

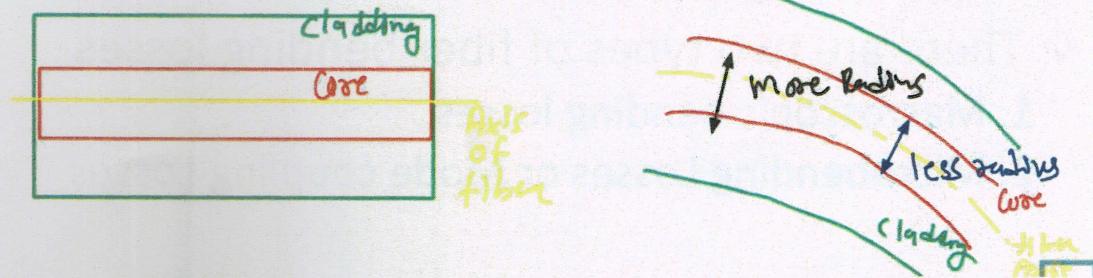
Fiber bending losses

Outlines

- ❖ Basics of Fiber Bending Loss
- ❖ Types of Fiber Bending Loss
- ❖ Macroscopic Bending Loss
- ❖ Micro bending Losses or Mode Coupling Losses

Basic of fiber bending loss

- ❖ If there is abrupt change in the radius of curvature of fiber; then the radiation loss takes place from fiber.



Basics of fiber Bending Loss

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- ❖ If there is abrupt change in the radius of curvature of fiber; then the radiation loss takes place from fiber.
- ❖ If there is sharp bend of the fiber then there is a probability of mechanical failure of optical cable.
- ❖ Usually the higher order modes are not tightly bound to the core layer; so due to the sharp bends, the radiation losses of such modes take first.

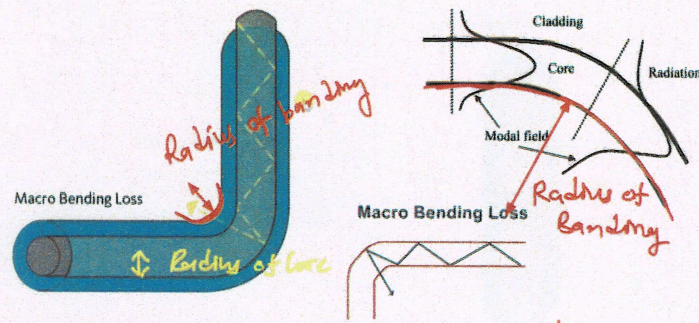
Types of Fiber Bending Loss

Types of Fiber Bending Loss

- ❖ There are two types of fiber bending losses
 1. Macroscopic bending losses
 2. Microbending Losses or Mode coupling Losses

Macroscopic Bending Loss

Macroscopic Bending Loss



Macroscopic Bending Loss

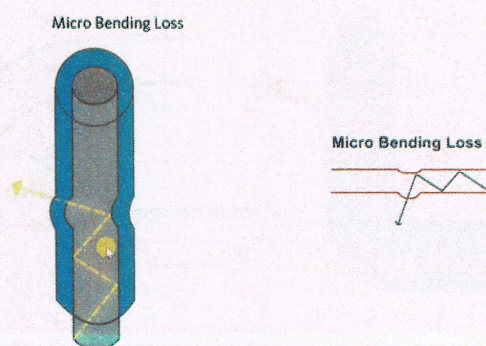
Macroscopic Bending Loss

- ❖ There is a radiation loss, when the radius of curvature of bend is greater than the diameter of fiber. Such losses are also referred as large radius losses.
- ❖ As the radius of curvature of bend decreases, such losses increase exponentially.
- ❖ There is a certain critical value of radius of curvature up to which such losses can be observed.
- ❖ In optical cable; the wavefront perpendicular to the direction of propagation must be maintained to achieve this the part of mode, which is on the outside of bend must travel faster.
- ❖ It indicates that, the light rays travelling through cladding; should travel faster.
- ❖ so the energy associated with that part is lost through radiation.



Microbending Losses or mode Coupling losses

Microbending Losses or Mode Coupling Losses



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Micro bending Losses or Mode Coupling Losses

Microbending Losses or Mode Coupling Losses

- ❖ These are the losses due to small bending or small distortion.
- ❖ If there are small fluctuations in the radius of curvature of fiber axis, then microbends are created and light rays radiate out from these microbends.
- ❖ The Microbends are formed due to two main reasons:
 - ❖ Non uniformities in the core radius, while manufacturing the cable.
 - ❖ During the cabling of fibers, non uniform lateral pressure can be created.
- ❖ To minimize the losses due to microbends we should take following steps:
 - ❖ While manufacturing the cable; a precise control of core diameter is maintained.
 - ❖ A compressible jacket is fitted over the fiber, so that when the external pressure is applied then the deformation of jacket takes place and there will not be creation of microbends in the core layer of fiber.

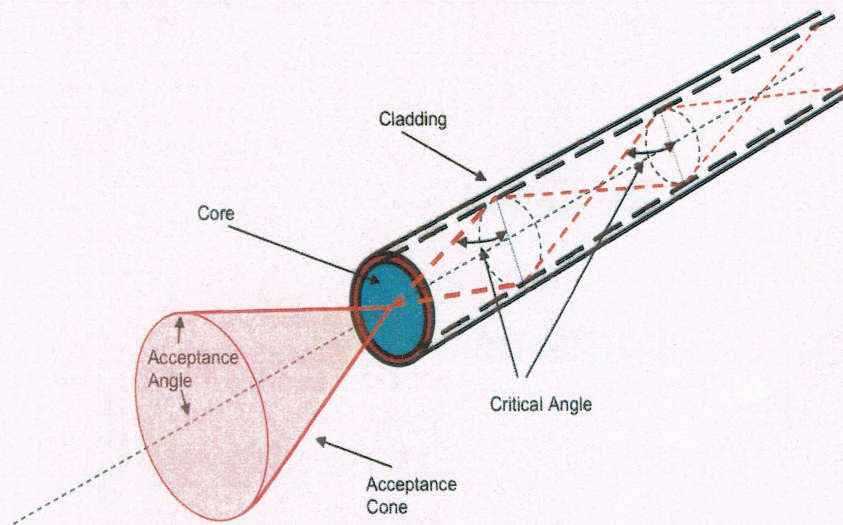
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Review

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Acceptance angle

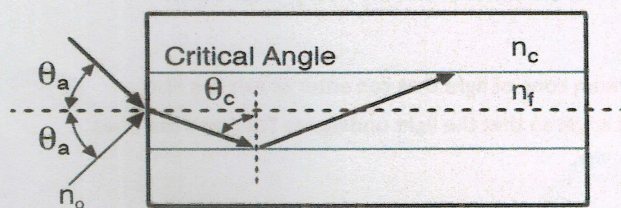
- There is a specific angle with respect to the normal or fiber axis at which the fiber will accept light. This angle is called the acceptance angle and, for reasons we will investigate, this angle is dependent on the difference in the indices of refraction of the outside medium and the fiber medium. The acceptance angle is a measure of the fiber's light gathering ability, and it is measured as the half-angle of the acceptance cone (the maximum cone of light that can enter or exit the fiber.) Note below:
- The acceptance cone is three dimensional.
- The acceptance angle is $\frac{1}{2}$ angle of the maximum cone of light that can enter or exit the fiber.
- The incident angle is greater than the critical angle so that the light undergoes TIR down the fiber.



Geometrically, the numerical aperture is defined by the relationship $NA = n_o \sin \theta_a$ where θ_a is the acceptance angle of the maximum cone of light that can enter the fiber and n_o is the refractive index of the medium outside the fiber.

In the figure below, θ_c is the critical angle, n_f is the index of refraction of the fiber and n_c is the index of refraction of the cladding.

Numerical Aperture



$$\text{Full Acceptance Angle} = 2 \theta_a$$

Adapted from
<http://assets.newport.com/web600w-EN/images/1381509.gif>

Using geometry and trigonometry, it is possible to derive the following for large core fibers (Saleh, 2007):

$$NA = n_o \sin \theta_a = \sqrt{n_f^2 - n_c^2}$$

◆ Use this equation to check your mathematical reasoning with your conceptual reasoning in previous questions:

❖ What happens when $n_c = n_o$?

$\theta_a = 0$. All rays enter the cladding.

❖ What happens when $n_c > n_o$?

No possible θ_a . All rays refract into the cladding.

❖ We have seen that the media (core, cladding, outside) make a difference in the numerical aperture. Explain this difference carefully in terms of the indices of refraction, the acceptance angle, the angle of refraction at the end face, and the critical angle.

The numerical aperture is determined by the core and cladding. The acceptance angle is determined by core, cladding, and the outside. The greater the difference in the index of refraction between the core and cladding, the smaller the critical angle and the larger the acceptance angle.

D. Summary: Critical Angle, Acceptance Angle & Numerical Aperture

- In fiber optics transmission, there is interplay of optics principles in order to achieve the best possible result. Desired results will differ depending on the purpose of the use of fiber optics in medicine. Sometimes we only want to illuminate and view the inside of the body as in a colonoscopy or appendectomy, but there are cases where we want to cut or irradiate tissue as in laser surgery. To move forward we will sum up what we have learned so far:

1. The incident angle needed for TIR to occur depends on the critical angle. TIR will only occur when the incident angle at the core/cladding interface is greater than the critical angle. Smaller critical angles will allow TIR over a larger range of incident light angles at the end face of the fiber where the light comes in.
2. The differences in the indices of refraction of the media (core, cladding, and outside) determine the critical angle, the numerical aperture, and the acceptance angle. The greater the difference in index of refraction between the core and cladding, the smaller the critical angle and the