence during the light transmission and therefore in the figure above, angle A is shown at both the entrance and exit ends of the fiber. The sketch below shows a typical projecting lamp illuminating a fiber bundle. Angle A is the Acceptance Angle of a .25 N.A. fiber (29°). Angle B is the Incident Angle from the lamp and angle C is the Acceptance Angle of a .66 N.A. fiber (83°).



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When we calculate the minimum N.A. required for the 45° Angle of Incidence, we get .38. Therefore, the fiber with an N.A. of .66 will accept all of the light from the lamp, but the output angle will only be 45° and not the 83° which might be expected. However, the .25 N.A. fiber which cannot accept all of the light, will have an output angle of 20°. Using a low N.A. fiber will not focus the light from a lamp because it can't receive any light beyond its Critical Angle and therefore has a narrow output cone.

Transmission Characteristics of Optical Fibers

High quality optical glass (crown and flint glass) is used for the light transmitting core of fibers and an optical glass with a different refractive index is used for the cladding. Wavelengths between 400 and 900 nanometers are transmitted uniformly, with only minor variations.

Most fibers up to 40"(1016mm) long transmit between 40% and 60% of the light entering the fiber (a loss of 2.2dB to 4dB). Transmission in the UV range is very low and wavelengths below 350nm are not transmitted, but when the application requires UV light, more expensive Fused Silica fibers can be used.

The near infrared range (.8 micron to 1.3 micron) is transmitted very well by glass fibers. At 1.4 micron, all fibers except those specifically designed for IR transmission show a significant drop because of absorption within the glass. Eventually, the transmission curve reaches zero. Low OH fused silica fibers specifically developed for the near infrared do not show this drop at 1.4 micron and transmit quite efficiently between .4 and 2.5 microns. Fluoride and Chalcogenide fibers, the newest additions to the fiber family, cover from 1 micron to 10 microns.

Transmission Characteristics of Optical Fiber Bundles

Although specific information on the performance of a single fiber is valuable, it is important to understand how optical fibers perform when manufactured into bundles. Where a 3-foot (914mm) fiber bundle will transmit approximately 50% of the light entering within the acceptance angle,
a 10-foot (3m) bundle is expected to transmit only about 35% of the light entering. Because of this, in the past, bundle lengths of over 25 (7.6m) feet were impractical. Today, newer, more optically advanced (but more expensive) fibers show bundle transmission of approximately 30% at 30-foot (9.1m) lengths.

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