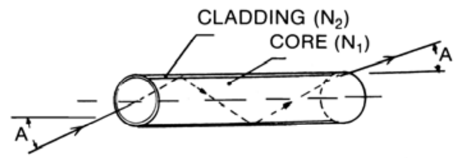
Fiber Characteristics

Fiber Composition

Most optical fibers consist of two different types of optically transmittive materials. The core, about 75-90% of the fiber depending on the fiber diameter, has a higher refractive index than the cladding. This creates a reflecting interface between core and cladding which keeps the light within the core due to total reflection.



Most optical fibers are made from glass, plastic or synthetic fused silica (often referred to as "quartz", but actually the fibers consist of non-crystalline "quartz glass".). Each fiber has different properties producing various advantages. Due to their low attenuation silica fibers are commonly used in data communication. Glass is still the best choice for illumination and sensing applications, due to a reasonable cost-benefit ratio. Plastic fibers can be used for assemblies not requiring heat above 175°F/80°C. Single plastic fibers are usually larger in diameter than glass fibers, which results in restricted bending radii.

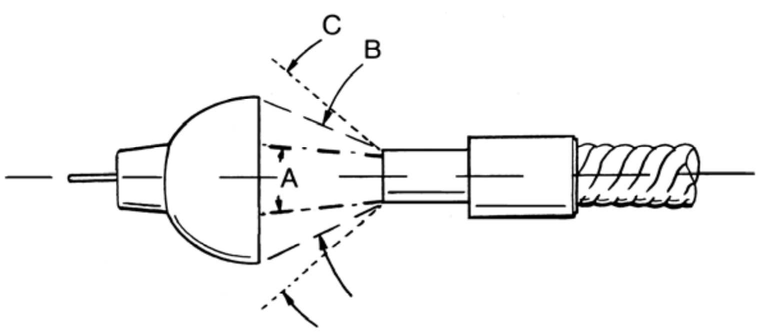
Numerical Aperture

The sketch above shows a typical fiber. The core has a refractive index of N1 and the cladding an index of N2. Light enters the fiber at angle A and is transmitted through the fiber. If the angle A is too large, the light 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 NA The Acceptance Angle of the fiber is two times the Critical Angle.

$$NA = \sqrt{(N_1)^2 - (N_2)^2} \qquad f^{\#} = 1/2\ NA$$

EXAMPLE: If N1 is 1.62 and N2 is 1.52, the NA 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 fibers tend to preserve the angle of incidence during the light transmission and therefore in the figure above, the 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. The angle A is the Acceptance Angle of a .25 NA fiber (29°). Angle B is the Incident Angle from the lamp and angle C is the Acceptance Angle of a .66 NA fiber (83°).



The calculated minimum NA. required for the 45° Angle of Incidence is .38. Therefore, a fiber with an NA. 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 NA. fiber which cannot accept all of the light, will have an output angle of 20°. Using a low NA. 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. Multicomponent glass fibers typically reach NA values up to 0.9, whereas quartz silica fibers typically do not exceed 0.4 NA values.

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Transmission Characteristics of Optical Fibers

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

In this range SCHOTT's standard multicomponent glass optical fibers (GOF70 and GOF85) have attenuation levels between 150 and 300 dB/km. While featuring improved transmission for wavelengths between 350 and 450 nm, transmission for the deeper UV range is very low and wavelengths below 350 nm are not transmitted. Glass optical fibers feature as well transmission in the near infrared range (0.8 µm to 1.3 µm). At 1.4 micron, all fibers except those specifically designed for IR transmission, show a significant drop in transmission due to OH-Absorption within the glass. In the range from 1.4 up to 2.0 µm specifically designed glass optical fibers for IR-transmission can be used.

For improved transmission over the entire range from 250 nm up to 3.0 µm quartz glass (fused silica) fibers are the best choice, but have a lower NA.

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. Due to total reflection, a portion of the light will be reflected at the polished glass surface of the fiber at the entrance as well as the exit. In addition, the interstitial gaps between the fibers, usually filled with epoxy glue, will not transmit any light. The losses due to these two effects can be estimated at approximately 25 % -30 %, depending on the polishing quality. The loss of the interstitial gaps can be reduced by hot fusing the entrance end instead of gluing the fibers together. Thus, transmission can be increased up to 15 %. In addition, transmission loss will be caused with increasing length of the lightguide. A 3-foot/1m lightguide will transmit approximately 60% of the light emitted by the lamp towards the fiber bundle within the NA. A 10-foot/3m light guide will transmit about 55% of the light and a 30-foot/10 meter lightguide roughly of 40 %.

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