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Introduction to Fiberoptic Communications

Lecture 1

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Problems

1. Using simple ray theory, describe the mechanism for the transmission of light within an optical fiber. Briefly discuss with the aid of a suitable diagram acceptance angle for an optical fiber. Show how this is related to the fiber numerical aperture and refractive indices for the fiber core and cladding.

   An optical fiber has a numerical aperture of 0.20 and a cladding refractive index of 1.59. Determine :

a. The acceptance angle for the fiber in water which has a refractive index of 1.33;

b. The critical angle at the core-cladding interface

Problems

2. Define the relative refractive index difference for an optical fiber show how it may be related to the numerical aperture.

   A step index fiber with large core diameter compared with the wavelength of the transmitted light has an acceptance angle in air 22° and relative refractive index difference of 3%. Estimate the numerical aperture and the critical angle at the core-cladding interface for the fiber.

Problems

3. Explain what is meant by a graded index optical fiber, giving an expression for the possible refractive index profile. Using simple ray theory concept, discuss transmission of light trough the fiber. Indicate the major advantage of this type of fiber with regard to multimode propagation.

Problems

4. The relative refractive index difference between the core axis and the cladding of a graded index fiber is 0.7% when refractive index at the core axis is 1.45. estimate values for the numerical aperture of the fiber when :

a. The index profile is not taken into account ; and

b. The index profile is assumed to be triangular

Problems

5. The velocity of light in the core a step index fiber is 2.10X$10^8 ms^{-1}$, and the critical angle at the core-cladding interface is 80°. Determine the numerical aperture and the acceptance angle for the fiber in air, assuming it has a core diameter suitable for consideration by ray analysis. The velocity of light in vacuum is 2.998 X$10^8 ms^{-1}$

Problems

6. Skew rays are accepted into a large core diameter (compared to the wavelength of the transmitted light) step index fiber in air a maximum axial angle of 42°. Within the fiber they change direction by 90° at each reflection. Determine the acceptance angle for meridional rays for the fiber in air.

Problems

7. Briefly indicate with the aid of suitable diagrams the difference between meridional and skew ray path in step index fibers.

   Derive an expression 2γ at each reflection in a step index fiber in terms of the fiber NA and γ, it may be assumed that ray theory holds for the fiber.

   A step index fiber with a suitably large core diameter for ray theory considerations has core and cladding refractive indices of 1.44 and 1.42 respectively. Calculate the acceptance angle in air for skew rays which change direction by 150° at each reflection.

Problems

8. An optical fiber in air has an NA of 0.4. compare the acceptance angle for meridional rays with that for skew rays which change direction by 100° at each reflection. Therefore $\gamma = 50°$.

Problems

9. A silica optical fiber with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and cladding refractive index of 1.47.

Determine,

a. The critical angle at the core-cladding interface;

b. The NA for the fiber;

c. The acceptance angle in air for the fiber

Problems

10. A typical relative refractive index difference for an optical fiber designed for long distance transmission is 1%. Estimate the NA and the solid acceptance angle in air for the fiber when the core index is 1.46. further, calculate angle at the core-cladding interface within the fiber. It may be assumed that the concept of geometric optics hold the fiber.

Clue

- Numerical aperture:

$$NA = n_0 sin\theta_a = (n_1^2 - n_2^2)^{\frac{1}{2}}$$

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2}$$

$$\cong \frac{n_1 - n_2}{n_1} \quad \text{for } \Delta < 1$$

$$NA = n_1(2\Delta)^{\frac{1}{2}}$$

- For small angles the solid acceptance angle in air

$$\zeta \cong \pi\theta_a^2 = \pi \sin^2 \theta_a$$

- Then acceptance conditions for skew rays are :

$$n_0 \sin \theta_{as} \cos \gamma = (n_1^2 - n_2^2)^{\frac{1}{2}} = NA$$

- And in the case fiber in air (*$n_0 = 1$*)

$$\sin \theta_{as} \cos \gamma = NA$$

GOOD LUCK…