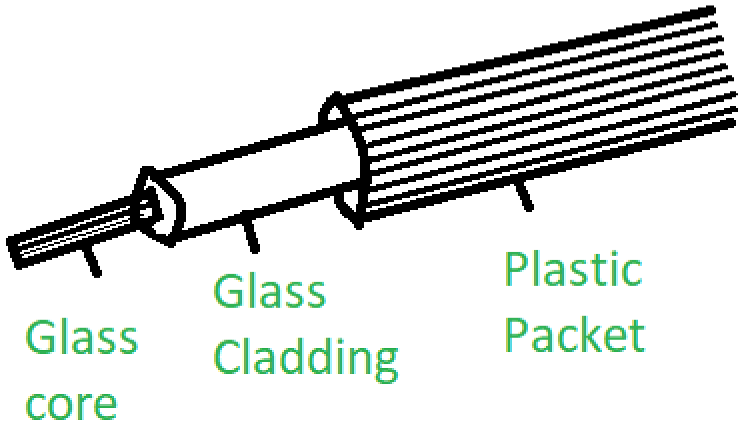
FIBER OPTICS AND TYPES

Dr. A. ABBAS MANTHIRI
Assistant Professor of Physics
Jamal Mohamed College(Autonomous)
Tiruchirappalli - 20

Fiber Optics and Types

- An Optical Fiber is a cylindrical fiber of glass which is hair thin size or any transparent dielectric medium
- The fiber which is used for optical communication is waveguides made of transparent dielectrics



Main element of Fiber Optics:

- **Core:**

  It is the central tube of very thin size made of optically transparent dielectric medium and carries the light transmitter to receiver and the core diameter may vary from about 5um to 100 um.

- **Cladding:**

  It is outer optical material surrounding the core having reflecting index lower than core and cladding helps to keep the light within the core throughout the phenomena of total internal reflection.

- **Buffer Coating:**

  It is a plastic coating that protects the fiber made of silicon rubber. The typical diameter of the fiber after the coating is 250-300 um.

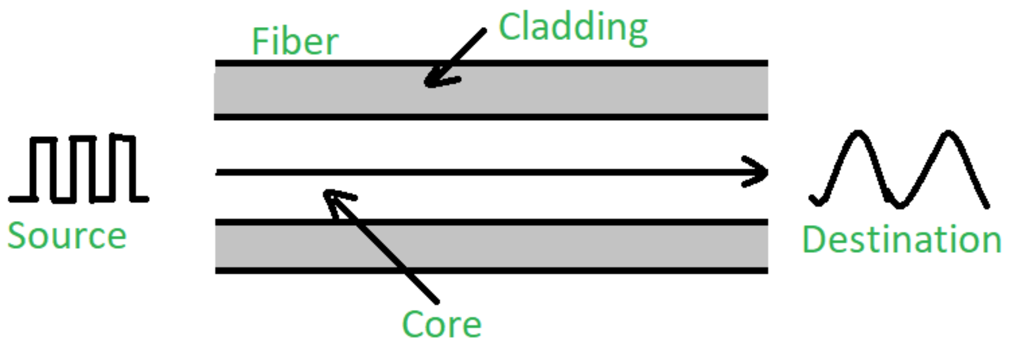
Types of Fiber optics:

Generally optical fiber is classified into two categories based on: the number of modes, and the refractive index. These are explained as following below.

➢ On the basis of the Number of Modes: It is classified into 2 types:

- Single-mode fiber
- Multi-mode fiber

➢ Single-mode fiber:

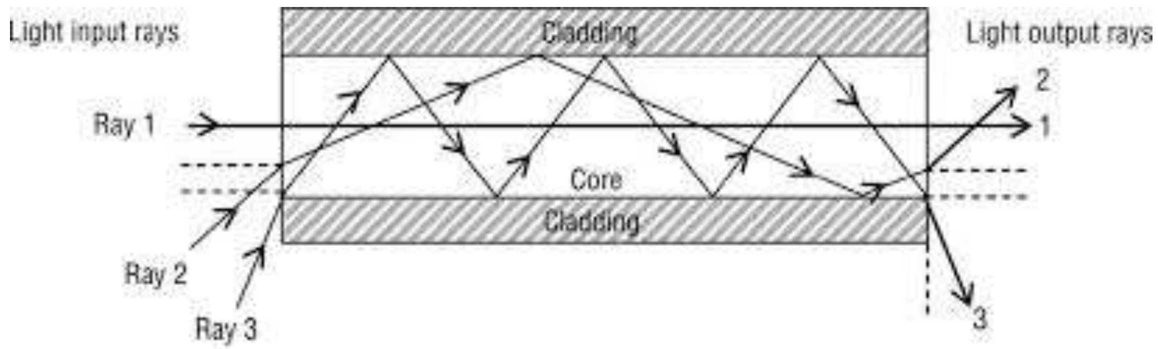


- In single-mode fiber, only one type of ray of light can propagate through the fiber.

- This type of fiber has a small core diameter (5um) and high cladding diameter (70um) and the difference between the refractive index of core and cladding is very small

- There is no dispersion i.e. no degradation of the signal during traveling through the fiber. The light is passed through it through a laser diode.

➢ Multi-mode fiber:



- Multimode fiber allows a large number of modes for the light ray traveling through it

- The core diameter is generally (40um) and that of cladding is (70um). The relative refractive index difference is also greater than single mode fiber

- There is signal degradation due to multimode dispersion. It is not suitable for long-distance communication due to large dispersion and attenuation of the signal

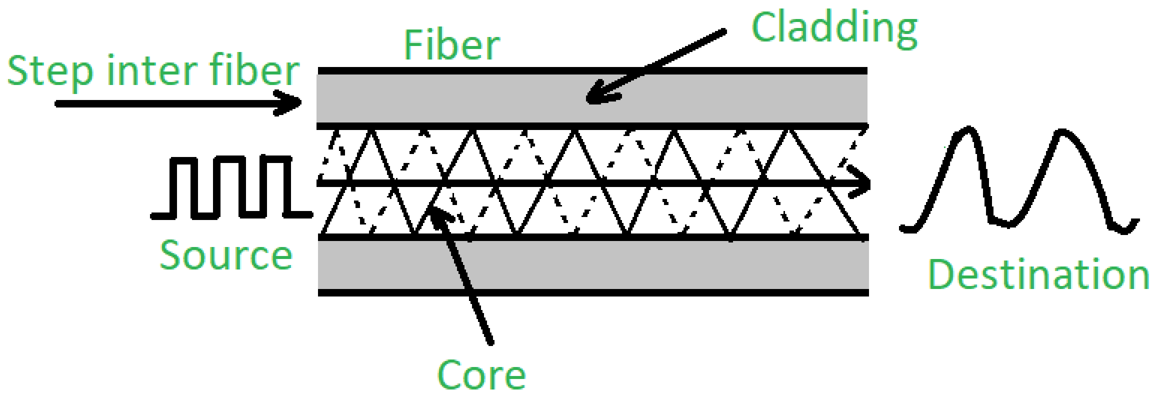
The number of propagating modes $N = \left[\frac{\pi d}{\lambda}\sqrt{n_1^2 - n_2^2}\right]^2$

- There are two categories on the basis of Multi-mode fiber i.e.**Step Index Fiber** and **Graded Index Fiber**. Basically these are categories under the types of optical fiber on the basis of **Refractive Index**

- On the basis of Refractive Index : It is also classified into 2 types:

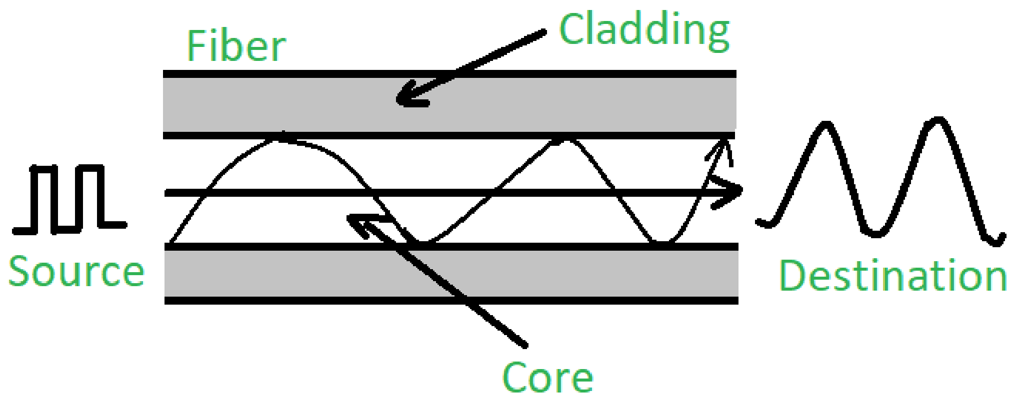
    - Step-index optical fiber
    - Graded index optical fiber

- **Step-index optical fiber :**



- The refractive index of core is constant. The refractive index of the cladding is also constant
- The rays of light propagate through it in the form of meridional rays which cross the fiber axis during every reflection at the core-cladding boundary

➢ Graded index optical fiber :



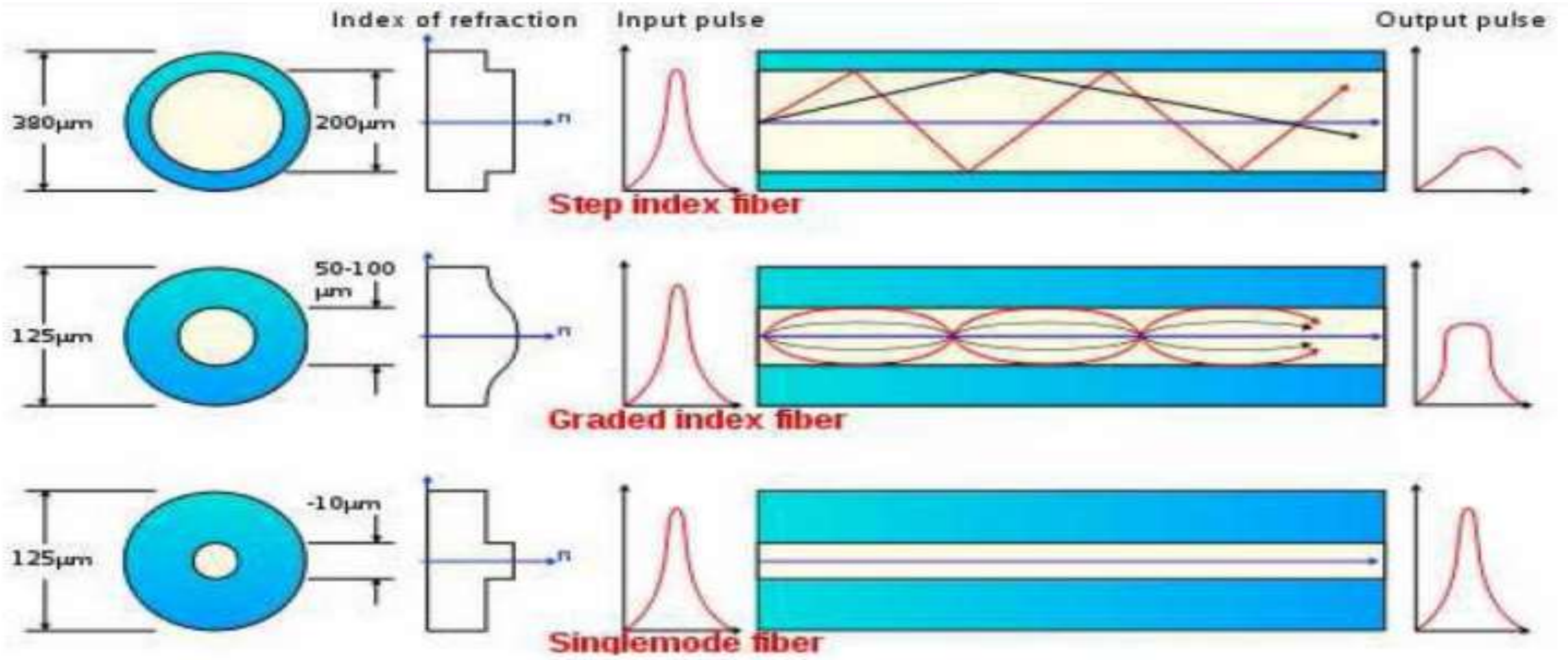
- In this type of fiber, the core has a non-uniform refractive index that gradually decreases from the center towards the core-cladding interface

- The cladding has a uniform refractive index

- The light rays propagate through it in the form of skew rays or helical rays. it is not cross the fiber axis at any time

Optical Fiber Index Profile

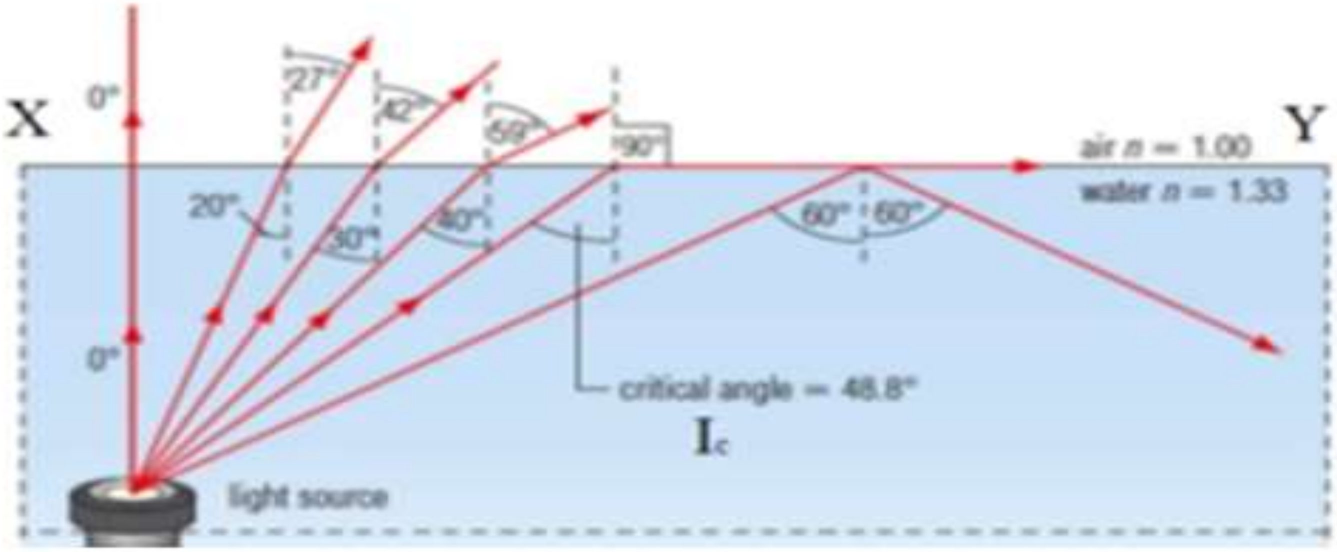
- Index profile of an optical fiber is a graphical representation of the magnitude of the refractive index across the fiber
- Some optical fiber has a step index profile, in which the core has one uniformly distributed index and the cladding has a lower uniformly distributed index
- Other optical fiber has a graded index profile, in which refractive index varies gradually as a function of radial distance from the fiber center
- Graded-index profiles include power-law index profiles and parabolic index profiles. The following figure shows some common types of index profiles for single mode and multimode fibers.



Construction:

It consists of a very thin fibre of silica or glass or plastic of a high refractive index called the core. The core has a diameter of 10 μm to 100 μm. The core is enclosed by a cover of glass or plastic called cladding. The refractive index of the cladding is less than that of the core (which is a must condition for the working of the optical fibre). The difference between the two indices is very small of order 10-3. The core and the cladding are enclosed in an outer protective jacket made of plastic to provide strength to the optical fibre. The refractive index can change from core to cladding abruptly (as in step-index fibre) or gradually (as in graded-index fibre).

Total Internal Reflection of Light and its Explanation:



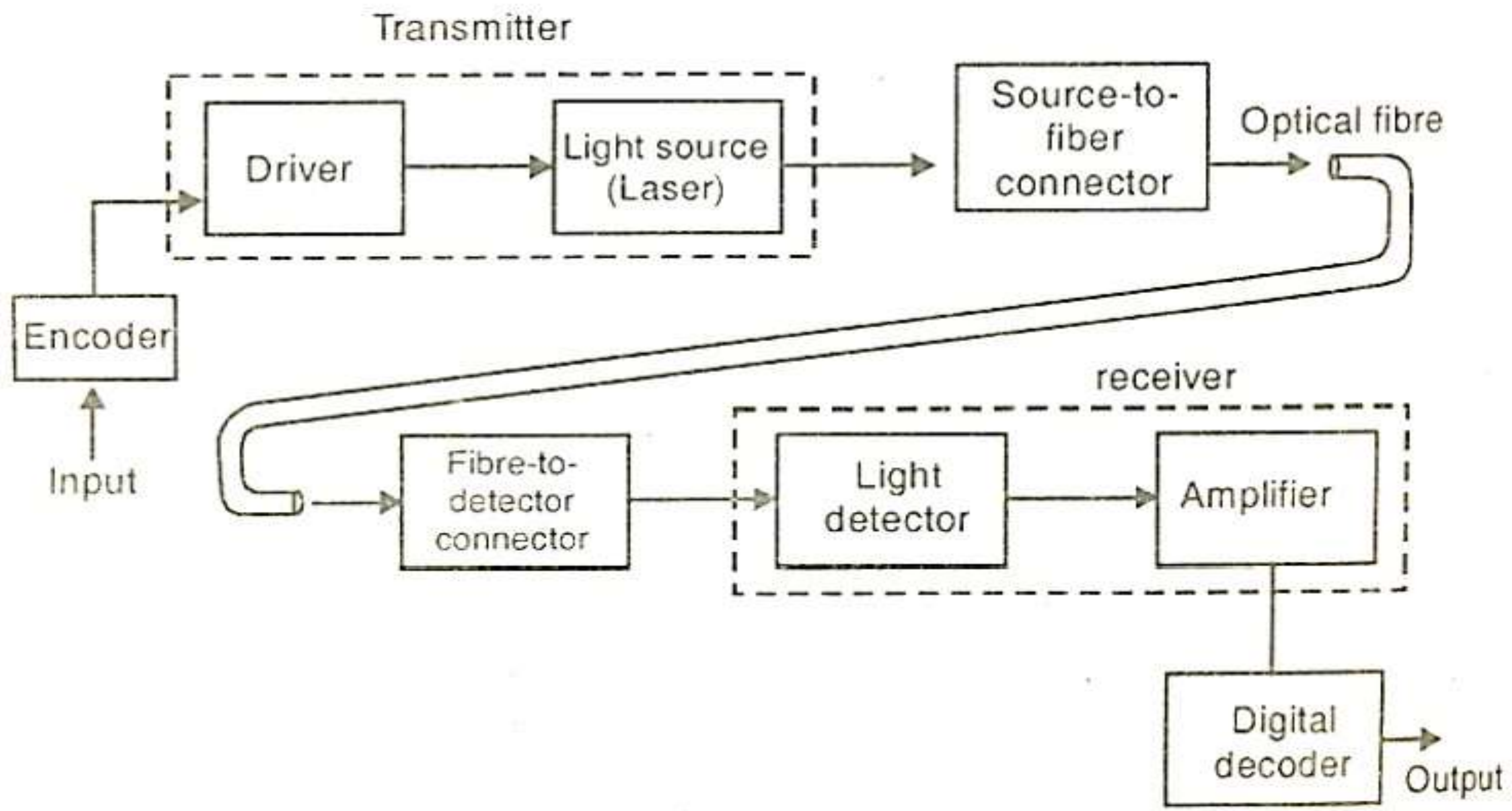
Let us consider a point source O in an optically denser medium (Water or medium with higher refractive index). Let XY be the boundary separating the optically denser medium (Water or medium with lower refractive index). As the angle of incidence increases, the angle of refraction also increases. At a particular angle of incidence i_C, the angle of refraction is 90° and hence the refracted ray moves along the surface of water i.e. along XY.

If the angle of incidence is more than i_C, there is no refracted ray, the incident ray is completely reflected back in the water (or medium with higher refractive index)). This phenomenon is known as total internal reflection.

The critical angle is the minimum angle of incidence when the total internal reflection of light takes place

THE FIBER OPTIC COMMUNICATION SYSTEM

Figure shows the schematic diagram of a fiber optic communication system



The major components of an optical fiber communication system are

- The optical transmitter
- The optical fiber
- The optical receiver

Principle:

- Basically, a fiber optic system converts an electrical signal to an infrared light signal
- This signal is transmitted through an optical fiber. At the end of the optical fiber, it is reconverted into an electric signal

Working:

- Encoder encodes the information in the binary sequence zeros and ones
- Encoder is an electric circuit where in the information is encoded into binary sequences of zeros and one. In the light wave transmitter each ‘one’ corresponds to an electrical pulse and ‘zero’ corresponds to an absence of a pulse
- These electrical pulses are used to turn a light source on and off very rapidly. The driver converts the incoming electrical signal into a form that will operate with the light source.

- The optical fiber acts as a wave guide and transmits the optical pulses towards the receiver, by the principle of total internal reflection

- The light detector receives the optical pulses and converts them into electrical pulses. These signals are amplified by the amplifier

- The amplified signals are decoded by the decoder

LOSSES IN OPTICAL FIBERS

When light propagates through an optical fiber, a small percentage of light is lost through different mechanisms. The loss of optical power is measured in terms of decibels per km for attenuation losses.

ATTENUATION:

It is defined as the ratio of optical power output (Pout) from a fiber of length ‘L’ to the power output (Pin)

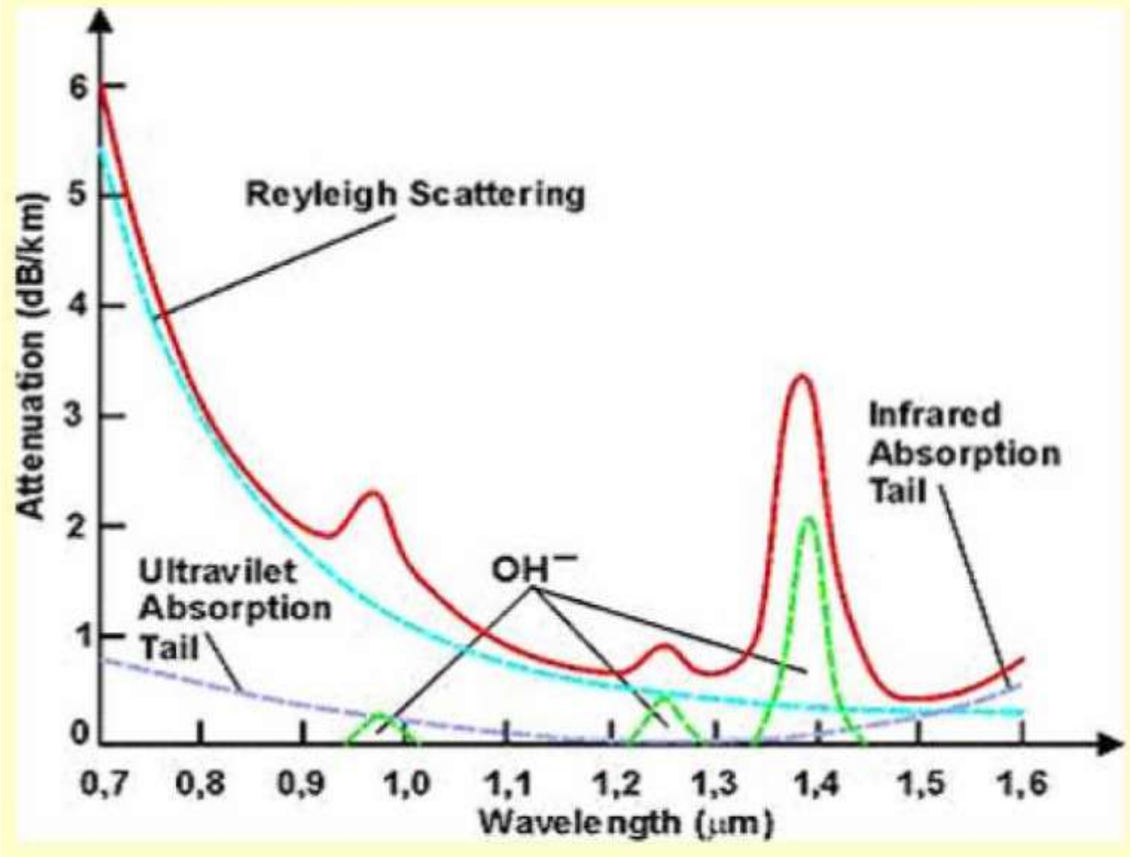
$$\text{Attenuation}\ (\alpha) = \frac{-10}{L}\log\frac{P_{in}}{P_{out}}\ dB/Km$$

Since attenuation plays a major role in determining the transmission distance, the following attenuation mechanisms are to be considered in designing an optical fiber.

Absorption Losses: The absorption losses in optical fibers due to three factors, UV, IR and ion resonance

UV absorption

It is caused by valence electrons in the silica materials from which fibers are manufactured. Light ionizes the valence electrons into conduction. The ionization is equivalent to a loss in the total light field and consequently, contributes to the transmission losses of the fiber



IR absorption

IR absorption is a result of photons of light that are absorbed by the atoms of the glass core molecules. The absorbed photons are converted to random mechanical vibrations typical of heating

Ion resonance absorption

Ion resonance absorption is caused by OH^- ions in the materials. The source of the OH^- ions in water molecules that have been trapped in the glass during the manufacturing process. Iron, copper and chromium molecules also cause ion absorption

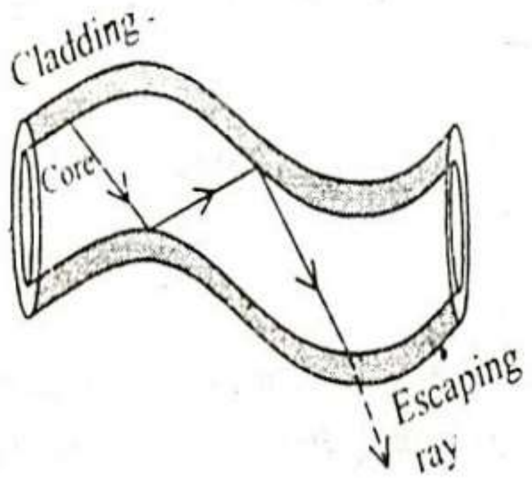
Material or Rayleigh scattering losses

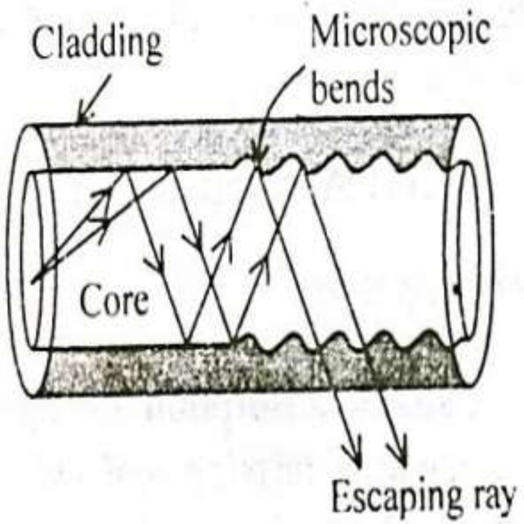
Scattering losses due to sub microscopic irregularities in optical fiber. Light ray are diffracted when it fall on the irrugularties. The light disperse in many directions. Some of the diffracted light continues in the fiber, and some of it escaper through the cladding. The escaped light rays represent a loss in light power. This is called Rayleigh scattering loss.

Radiation losses

Radiative loss occurs in fibers due to bending of finite radius of curvature in optical fibers. The types of bends are

a. Macroscopic bends   b. Microscopic bends





Macroscopic bends:

If the radius of the core is large compared to fiber diameter, it may cause large-curvature at the position where the fiber cable turns at the corner. At these corners the light will not satisfy the condition for total internal reflection and hence it escapes out from the fiber. This is called as macroscopic / macro bending losses. Also note that this loss is negligible for small bends

Microscopic bends:

Micro-bends losses are caused due to non-uniformities or micro bends inside the fiber as shown. This micro bends in fiber appears due to non uniform pressures created during the cabling of the fiber or even during the manufacturing itself. This lead to loss of light by leakage through the fiber.

Coupling Losses

In fiber optic system, in coupling loss, fiber coupler will act as a loss in that Fiber Optic System. Fiber coupler used for couple two fiber cable. During this coupling process some light signal was loss in that Fiber Optic System, which is known as coupling loss.