---Fiber Optics---

1- Introduction

Since its invention in the early 1970s, the use and demand for optical fibers has grown exponentially. The uses of optical fibers today are very numerous. With the explosion of information traffic due to the Internet, computer networks, multimedia, voice, data, and video, the need for a transmission medium with bandwidth capabilities to handle such vast amounts of information is critical.

2- Optical Fiber and Basic structure of optical fiber cable

An optical fiber is a cylindrical wave guide made of transparent dielectric, (glass or clear plastic), which guides light waves along its length by total internal reflection. It is very thin like human hair, approximately 10 μm to 1 mm.

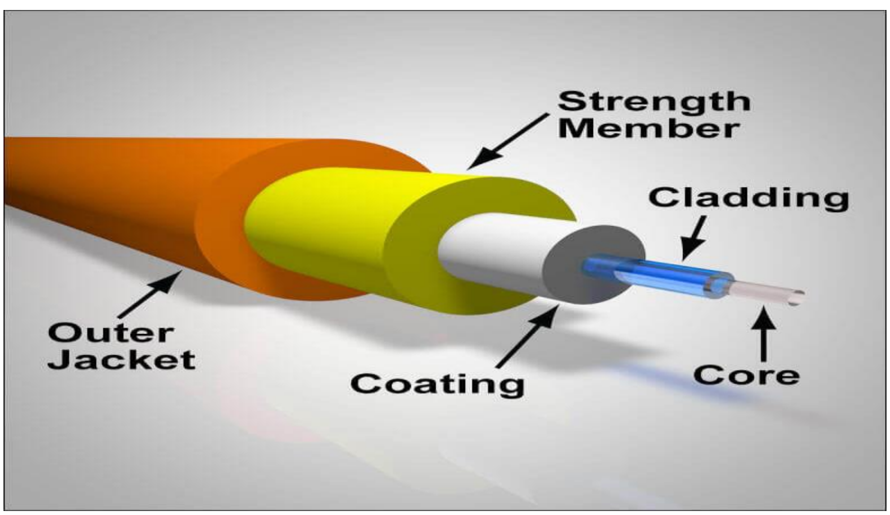


Figure: Structure of optical fiber

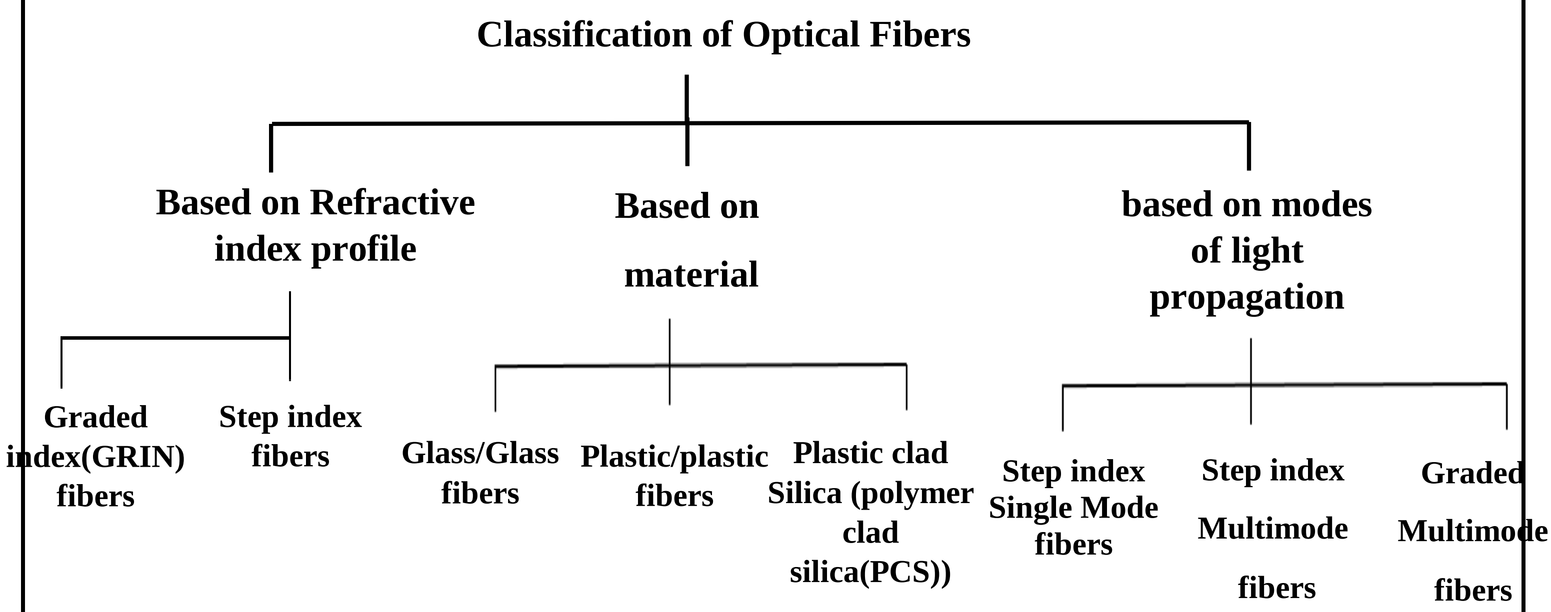
❖ *The basic structure of an optical fiber cable includes:*

a) Core: This is the central part of the fiber where the light travels. The core is made of high-purity glass or plastic, and it is designed to keep the light inside the fiber by using the principle of **total internal reflection**.

b) Cladding: This is a layer of material that surrounds the core and is designed to keep the light inside the core. The cladding is made of a material with a lower refractive index than the core, which means that when the light tries to escape from the core, it is reflected back into the core.

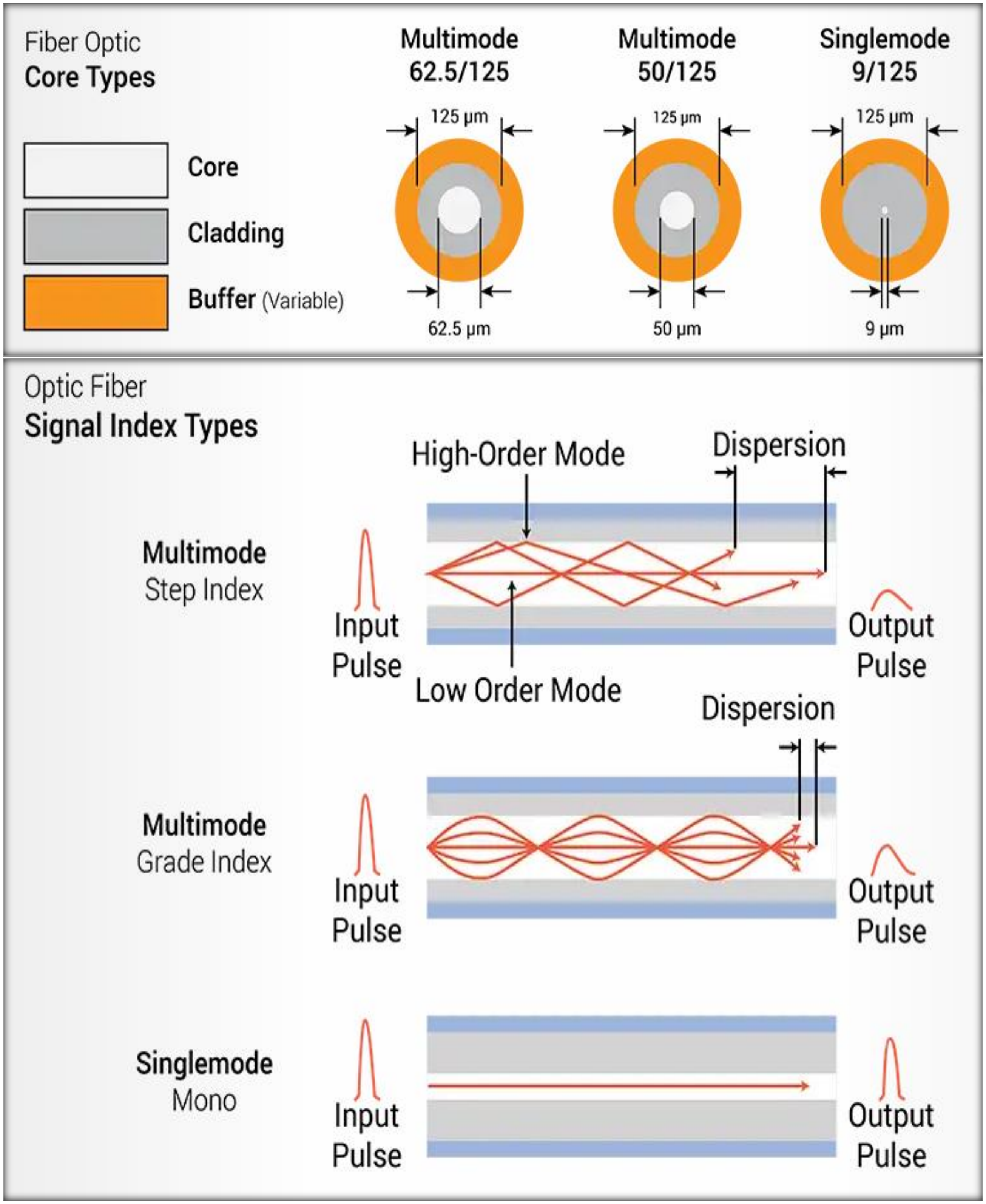
c) Coating: This is a protective layer that surrounds the cladding and helps to protect the fiber from damage. The coating is usually made of a plastic material, and it also provides some mechanical strength to the fiber.

3- Classification of Optical Fibers



❖ ***The three types of optical fibers are:***

1) **Step-index Single Mode** (Coupling more difficult, No modal dispersion, High data rate and Long distance).
2) **Step-index Multimode** (Easy coupling, Modal dispersion, Lower data rates and shorter distances).
3) **Graded-index (GRIN)** fiber (Easy coupling, Less modal dispersion, Good compromise between multimode and single-mode fiber).


Fiber Optic
Core Types
Core
Cladding
Buffer (Variable)
Multimode
62.5/125
125 µm
62.5 µm
Multimode
50/125
125 µm
50 µm
Singlemode
9/125
125 µm
9 µm
Optic Fiber
Signal Index Types
High-Order Mode
Dispersion
Multimode
Step Index
Input
Pulse
Low Order Mode
Output
Pulse
Dispersion
Multimode
Grade Index
Input
Pulse
Output
Pulse
Singlemode
Mono
Input
Pulse
Output
Pulse

4-Properties of Optical Fiber

a) Total internal reflection (TIR) is the phenomenon in which a ray of light traveling from a denser medium (a medium having higher refractive index) to a rarer medium (a medium having a lower refractive index) is reflected in the denser medium at the interface between the two media. **Total internal reflection** occurs when the refractive index of the core material n_1, slightly greater than that of the cladding n_2, and when the angle of incidence is greater than a certain angle, called a **critical angle**, then all of the light is reflected back into medium 1, a condition called **total internal reflection**. If the angle of incidence is equal to or less than the critical angle, then TIR will not occur.

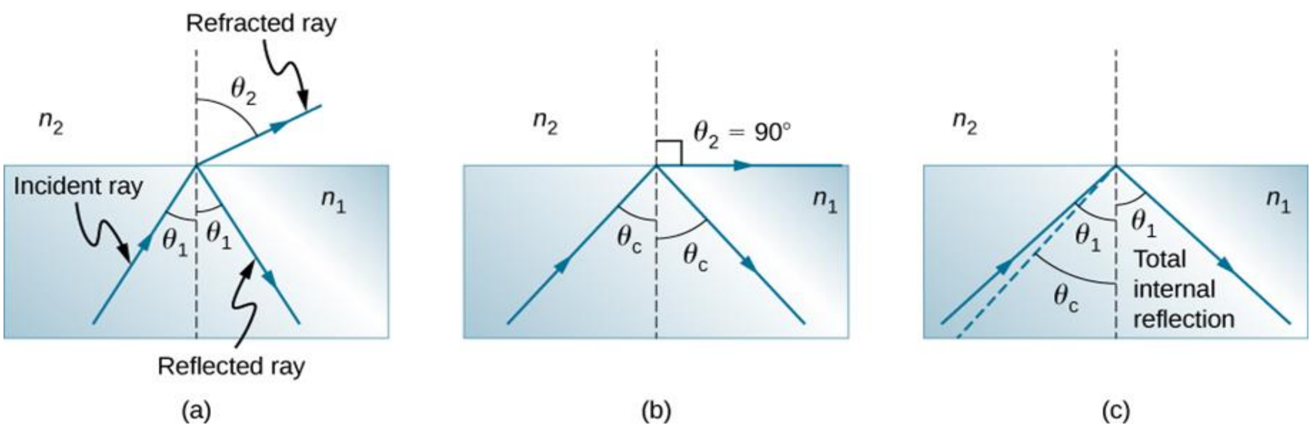


Figure: (a) A ray of light crosses a boundary where the index of refraction decreases. That is, $n_2 < n_1$. The ray bends away from the perpendicular. (b) The critical angle θ_c is the angle of incidence for which the angle of refraction is 90°. (c) Total internal reflection occurs when the incident angle is greater than the critical angle.

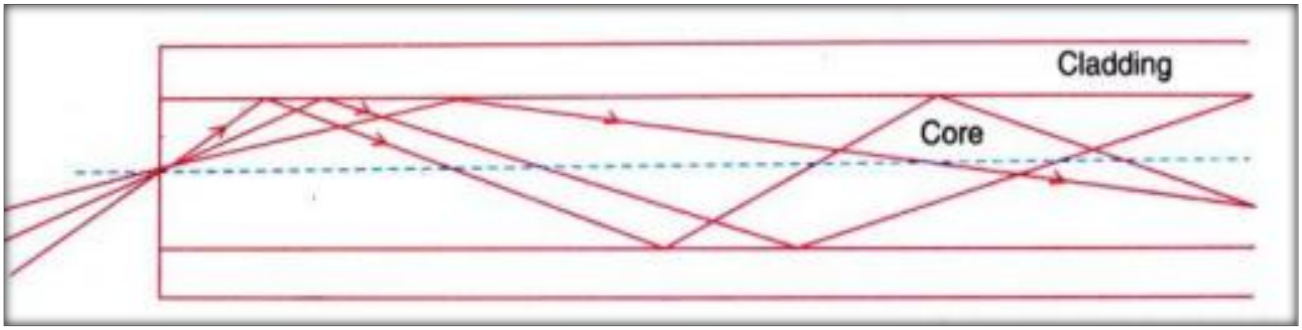


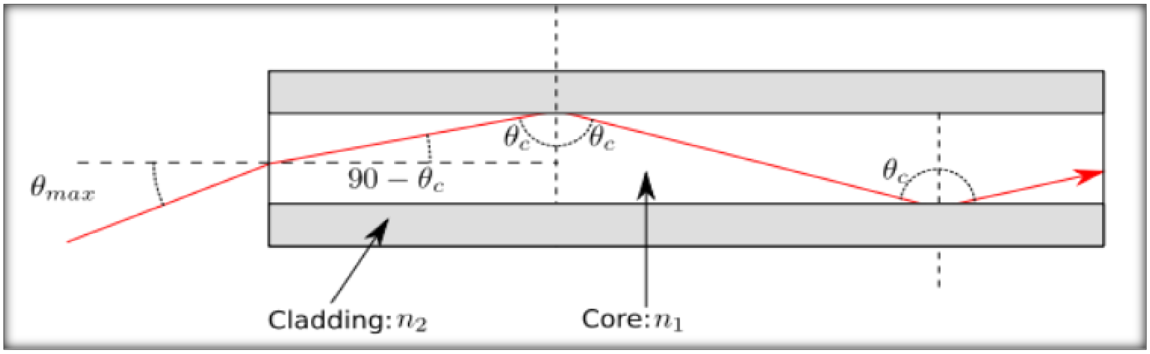
Figure: Propagation of Light through an Optical Fiber.

b) The critical angle θ_c for a combination of materials is defined to be the incident angle $\theta_1$that produces an angle of refraction of 90°. That is, θ_c is the incident angle for which θ_2= 90°. (As Figure shows, the reflected rays obey the **law of reflection** so that the angle of reflection is equal to the angle of incidence in all three cases).

Snell's law states the relationship between angles and indices of refraction. It is given by: $\mathbf{n_1 \sin\theta_1 = n_2 \sin\theta_2}$

When the incident angle equals the critical angle ($\theta_1 = \theta_c$), the angle of refraction is 90° (θ_2=90°). Noting that (sin 90°=1), Snell's law in this case becomes: $\mathbf{n_1 \sin\theta_1 = n_2} \longrightarrow \mathbf{\sin\theta_1 = \frac{n2}{n1}}$ $\mathbf{,(\theta_1 = \theta_c)} \longrightarrow \mathbf{\theta_c = \sin^{-1}(\frac{n2}{n1})}$

c)Numerical aperture (NA)



- There is a maximum angle of incidence θ_{max} that ensures light to remain inside the optical fiber.

$$NA = n1\sqrt{1-\frac{{n_2}^2}{n_1^2}}$$

Or,

$$NA = \sqrt{{n_1}^2 - {n_2}^2}$$

5-Advantages of Fiber Optics:

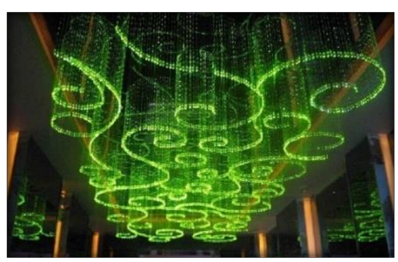
1. **High bandwidth**: Fiber optic cables have a much higher bandwidth capacity than copper wires, allowing for faster data transmission speeds.
2. **Low signal attenuation**: Optical signals experience less signal loss over long distances compared to electrical signals over copper wires,

which means that fiber optic cables can transmit data over much longer distances without the need for signal boosters.

3. **Immunity to electromagnetic interference**: Fiber optic cables are immune to electromagnetic interference, making them ideal for use in environments with high levels of electromagnetic interference, such as near power lines or in areas with high radio frequencies.
4. **Security**: Fiber optic cables are difficult to tap into or intercept, making them more secure than copper wires.
5. **Lightweight and flexible**: Fiber optic cables are lightweight and flexible, which makes them easier to install and handle compared to traditional copper wires.
6. **Resistance to environmental factors**: Fiber optic cables are more resistant to temperature changes, humidity, and other environmental factors that can affect traditional copper wires.
7. **Higher reliability**: Fiber optic cables are less prone to failure due to environmental factors or physical damage, making them more reliable for critical applications.

6-Application of Fiber Optics:

1.The Illumination:



2. Glow cables:

3. Interior light decorations with cold light:

4. Communication:

Some features of Fiber Optics in used in communication:

i. For short distance communication multi-mode fibers are used.
ii. For long distance communication single mode fiber is the only choice.
iii. The frequency for single mode fiber is selected such that minimum absorption takes place in the core medium.
iv. Small core diameter, single mode fibers use laser source.

- **What is an optical fiber communication system?**

The main parts of the optical fiber communication system are:

1. The transmitter. (The heart of a transmitter is a light source usually LEDs (Light Emitting Diodes) or laser diodes (LDs).

2. The fiber. (The transparent flexible filament that guides light from a transmitter to a receiver).
3. The receiver. (The main component of an optical receiver is its photo-detector).

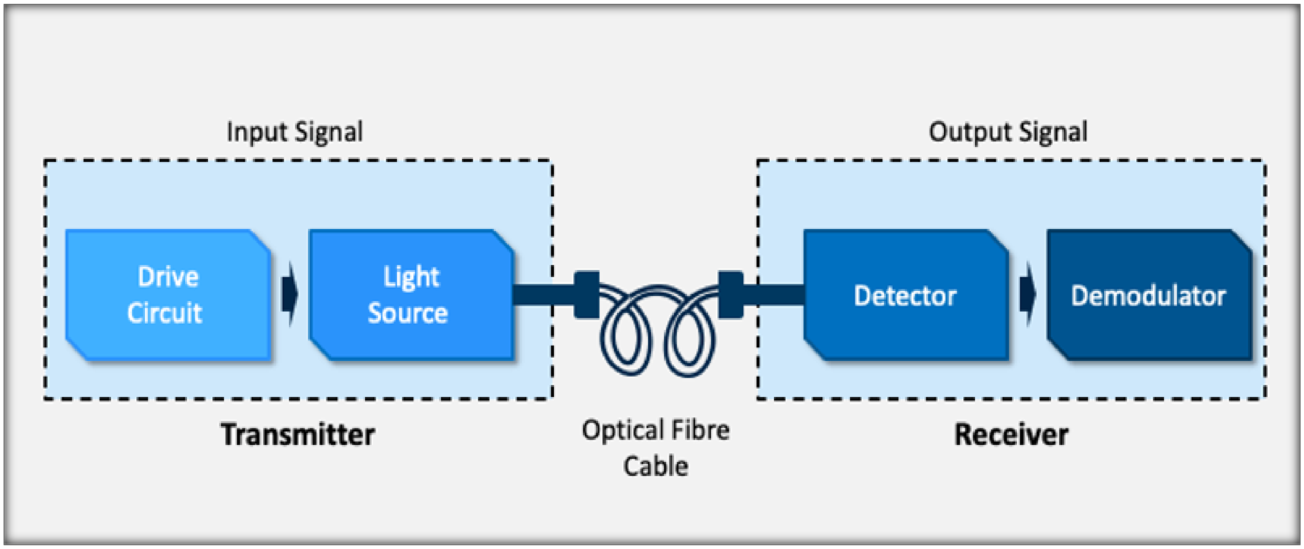


Figure: Fiber Optic Communication System.

In an optical fiber communication system, data is transmitted in the form of light pulses through the optical fiber, offering advantages such as high bandwidth, low signal attenuation, and immunity to electromagnetic interference. This makes it the preferred choice for long-distance and high-speed communication.