Module:6 Propagation of EM waves in Optical fibers

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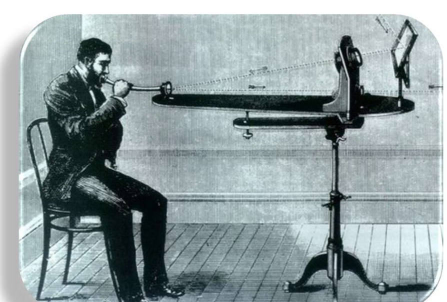
Module-6 Propagation of Electromagnetic waves in optical fibers

- Optical fiber
- Light propagation in optical fiber
- Acceptance angle and numerical aperture Type of fibers
- Attenuation and dispersion

1880 – Alexander Graham Bell

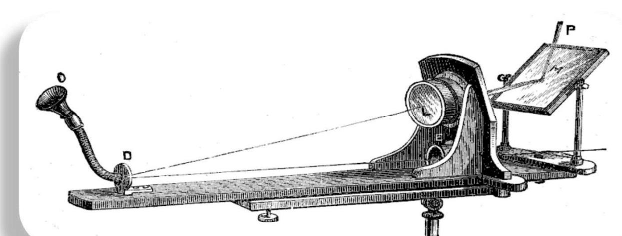


first practical application of transmitting information by bending light

Photophone - telecommunications device that allows transmission of speech on a beam of light

small mirror with light that vibrated to the sound

receiver that would in turn focus light on and off of crystalline selenium cells which would change their resistance
The first wireless data transmission in the world occurred from two rooftops over 700ft apart using this technology.



Advantages of Optical Fibre

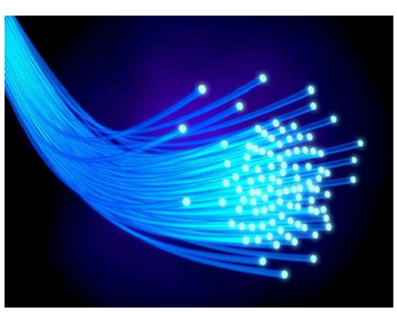
- ❑ Thinner, smaller in size
- ❑ Flexible, so can be bend
- ❑ Less Expensive
- ❑ Higher Carrying Capacity
- ❑ Less Signal Degradation & Digital Signals
- ❑ Light Signals
- ❑ Non-Flammable, non-conductive, non- radiative, non-inductive
- ❑ Light Weight
- ❑ No short circuit as in metals
- ❑ No need to ground, so no voltage problem

Areas of Application

- ❑ **Telecommunications**
- ❑ **Local Area Networks**
- ❑ **Cable TV**
- ❑ **CCTV (Closed-circuit television)**
- ❑ **Optical Fiber Sensors**

Optical fiber

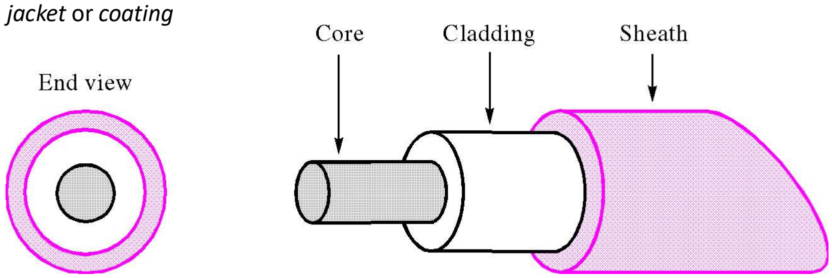
Optical fiber is a transparent, flexible cylindrical dielectric waveguide made of low loss materials (silica glass). It has a central core embedded in an outer cladding of slightly low refractive index



Structure of an optical Fiber

An optical fiber consists of 3 distinct parts:

1) Core : silica glass, SiO_2
2) Cladding: glass or plastic
3) Sheath: *jacket* or *coating*



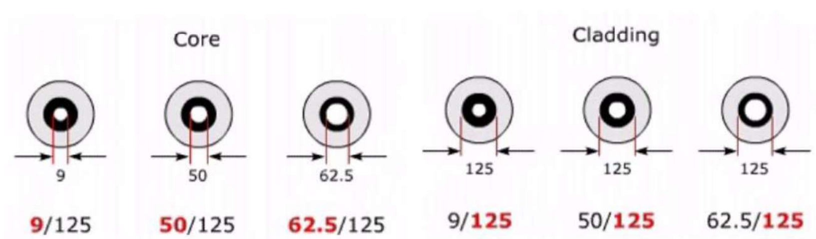
n_1 is refractive index of core
n_2 is refractive index of cladding

$n_1 > n_2$

Structure of Optical fiber

- ❑ The core and cladding act as an optical wave-guide.
- ❑ Core - it is a transmission area of fiber - typical core diameters range from 50 to 500 µm
- ❑ Cladding - it surrounds the core and *has a different index of refraction* less than the core.
- ❑ The size of the fibers are specified by the outer diameters of the core and cladding.
- ❑ A 50/150 fiber means that the core diameter is 50 µm while the outside dimension of both the core plus cladding together is 150 µm.
- ❑ The core and cladding are surrounded by the sheath.

What do the fiber terms 9/125, 50/125 and 62.5/125 (micron)?

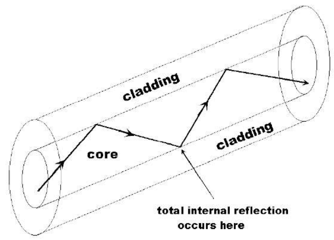


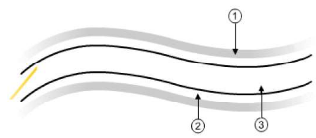
Remember: A **micron** (short for micrometer) is one-millionth of a meter

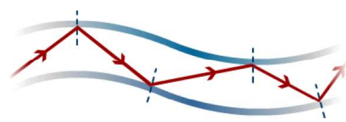
Typically n(cladding) < n(core)

Working principle of Optical fiber

Optical fiber works under the principle of total internal reflection







Optics basics

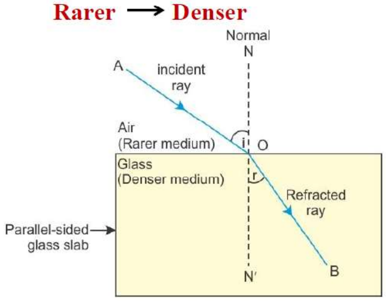
Rarer medium : medium with less refractive index (n_1)

Denser medium : medium with high refractive index (n_2)

($n_2>n_1$)

i is angle of incident and *r* is angle of refraction

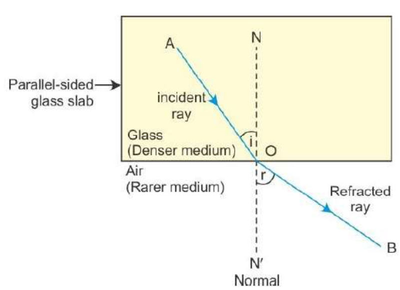
Rarer ⟶ Denser



The refracted ray bends towards the normal

(i > r)

Denser ⟶ Rarer

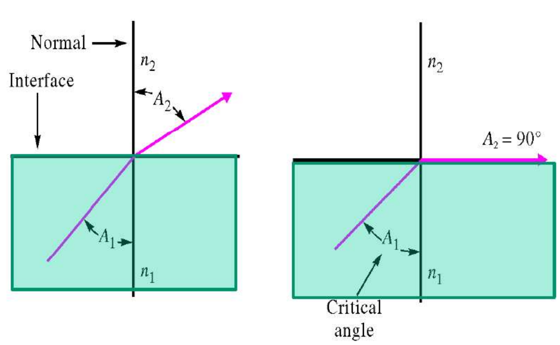


The refracted ray bends away from the normal

(i < r)

Critical angle

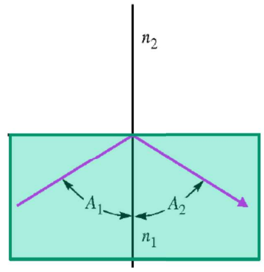
When a light ray passes from denser medium to a rarer medium, then the critical angle defined as the angle of incidence that will produce a 90° angle of refraction.



(A) (B)

Total Internal Reflection

The angle of incidence exceeds the critical angle, then the incident ray is reflected in the same medium and this phenomenon is called total internal reflection.



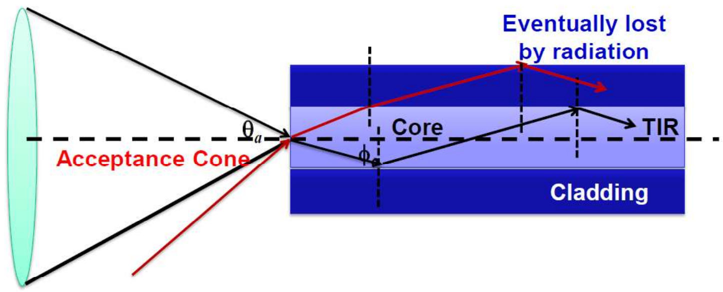
(C)

Condition for internal reflection

- **The ray of light should be traverse from denser to rare medium.**
- **The incident angle should be more than the Critical angle.**

ACCEPTANCE ANGLE

The maximum angle of incident with respect to the fiber core axis at the core-cladding interface, which allow to transmit the light in the fiber by total internal reflection.

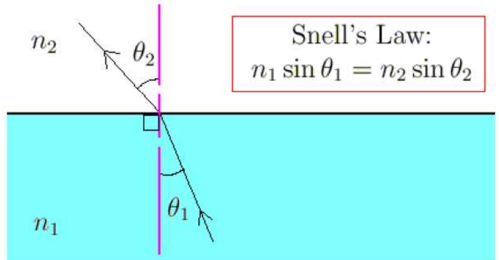


Acceptance cone : Multimode optical fiber will only propagates light that enters the fiber with in a certain cone known as acceptance cone of the fiber .

Half angle of the cone is the acceptance angle

- Any rays which are incident on into the fiber core at an angle greater than θ_a will be transmitted to the core-cladding interface at an angle less than ϕ_c and will not be totally internally reflected.
- Thus, for rays to be transmitted by total internal reflection within the fiber core they must be incident on the fiber core within an acceptance cone defined by the conical half angle θ_a.
- Hence, θ_a is the maximum angle to the axis at which light may enter the fiber in order to be propagated and is often referred to as the acceptance angle for the fiber.

Snell's law



θ_1 is incident angle in medium 1 and θ_2 is refracted angle in medium 2

The ratio of the sine angle of incident rays in medium 1 to the refracted rays in medium 2 is equal to the ratio of refractive index of medium 2 to that of medium 1

$$\boxed{\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}} \qquad \sin\theta_1 n_1 = \sin\theta_2 n_2$$

References

- Djafar K. Mynbaev and Lowell L.Scheiner, Fiber Optic Communication Technology, 2011, Pearson.
- Ajoy Ghatak and K. Thyagarajan, Introduction to Fiber Optics, 2010, Cambridge University Press.