UNIT – II LASER AND FIBER OPTICS

TOPIC – VII: Types of optical fibres (material, refractive index, mode)

Optical fibers are classified into three major types based on (a) material (b) the number of modes and (c) the refractive index profile.

Classification based on material used

Optical fibers are generally made from two basic materials.

(i). *Glass fiber* and

(ii). *Plastic fiber*

Glass fiber

If the optical fiber is made from fusing mixtures of metal oxides and silica glasses, it is known as glass fiber.

Examples

(i). GeO_2 - SiO_2 core, SiO_2 cladding

(ii). SiO_2 core, P_2O_3 - SiO_2 cladding

Plastic fiber

Plastic fibers are typically made of plastic.

Examples

1. Polystrene core, methylmetha crylate cladding
2. Polymethylmetha crylate core, co - polymet cladding

They are cheap and flexible. They exhibit considerably greater attenuation than glass fibers. Plastic fibers may be handled without special care due to its toughness and durability.

Classification based on the number of modes

Depending on the number of modes of propagation, optical fibers are classified as:

(i). *Single mode fiber*

(ii). *Multimode fiber*

Single mode fiber

If only one mode is transmitted through an optical fiber it is said to be a single mode

fiber. It is designed to have small index difference between the core and cladding, and its core diametre is of the order of a few times the wavelength of light.

The single mode fiber must be excited with laser diodes.

Multimode fiber

If more than one mode is transmitted through an optical fiber, it is said to be a multimode fiber.

Multimode offers several advantages over single mode fibers. The large core radii of multimode fiber makes it easier to launch optical power into the fiber and facilitates the end - to end connection of similar fibers.

Classification based on the refractive index profile

Refractive index Profile

In any optical fiber, the cladding has a uniform refractive index. However, the refractive index of the core may either remain constant or vary in a particular way.The curve that denotes the variation of refractive index with respect of the radial distance from the axis of the fiber is called the **refractive index profile.**

Optical fibers may be classified into two types based on the comparison of refractive indices of cladding and core materials.

(i). *Step - index fiber*

(ii). *Graded - index fiber*

Step index fiber

In step index fiber, the variation in refractive indices of core and cladding is done step by step.(Fig .4 a)

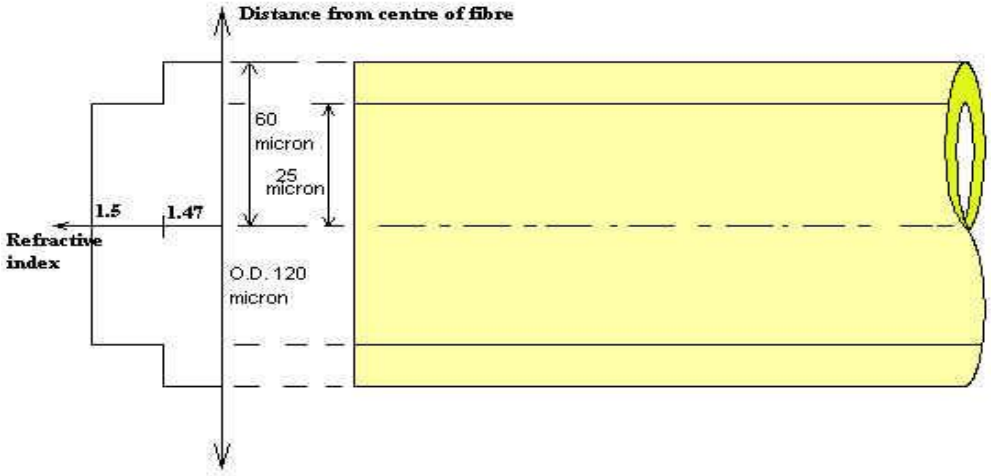

Fig .4 a Step index fiber

Graded index fiber

In graded index fiber, the variation in refractive index of the core is related to the radial distance from the fiber axis. Refractive index is maximum at the fiber axis and minimum at the core cladding interface. (Fig .4 b)

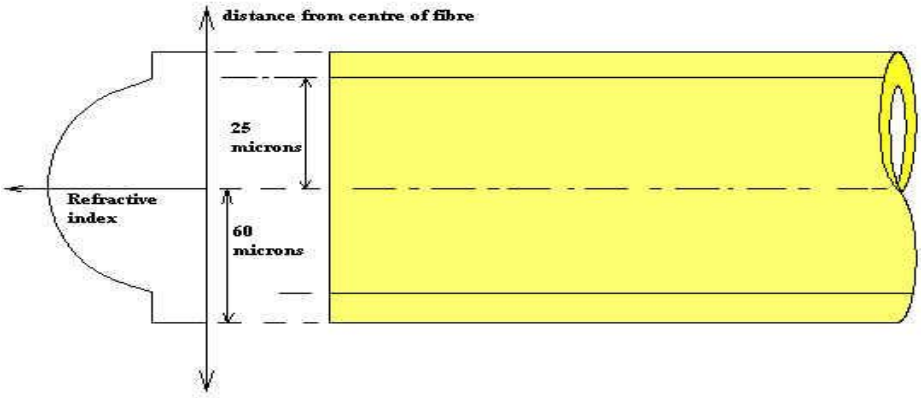

Fig .4 b Graded index fiber

Types of optical fibers based on the refractive index profile and the number of modes

Optical fibers may be classified depending on the refractive index profile and the number of modes

(i). *Single mode step index fiber*

(ii). *Multimode step index fiber*

(iii). *Multimode graded index fiber*

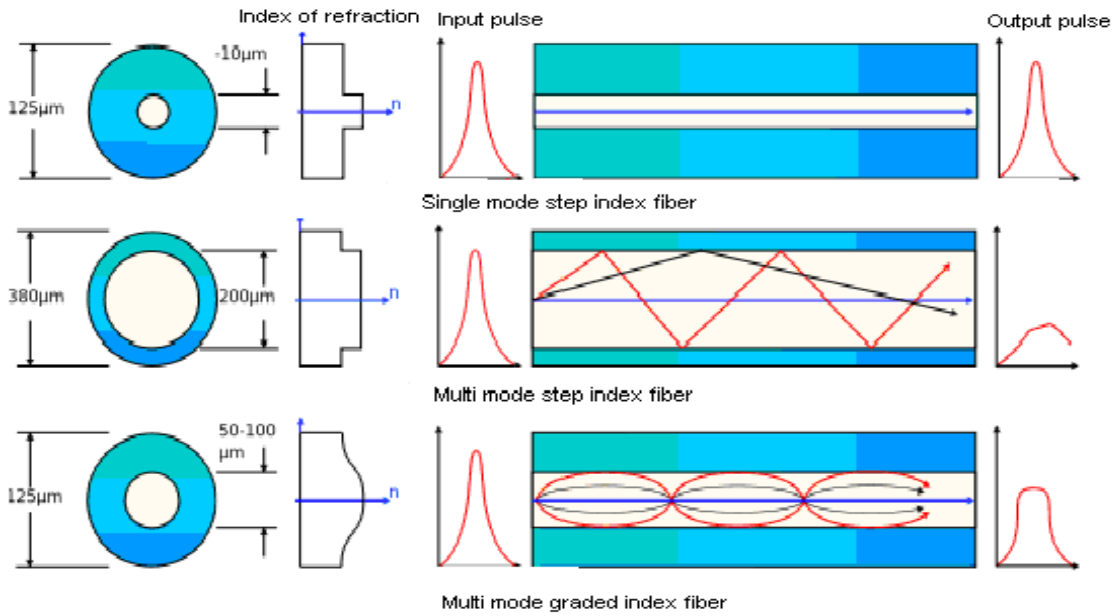

Fig .5 Light propagation through different types of fibers

Single mode step index fiber

The basic structure of a single mode step index fiber is shown in Fig.15.5. It

consists of thin core of uniform refractive index of a higher value. The core is surrounded by a cladding of uniform refractive index lesser than that of the fine core (Fig.5).

As the refractive index changes abruptly (or in step) at the core - cladding boundary, its refractive index profile takes the shape of a step .A typical step index single mode fiber may have a core diameter of 5 to 10 μm and external diameter of cladding 50 to 125 μm (Fig.5). Due to its small core diameter, only a single mode of light ray transmission is possible.

Characteristics of single mode step index fiber

The chief characteristics of single mode step index fiber are as follows:

- It has a very small core diameter.
- Its numerical aperture is very small.
- It supports only one mode in which the entire light energy is concentrated.
- Because of a single mode of propagation of light, the modal dispersion loss is completely eliminated.
- It has very high bandwidth.
- Light is passed into the single mode fiber through laser diodes.

Advantages

- It has a very high capacity.
- About 80% of optical fibers manufactured in the world today are of this type.

Disadvantages

In spite of its so many advantages, the manufacturing and handling of this type of fiber is very expensive.

Applications and Uses

- This type of fiber is used as under - sea cable
- It finds particular application in submarine cable system.
- It is used in long distance telephone.

Multimode step index fiber

The geometry of normal cross -section of a typical step index multimode fiber is shown in (Fig.5). Its core has a much larger diameter, which makes it easier to support propagation of a large number of modes.

It has a core material with uniform refractive index and a cladding material o lesser refractive index than that of the core.

There is a sudden increase in the value of refractive index from cladding to core. Thus, its refractive index profile takes the shape of a step (Fig 15.5).

A typical multimode step index fiber has a core diameter of 50 to 200 μm and an external diameter of cladding 125 to 300 μm.

Because of larger diameter of the core, propagation of many modes within the fiber is allowed. This is explained in Fig(5) by many different possible light ray paths through the fiber.

Characteristics of multimode step index fiber

- Light can be launched into a multimode fiber using a light emitting diode.
- It has larger core diameter
- It has low bandwidth
- It has high numerical aperture
- It has high attenuation

Advantages

- Since LEDs are the source of light, they are easier to operate.
- They are less expensive and require less complex circuitry.
- They have longer life than laser diodes, thus making them more desirable in many applications.

Disadvantages

They suffer from intermodal dispersion loss or transmit time dispersion.

Application and uses

They are widely used in data links that require low bandwidth.

Multi mode graded index fiber (GRIN)

The geometry of normal cross - section of a typical graded - index fiber is shown in (Fig .5)

The typical multi mode graded index fiber has a core diameter of 50 to 200 μm and external diameter of cladding 100 to 250 μm. The refractive index of the core of maximum at the axis of the fiber and it gradually decreases towards the cladding. The refractive index profile is shown in (Fig .5).If the diameter of the core is high, the intermodal dispersion loss must be hogh. But, because of gradual decrease in the refractive index of the core, the intermodal dispersion loss is minimized. The light ray propagation for this fiber is shown in (fig 5.5)

Characteristics of multi mode graded index fiber

- It has an intermediate bandwidth.

- It has low attenuation.
- It has a small numerical aperture.
- The source of light is either laser or LED.

Advantages

- Intermodal dispersion can be reduced with this type of fiber
- It is a high quality fiber

Disadvantages

- It is most expensive of all types of fibers.
- Is splicing could be difficult

Applications and Uses

- It is widely used in intra - city trunks between central telephone offices.
- It is used in medium - distance applications.