Al-Mustaqbal University

Department (Biomedical Engineering)

Class (Third Stage)

Subject (Medical Optics)

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1st term – Lect. (Fiber Optics)

Fiber Optics

An optical fiber is a flexible transparent fiber made of high-quality extruded glass (silica) or plastic, slightly thicker than a human hair. It can function as a waveguide or “light pipe” to transmit light between two ends of the fiber. Optical fibers are widely used in fiber-optic communications where they permit transmission over long distances and at higher bandwidths than wire cables. Fiber are used instead of metal wires because signals travel along them with less loss and also immune to electromagnetic interference.

Advantages:

1. Less expensive
2. Thinner
3. Light weight
4. High carrying capacity
5. Less signal degradation
6. Flexible and strength
7. Immune to electrical and electromagnetic interference
8. Longer life than copper or coaxial cables

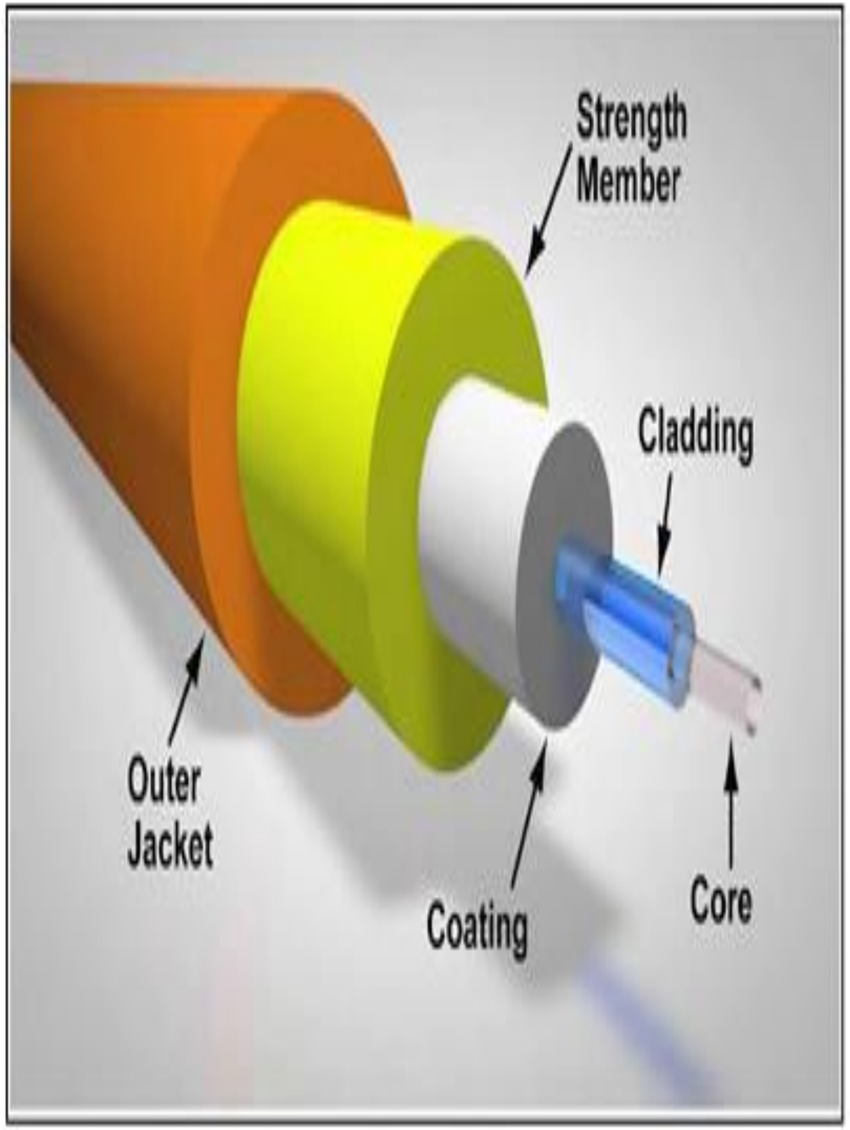
Disadvantages:

1. Limited bending radius
2. Sensitivity to radial forces
3. Complicated joining and contacting process

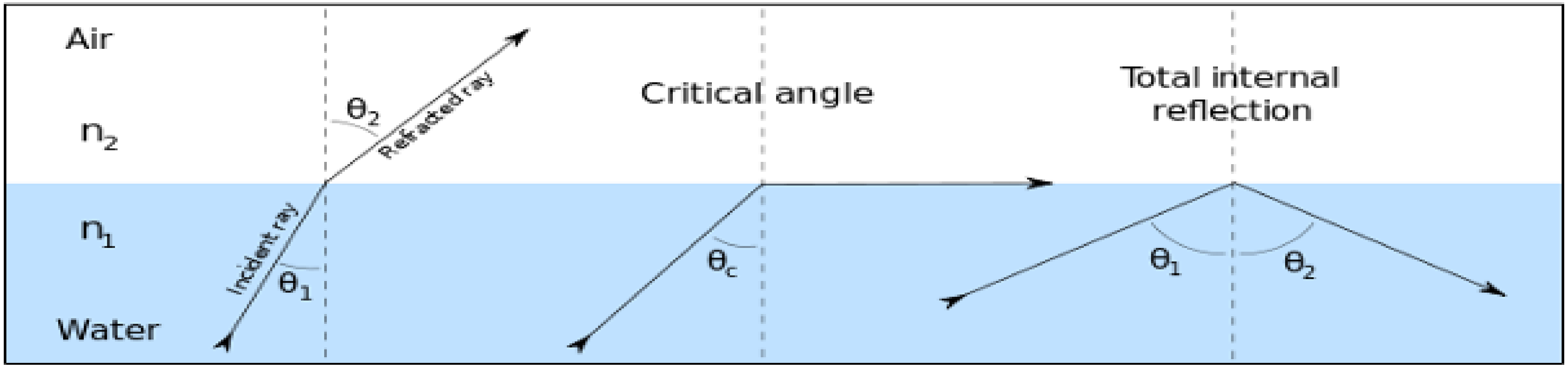
Optical fiber structure

A typical bare fiber consists of a core, cladding and polymer jacket (buffer coating). The dimensions of the core ranging from 5-50 micrometer, the cladding is about 125 micrometer and the jacket of 250 micrometer. The polymer coating is used for mechanical protection. The coating also reduces the internal reflection at the cladding so the light is only guided by the core only.

The core is made of a material of higher refractive index (n1) than the cladding of (n2).



When the light enters one end of the optical fiber , it travels from a dense medium towards rare medium with a finite angle. The light ray hits the core-cladding interface with an angle greater than the criticl angle and thus gets refelected at the interface due to total internal reflection. It suffers multiple total internal refelection the whole length of the fiber and finally emerges out of the other end of the fiber.



Snell's Law

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \qquad \sin\theta_c = \frac{n_2}{n_1}$$

Classifications of Optical Fiber

The optical fibers are classified depending on the

1. • refractive index profile (step-index and graded index)
2. • modes (single mode and multimode).

The modes of an optical fiber can be defined as the set of guided electromagnetic waves. The modes of the fibers depend on:

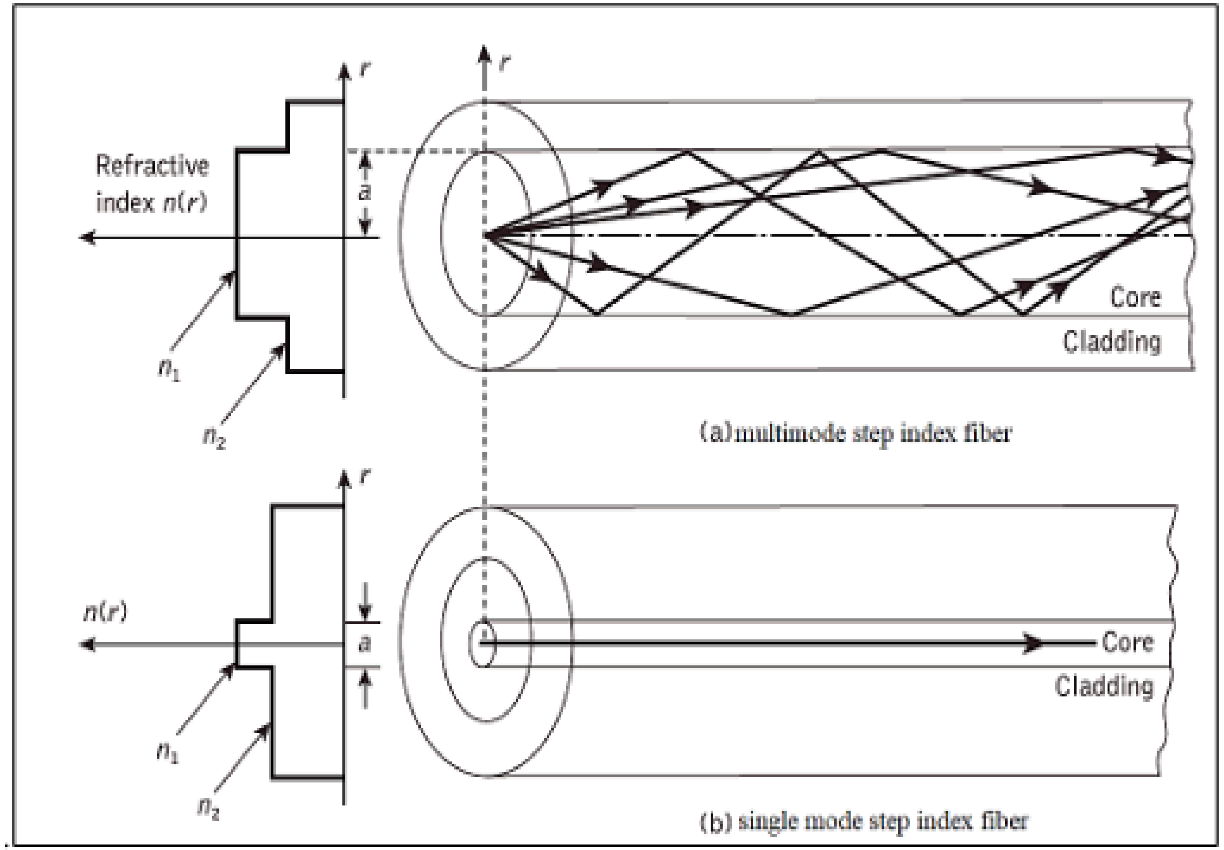
- Wavelength of the light passing through the fiber.
- The core diameter of the fiber.
- The material of the fiber.

1. Step- index optical fiber

The optical fiber has a core of constant refractive index n1 and a cladding of a slightly lower refractive index n2 is known as step index fiber. This is because the refractive index profile for this type of fiber makes a step change at the core cladding interface. The refractive index profile may be defined as:

$$n(r) = \begin{cases} n_1 & r < a\ (core) \\ n_2 & r \geq a\ (cladding) \end{cases}$$

Where ***r*** is the distance from the fiber axis and ***a*** is the radius of the core of optical fiber.



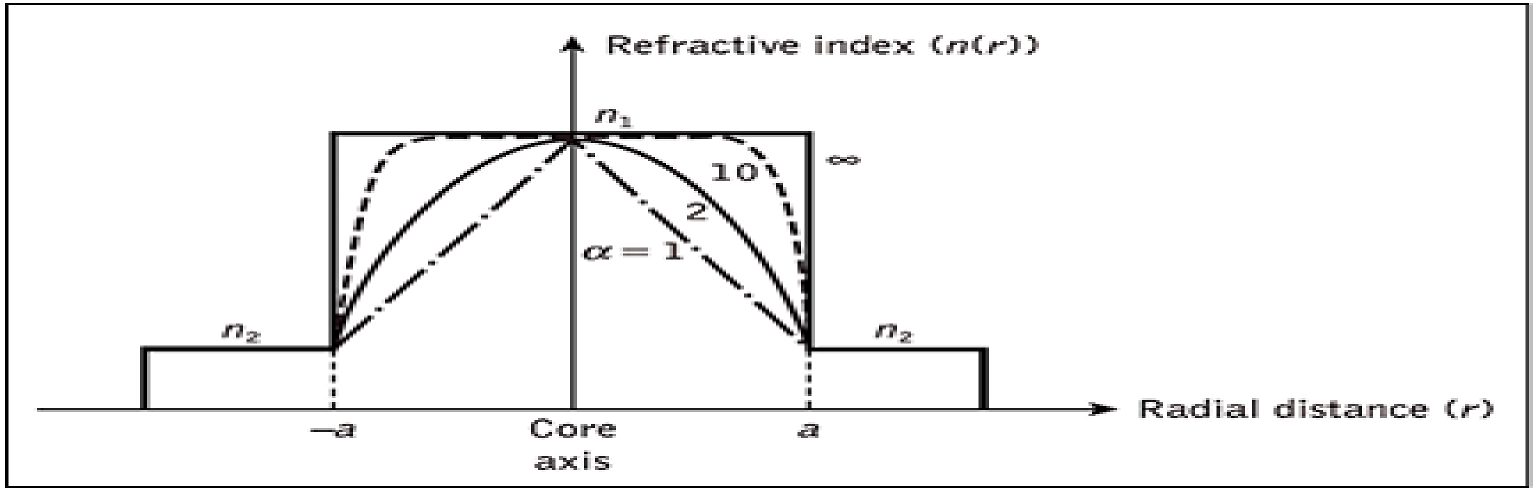
The multimode step index fiber with a core diameter of around 50 μm or greater, which is large enough to allow the propagation of many modes within the fiber core. In Figure above, many different possible ray paths through the fiber. The single mode or monomode step index fiber which allows the propagation of only one transverse electromagnetic mode and hence the core diameter must be of the order of 2 to 10 μm. The propagation of a single mode is corresponding to a single ray path only (usually shown as the axial ray) through the fiber.

2. Graded- index optical fiber

Graded index fibers do not have a constant refractive index in the core but a decreasing core index $n(r)$ with radial distance from a maximum value of n1 at the axis to a constant value n2 beyond the core radius a in the cladding. This index variation may be represented as:

$$n(r) = \begin{cases} n_1 \left(\sqrt{(1 - 2\Delta (r/a)^{\alpha}}\right) & r < a \ (core) \\ n_1 \sqrt{(1 - 2\Delta} = n_2 & r \geq a \ (cladding) \end{cases}$$

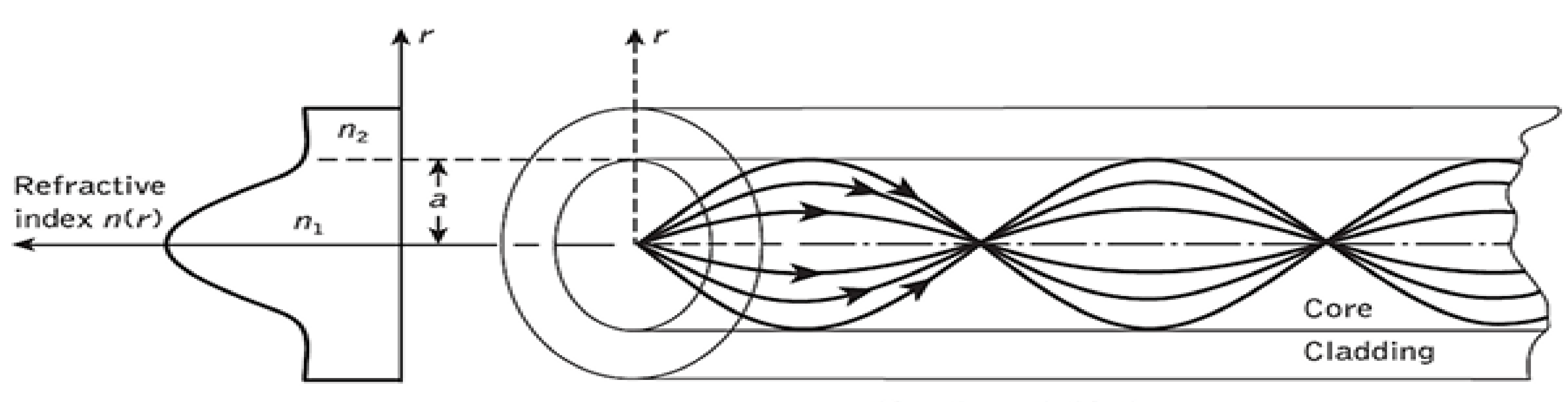
where Δ is the relative refractive index difference and α is the profile parameter which gives the characteristic refractive index profile of the fiber core.



When $\alpha = 1$, the refractive index falls linearly (triangular profile)

$\alpha = 2$ (parabolic profile)

$\alpha = \infty$ (step index profile)



multimode graded index

A multimode graded index fiber with a parabolic index profile core is illustrated in the Figure above. It may be observed that the meridional rays shown appear to follow curved paths through the fiber core. The gradual decrease in refractive index from the center of the core creates many refractions of the rays as they are effectively incident on high to low index interfaces. A ray is shown to be gradually curved, with an increasing angle of incidence, until the conditions for total internal reflection are met, and the ray travels back towards the core axis, again being continuously refracted.

Signal Degradation in Optical Fiber

The Signal Degradation in Optical Fiber is caused by:

1. attenuation or fiber loss. The intensity of the light pulse decreases as the pulses travel along the length of the fiber (usually is expressed in terms of dB/km).
2. dispersion and it does not involve loss of light intensity, but that do cause the pulse to broaden and to move out of its time slot