F.Y.B.Sc.

Physics-I FIBRE OPTICS Unit-VI

1. What is Fiber Optics?

Ans: For communication purpose ,light beam is used for following reason :

- It's higher frequency of about 10^{15} Hz over radio waves (10^{6}Hz) and microwaves (10^{10} Hz).
- It has a huge information carrying capacity compared to radio and microwaves.

- An optical fiber is a thin, flexible pipe made up of a transparent hard glass/plastic.
- This pipe can guide the light beam through it when a beam of light enters one end of a fiber.
- Because of transparent glass the light beam is completely internally reflected.
- The full reflection, the optical or light energy gets trapped in the pipe.
- The information transmits through the fiber optics more than 10 Terabytes.

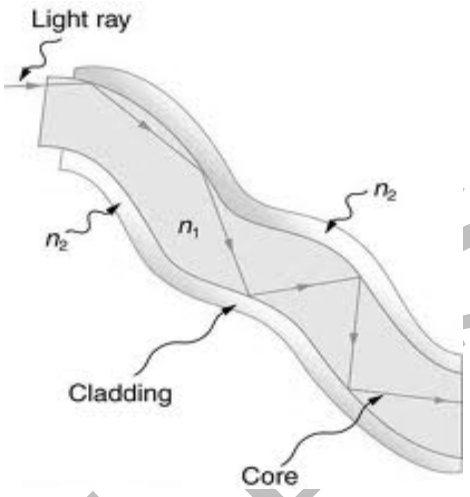
2. State the advantages of optical fiber transmission systems over conventional Copper wire system in telecommunications applications.

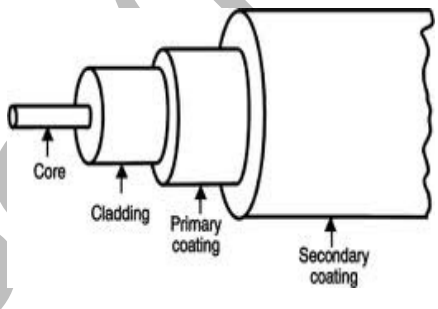
Ans:
1) Optical fibers have lower transmission losses and wider bandwidths as compared to copper wires.
2) The low weight and small hair sized dimensions of optical fibers offer a distinct advantages over heavy, bulky cable wires.
3) Optical fibers are dielectric in nature. Thus it is free from electromagnetic pulse effect.
4) Electromagnetic interference such as signal carrying wires and lighting not affects due to dielectric nature.
5) High degree of data security is afforded.
6) Silica, the principle material of which the optical fiber are made, is inexpensive.
7) Optic fibers have high information carrying capacity.

3. What are optical fibers? [Or] what do you mean by optical fiber? What is optical fiber?

Ans:

- An optical fiber is dielectric wave-guide that operates at the optical frequencies.
- Optical fibers works on the principle of total internal reflection.
- Glass and transparent plastic are the main elements used in making the fiber optic cables.
- This fiber waveguide is normally cylindrical in form.
- An optical fiber essentially consists of a central transparent region called **CORE.**
- The core is surrounded by a region of lower refractive index called the **CLADDING**.





- Fibers are usually coated with thin transparent layer of glass or other material of lower refractive index.
- Fibers can be classified by their core material.
- An optical fiber is a solid tube of glass or silica.
- It is made to high standards of purity to minimize attenuation.
- To increase the strength, it is provided with an outer jacket.
- Silica-based glass is the most widely used material in the production of optical fiber.
- The optical fiber waveguide confines electromagnetic energy in the form of light to within its surfaces and guides the light in a direction parallel to its axis.
- Optical Fibers used in a communication systems to transmit modulated light beams.

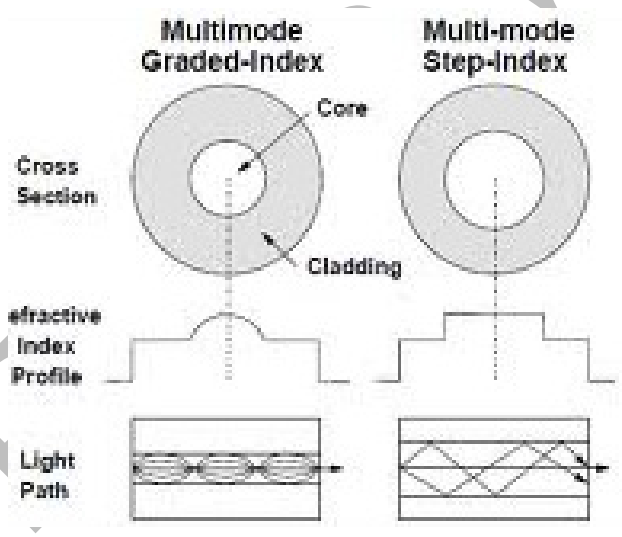
- It is having very high frequency of light (=10^{15}Hz)., thus these fibers can carry one hundred thousand times more information than the microwave.
- The optic fibers are less expensive to produce than copper wires.
- Optic fibers are also used in the field of medicine.

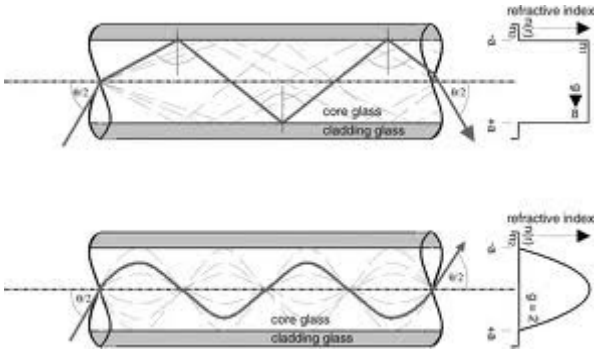
4. What are the types of optic fibers?

Ans: Optical fibers are of two types :

(i) Step –index fibers:

- Step index fibers were developed first.
- In this, the Refractive Index of the core is uniform throughout.
- The inner boundary of cladding undergoes abrupt (sudden) changes.
- It completely relies on the total internal reflection for containing the light within the core of fiber.
- The pulse of light injected from one end gets wider when it emerges from other end.
- It has a homogenous core of about 50 to 200 μm and cladding typically 20 μm thick.





(ii) Graded –index fiber:

- In this, the refractive index of the core is made to vary.
- The refractive core decrease from the axis outward.
- Power law relationship used for constructing the variation of refractive

index.

- In this, the Refractive Index of the cladding is uniform throughout.
- In this, if the travel light deviates from axis, it is returned to the gradient.
- The ray never touches the wall.
- The advantage of this type is that, the light rays travelling through it have same optical path length.
- Its core has a diameter of 20 μm to 90 μm

5. What do you mean by Numerical Aperture (NA)?

Ans :

- Numerical Aperture (NA) is related to the maximum acceptance angle.
- It is commonly used to describe the light acceptance capability of the fiber. It is also used to calculate source to fiber optical power coupling efficiency.
- The NA is a dimensionless quantity which is less than unity. It's value lying between 0.14 to 0.50.

Consider a ray of light which is incident on the entrance aperture of the fiber. Let i be the angle of incidence with the axis of fiber. Let r be the angle of refraction and Φ , the angle incidence.

Thus the condition for TIR is occur is-

$\sin\Phi_c = \frac{n_2}{n_1}$ .....(i)

$\sin\Phi_c$ = sin(90-r) .....(ii)

= cos r

Also , **sin r =** $\sqrt{1-\cos^2 r}$

= $\sqrt{1-\sin^2\phi_c}$ .....(iii)

Substituting (i) in (iii)

sin r = $\sqrt{1-(\frac{n_2}{n_1})^2}$

sin r = $\sqrt{(\frac{n_1-n_2}{n_1})^2}$ .....(iv)

This is the condition of total internal reflectance.

From the Snell's law

Where for air $n_0 = 1$

$n_1 = \frac{\sin i}{\sin r}$ where n_1 is the R.I. of the core.....(v)

$\sin r = \frac{\sin i}{n_1}$ .....(vi)

Equating equation (iv) and (vi)…

$\sin i = (n_1^2 - n_2^2)^{1/2}$

The maximum value of ' i' ,for a ray suffering TIR is represented as i_m then-

$\sin i_m = (n_1^2 - n_2^2)^{1/2}$ ..... where $(n_1^2 - n_2^2)$=1

$\sin i_m = 1$

Thus the term sin i_m in the equation is called as NUMERICAL APERTURE (NA) of the fibre. It is a measure of light gathering power of an optical fibre.

6 **Write a note on Applications of Fibre Optics.**

Ans: Communication is faithful transfer of Data or Information from one place to another. An optical fibre provides highest protection and realiability,it is playing important role in the field of modern field of communication.

In a fibre optics system has three basic units :

1. Optical Transmitter.
2. Optical fibre
3. Optical receiver.

Thus it can explained as follows :

Optical Transmitter :

1. It is the first basic unit that transfers electrical signals (i.e. current or voltage) into light pulses.
2. It consists of a miniature Laser Diode which can used for very long distance communication with high speed.
3. They are very highly coherent, Monochromatic and can be modulated easily by coupled with optical fibre.
4. Most of the signals are low frequency and very weak for long distance and it requires modulation and it can be done is in accordance with the signal to be transmitted
5. Optical transmitter performs two operations :
   a) It converts electrical signals into proper format.
   b) It transmits a signal superimposed on a high frequency carrier wave which carries information from one place to another through an optical fibre.
   c) It has high frequency of the order 10^{12} Hz to 10^{16} Hz.
6. Two types of modulation can be done : (a)Analog and (b) Digital
7. In Analogue, the light source emits a continuous beam of light of varying intensity.
8. In Digital, the light intensity changes ON/OFF fashion. The states are the binary digits of a digital system.

Optical Fibre :

1. It conducts the optical signals from the transmitter to the receiver end.
2. The path over which the signal is transmitted is called as the Transmission Channel.
3. The Transmission Channel provides the necessary wave guide for light.

Optical Receiver:

1. It is the last unit of the communication system.
2. It converts optical signals back to original electrical from using DETECTOR.
3. A DETECOR can be a semiconductor based Photo-diode.
4. It separates the transmitted information from the light carrier waves, called as DEMODULATION.
5. Using suitable signal i.e. amplifiers and filters one can obtained the transmitted information or signal at the receiver end.

7. Write a note on FIBRE OPTIC SENSORS

Ans: The basic function of optical fibre sensors is that the input variables as mentioned above get converted into its equivalent light signals.

Optical Fibre sensors are used to measure pressure, temperature. They also used to sensing and measuring strain, magnetic and acoustic field

TEMPERATURE SENSORS:

1. In this, an optical fibre carries the light beam to end from the surface where the temperature is to be measured.
2. The optical fibre used in the TEMPRURE SENSOR are in MULTIMODE i.e. fibre with core diameters about 50 μm and above.
3. The fibre at its one end is coated with a thin silicon layer; this layer is also coated with refractive coating.
4. Light from a source is allowed to pass through the fibre.
5. It then falls on the silicon surface and after reflection the reflected light pass through the same fibre in backward direction.
6. The external temperature which needs to be sensed changes the intensity of light passing through a fibre and therefore the light intensity of the reflected light varies according to the temperature.

7. This reflected light is detected by a detector and is analyzed to get desired output.

8. Give advantages of Optical Communication

Ans: Following are the advantages of Optical Communication:

1. A capacity of carrying information is very large and has a wider bandwidth.
2. They have a very low transmission loss.
3. Optical fibers are very light in weight, flexible, smaller in size which helps to make suitable in spaceship and aircraft.
4. Glass fibers can withstand high temperature, Temperature approaching 800^0C leaves glass fibre affected.
5. High degree of security and privacy can be offered by optical fiber.
6. There is no crosstalk, any interface or coupling with other communication channel.
7. Any electrical noise does not interfere with propagation of light signals because of dielectric nature of optical fibre.

9. What are the losses in OPTICAL FIBRE?

Ans :

1. Core and Cladding losses.
2. Scattering losses in glass fibre arise from microscopic variations in material density.
3. There may be absorption of light signal.
4. When light signal propagates along the fibre, it may get attenuated.
5. Radiation losses occur whenever an optical fibre undergoes a bend of finite radius of curvature