MODULE -4

PHOTONICS

Syllabus:

LASER

Properties of a LASER Beam, Interaction of Radiation with Matter, LASER action, Population Inversion, Metastable State, Requisites of a LASER System, Semiconductor LASER, LASER Range Finder, LIDAR, Road Profiling, Bridge Deflection, Speed Checker, Numerical Problems.

OPTICAL FIBER

Principle and Construction of Optical Fibers, Acceptance angle and Numerical Aperture (NA), Expression for NA, Modes of Propagation, Attenuation and Fiber Losses, Fiber Optic Displacement Sensor, Fiber Optic Temperature Sensor, Numerical Problems.

LASERS

Laser is the acronym for Light Amplification by Stimulated Emission of Radiation.

Properties of Lasers

1. The laser light is very nearly monochromatic.

2. The laser light is coherent with the waves all exactly in phase with one another.

3. Directionality**:** Laser beam is highly directional. It hardly diverges. This property is useful to measure long distance with higher accuracy.

4. Intensity: Laser is extremely intense; hence by Laser we can achieve very high energy density.

Interaction of Radiation with Matter

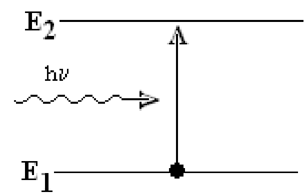
When radiation interacts with matter, it leads to the transition of an atom from one energy state to another.

Consider two energy states E_1 and E_2 $(E_2 > E_1)$ of a system. An electron at the energy state E_1 is excited to E_2 when it absorbs a light photon of energy $\Delta E = (E_2 - E_1)$. If an electron makes a transition from the higher energy state E_2 to E_1, a light photon of energy $\Delta E = E_2 - E_1$ is emitted. In both the case the frequency of the photon involved is $\nu = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$

There are three possible ways in which interaction of radiation and matter can take place.

1. Induced (stimulated) absorption:

"The process in which an atom in a lower energy state is raised to a higher energy state by absorbing a suitable photon is called stimulated absorption."



Induced Absorption

Consider two energy states with energies E_1 and E_2. Let a photon of energy $\Delta E = E_2 - E_1$ be incident on the atom. The atom absorbs the energy of the photon and its energy becomes equal to $E_1 + \Delta E = E_2$. Hence it makes a transition to the excited state E_2. This is called induced absorption.

Atom + photon → atom*

The number of such absorptions per unit time per unit volume is called the rate of absorption.

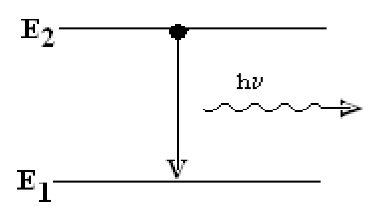
$\therefore$ Rate of absorption $\propto N_1 U_\upsilon$

Or Rate of absorption = $B_{12} N_1 U_\upsilon \rightarrow$ (1)

Where B_{12} → Einstein's coefficient of induced absorption.

2. Spontaneous emission:

The process in which an atom in the higher energy state falls to the lower state by emitting a photon on its own is called spontaneous emission.



Spontaneous Emission

Consider an atom in the excited state, the atom voluntarily emits a photon of energy ΔE equal to $(E_2 - E_1)$ and falls to the energy state E_1. The emission where an atom emits a photon without any aid by external agency is called spontaneous emission.

The photons emitted may have any direction and phase. Hence they are incoherent.

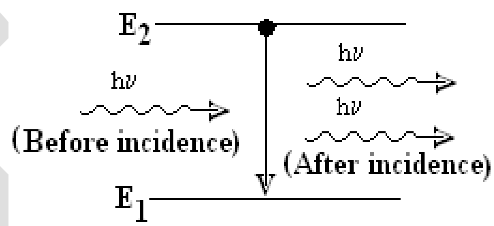
Atom*→ atom + photon

Rate of spontaneous emission = $A_{21} N_2$ ------------ (2)

where A_{21} → Einstein's coefficient of spontaneous emission

3. Stimulated emission:

"The process of the emission of a photon by a system under the influence of an incident photon of suitable energy, due to which the system transits from a higher energy state to a lower energy state is called stimulated emission."



Stimulated Emission

Consider an atom in the exited state with energy E_2. Let a photon of energy $\Delta E = E_2 - E_1$ interacts with this atom. As a result, the atom emits a photon and transits to the lower energy state. The emitted photon will have same phase, energy and direction of movement as that of the incident photon." The electromagnetic waves associated with the two photons will have same phase and thus they are coherent. This kind of emission is responsible for laser action.

Atom* + photon →Atom+ 2 photons

The rate of stimulated emission $= B_{21}N_2U_\upsilon$ --------------- (3)

where B_{21} is the Einstein's coefficient of stimulated emission.

LASER ACTION

The atom during stimulated emission process emits a photon and transits to the lower energy state. The emitted photon will have same phase, energy and direction of movement as that of the incident photon resulting in two photons of similar properties. These two photons induce stimulated emission of 2 atoms in excited state, there by resulting in 4 photons. These 4 photons induce 4 more atoms and give rise to 8 photons etc., as shown in figure.

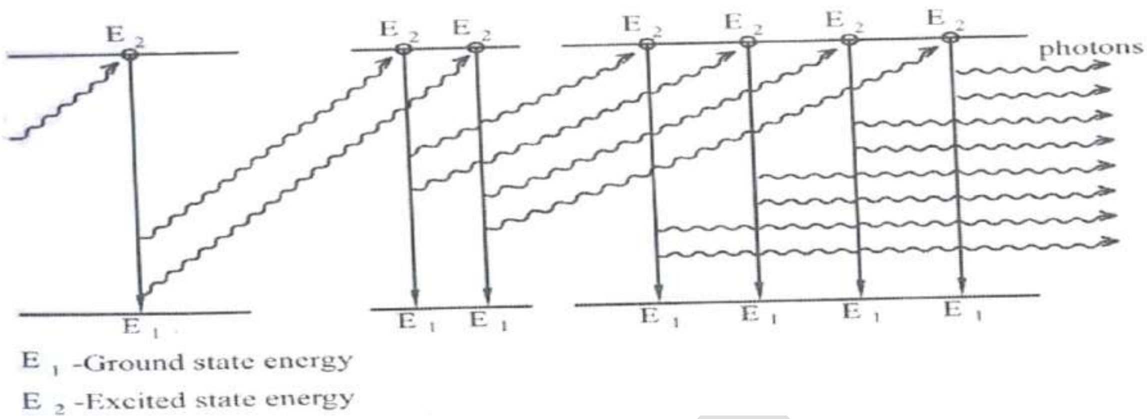


Fig: Amplification in Laser process

Condition for Laser action:

1. **Population inversion**

"It is the state of a system in which the number of atoms in the higher energy state is greater than the number of atoms in the lower energy state."

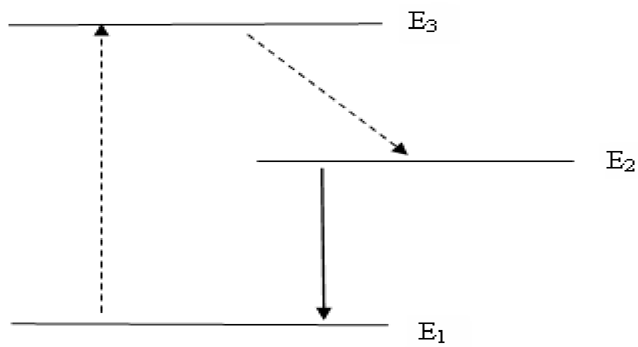
Under normal condition, the population is more in the lower state. But for stimulated emission, and hence for lasing action, more atoms must be present in the exited state. This can be achieved by some artificial means i.e. by providing energy in to the active medium of the laser system.

2. **Metastable state**

Under normal condition, population inversion doesn't exist. However, it is possible to achieve the population inversion in certain systems which possess a special exited state called **metastable state.**

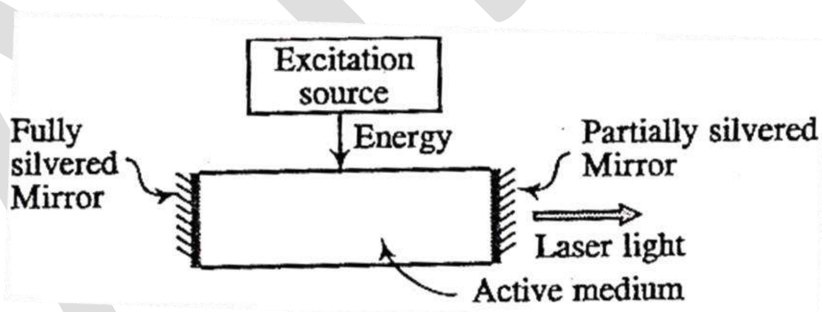
It is an exited state that is different from the ordinary exited state. The atoms which are excited to the higher energy states remain for a short duration of 10^{-8} sec and return to lower energy state. In case the state at which the atom is exited is a metastable state, then it stays there for a longer time of about 10^{-3} to 10^{-2} sec. This property helps in achieving population inversion.

Three Level Laser System



Consider 3 energy levels E_1, E_2, and E_3 of an atomic system. Let E_2 be a metastable state. By supplying suitable external energy, the atoms are exited from E_1 to E_3. The atoms in E_3 undergo spontaneous transition to E_1 and E_2 rapidly. Since E_2 is a metastable state, the atoms in this state stay for a longer time duration because of which the population in E_2 increases and population inversion is created. Once the population of E_2 exceeds that of E_1, stimulated emission takes place. The photons emitted are all identical with respect to phase, wavelength and direction and grow to a large number which is the laser light.

Requisites of Laser System



1) **Excitation mechanism:** An excitation mechanism/source provides energy in an appropriate from for pumping the atoms to higher energy levels (xenon flash lamp). If the pumping is achieved by light energy input, then it is called optical pumping (Ruby laser).If the pumping is achieved by electrical energy input, then it is called electrical pumping (He-Ne laser).

2) **Active medium:** A medium in which light gets amplified is known an active medium. The medium may be solid, liquid or a gas. A part of the input energy is absorbed by the active medium in which population inversion occurs at a certain state.

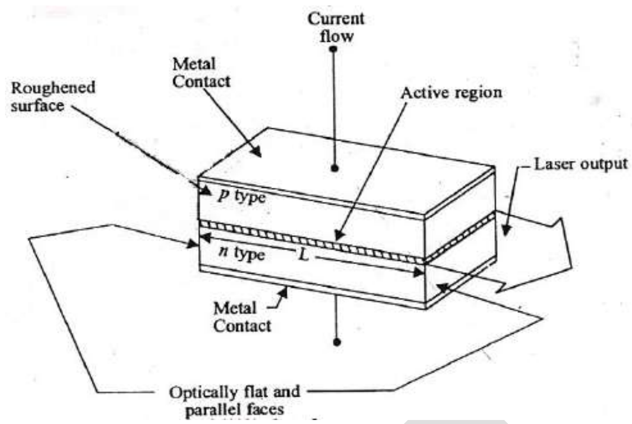
3) Laser cavity: It provides the feedback necessary to tap certain permissible part of laser energy from the active medium. It consists two mirrors along with the active medium called cavity. The mirrors reflect the photons to and fro through the active medium. A laser device consists of an active medium bound between two parallel mirrors of high reflectivity. Inside the cavity two types of waves exist, one moving towards the right and other to the left. These waves interfere constructively or destructively depending on the phase difference.

In order to arrange for constructive interference, the distance 'L' between the two mirrors should be such that the cavity should support an integral number of half wavelength, i.e. $L = m\frac{\lambda}{2}$, where L is the distance between the two mirrors and m is an integer >0. This results in the amplification of stimulated emission of radiation which is the laser light.

SEMICONDUCTOR DIODE LASER

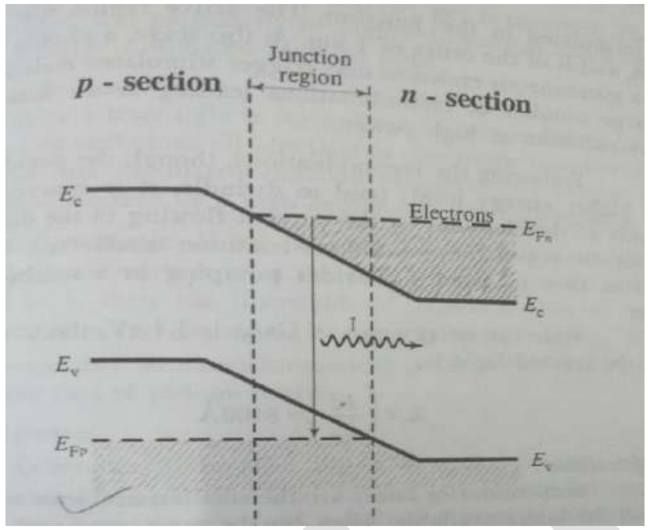
Construction:

A semiconductor diode laser is a specially fabricated p-n junction device that emits coherent light when it is forward biased. The direct band gap Gallium Arsenide single crystal is used for the construction of laser. The n-section is formed by doping with tellurium, whereas p-section is formed by doping with zinc. The doping concentration is high and is of the order of 10^{17} to 10^{19} dopants atoms/cm^3. The diode is extremely small in size with sides of the order of 1mm. The junction lies in the horizontal plane through the centre. The top and bottom faces are metalized and ohmic contacts are provided to pass current through the diode. The front and rear faces are polished parallel to each other and perpendicular to the plane of the junction. The other two faces are roughened to prevent lasing action in that direction. The active region consists of a layer of about 1 μm thickness.



Working:

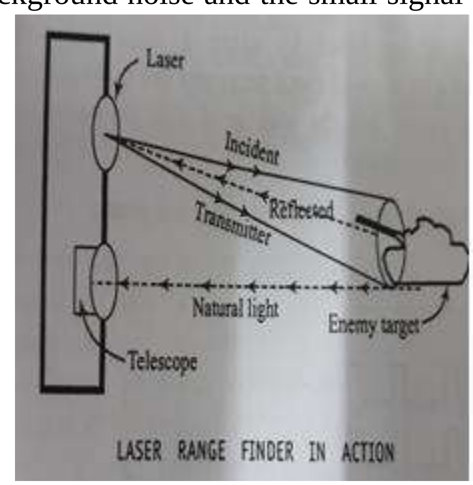
The population inversion can be achieved in a semiconductor by using it in the form of a heavily doped p-n junction and forward biasing it. With very high doping on n-side, the donor levels as well as a portion of the conduction band (CB) are occupied by electrons and the Fermi level lies within the CB. When a forward bias is applied, the fermi energy levels shifts and the new distribution is as shown in figure. Electrons and holes are injected in to the depletion region, where they appear in large number. At low forward current, the electron-hole recombination causes spontaneous emission of photons. As the current increases and reaches a threshold value, the carrier-concentration in the depletion region will reach very high values. The upper levels in the depletion region are having high population of electrons while the lower levels are having large number of holes. This is the state of population inversion. The narrow region where the state of population inversion is achieved is called inversion or active region. Thus the forward bias current plays the role of pumping agent in semiconductor laser. The photons that propagate in the junction plane induce the conduction electrons to jump in to the vacant state of VB. The stimulated electron hole recombination causes emission of coherent radiation.



Applications of Laser

LASER range finder in defense:

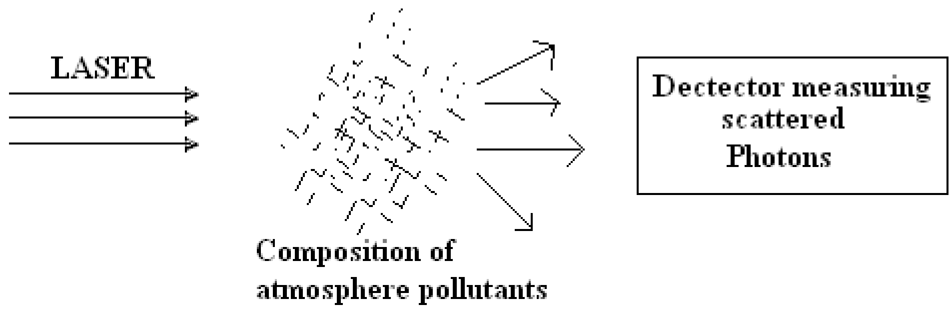
A high-power pulsed laser beam from Nd-YAG laser is directed towards the enemy target. The beam bounces from the surface of the target. Part of reflected beam called echo is received by the receiver. Inside the receiver there is an interface filter. The filter tunes the background noise and the small signal is amplified using photo-multiplier.



The range finder high speed clock measures the exact time since the pulse left the laser and until it is received, and then converts it into distance.

Here the distance is calculated usually within 1% of the actual distance. The range finders are also used for continuous tracking and ranging of missiles and aircrafts from ground or from air.

LIDAR (Measurement of pollutants in the atmosphere)



There are various types of pollutants in the atmosphere which includes oxides of nitrogen, carbon monoxide, sulphur oxide, dust, smoke, fly ash etc. In conventional techniques, samples of the atmosphere are collected and then chemical analysis is carried out to find the composition of the pollutants. But this is not a real time data.

In the application of laser for measurement of pollutants, the principle is very much similar to that of RADAR. This technique is called LIDAR which stands for light detection and ranging. Here a pulsed laser is used as the source of light and the light scattered back is detected by a photodetector. The distance to the matter and the concentrations of the matter is obtained by this method.

Absorption technique can also be utilized to study the atmospheric pollutants. Each material absorbs light of characteristic wavelength and from the absorption spectrum, the existence of the material can be identified.

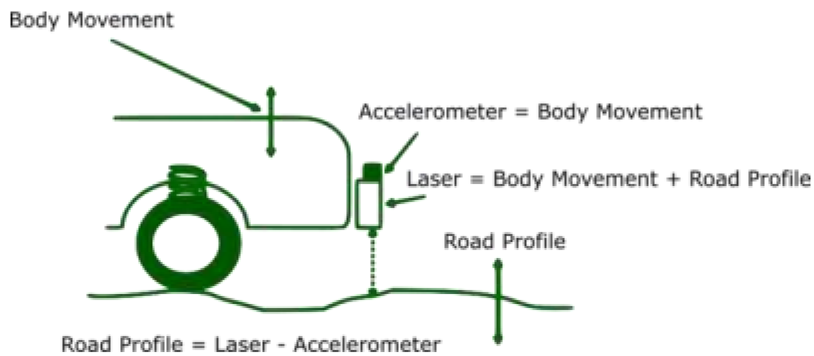
Road Profiling

Laser road profiling is a technique used for the precise measurement and analysis of road surface characteristics. It involves the use of laser technology to gather detailed data about the profile and roughness of roads, highways, and other paved surfaces. These measurements are crucial for assessing the condition of roadways, identifying potential hazards, and planning maintenance and rehabilitation efforts. Laser road profiling involves the following steps.

a) Laser Measurement: Laser road profiling systems utilize laser sensors mounted on vehicles or specialized equipment to scan the road surface. These sensors emit laser beams and measure the time it takes for the beams to bounce back after hitting the road. By analyzing the reflected signals the system can determine the road's elevation and roughness at various points along its length.

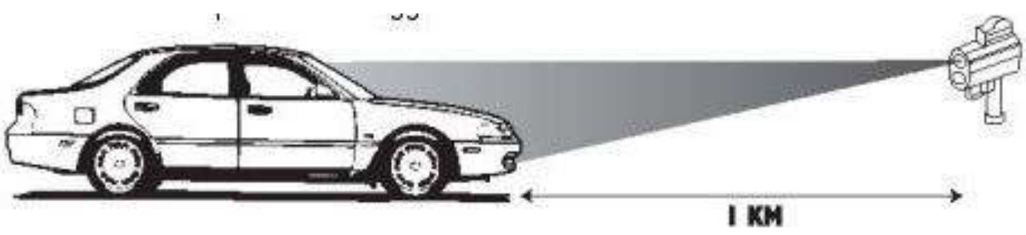
b) Profile Analysis**:** The collected data is processed to create a detailed profile of the road surface. The profile reveals variations in height, such as bumps, depressions, and undulations, providing an accurate representation of the road's condition. This information is vital for assessing ride quality, identifying potential safety hazards, and planning necessary repairs or resurfacing.

c) Roughness Measurement**:** Laser road profiling systems also measure the roughness of the road surface. Roughness refers to irregularities on the road that can cause discomfort to drivers and accelerate wear and tear of vehicles. By quantifying roughness parameters, such as International Roughness Index (IRI), or Ride Number, engineers can evaluate the road's condition and prioritize maintenance and improvement activities.



Speed Checker

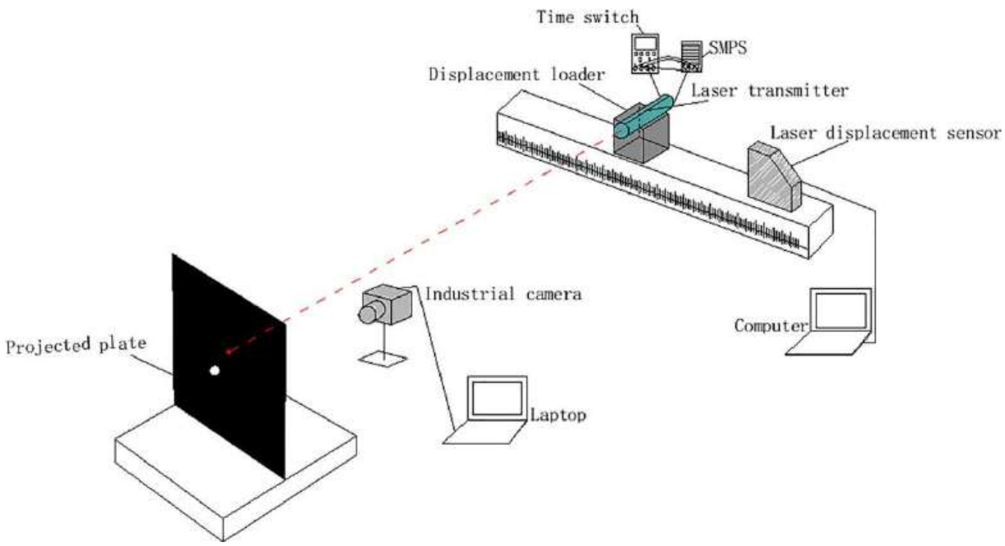
Laser speed checking is a technology used by law enforcement agencies to measure the speed of vehicles accurately. It utilizes laser beams to determine the speed of a moving object by measuring the time it takes for the laser beam to travel to the vehicle and back. The laser speed checking devices emit a narrow beam of infrared laser light towards a vehicle. The device measures the time it takes for the laser beam to be reflected back to the device. By knowing the speed of light, the device can calculate the speed of the target vehicle based on the time it takes for the beam to travel and return.



Bridge deflection

Bridge deflection refers to the amount of deformation or bending experienced by a bridge under the load it carries. Monitoring bridge deflection is crucial for ensuring the structural integrity and safety of the bridge.

Laser technology can be utilized for measuring bridge deflection. The basic principle involves the use of laser beams and sensors to detect and quantify the displacement or movement of the bridge. Laser deflection measurement offers several advantages, including non-contact measurement, high accuracy, and the ability to monitor large areas of the bridge. It provides valuable data for evaluating the performance and safety of bridges, enabling engineers and authorities to take appropriate actions for maintenance and structural improvements.



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OPTICAL FIBER

Introduction

A conventional method of long distance communication uses radio waves (10^6 Hz) and micro waves (10^{10} Hz) as carrier waves. A light beam acts as a carrier wave which is capable of carrying far more information, since optical frequencies are extremely large (10^{15} Hz).

Soon after the discovery of laser, some preliminary experiments in propagation of information carrying light waves through the open atmosphere were carried out, but it was realized that the unwanted elements such as rain, fog etc, leads to adverse effects. Thus, in order to have an efficient and dependable communication system one would require a guiding medium in which the information carrying light waves could be transmitted. This resulted in the development of optical fibers which are an efficient guiding medium for laser light.

Optical fibers are essentially light guides used in optical communication as waveguides. Use of light waves in place of radio and microwave have improved the speed of communication.

Optical fibers

An optical fiber is a cylindrical dielectric waveguide that transmits light along its axis through the process of total internal reflection.

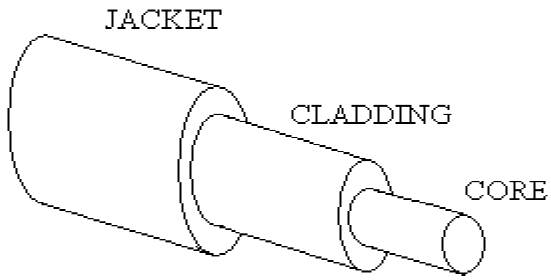
Total internal reflection

The basic principle of an optical fiber is multiple total internal reflections.

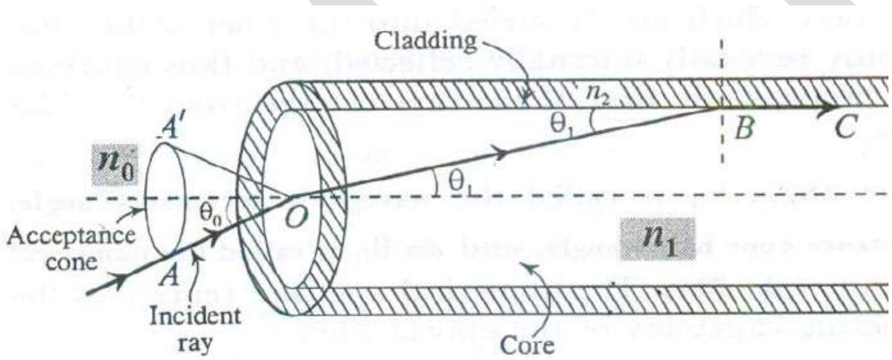
When a ray of light travel from denser to a rarer medium, at an angle of incidence greater that critical angle Θ_c, the ray is not refracted but it is reflected into the same denser medium. This property is called total internal reflection.

Structure of Optical Fiber:

An optical fiber consists of a very thin transparent cylindrical core having refractive index n_1 surrounded by a cylindrical shell called cladding of slightly lower refractive index n_2. The core-cladding system is surrounded by a plastic jacket.



Expression for Angle of Acceptance and Numerical Aperture:



Consider an optical fiber into which light is launched at one end from a medium of RI $\mathbf{n_0}$. Let $\mathbf{n_1}$be the RI of core and $\mathbf{n_2}$be that of the cladding. Assume that a ray of light enters the fiber at an angle θ_0 with respect to the axis of the fiber. The light ray refracts at an angle $\theta_1$and strikes the core – cladding interface at an angle of$(90-\theta_1)$. If $(90-\theta_1)$ is greater than the critical angle for the core – cladding interface, the ray undergoes total internal reflection at the interface.

It is clear from the figure that any light ray which enters the core at an angle less than θ_0 will undergo total internal reflection at the core – cladding interface and will propagate along the fiber. The angle θ_0 is called the acceptance angle. It is the maximum angle that a light ray can have relative to the axis of the fiber and thus propagate down the fiber. Sine of the acceptance angle θ_0 , $\sin\theta_0$, is called the numerical aperture (NA) of the fiber. It represents the light gathering capacity of the optical fiber.

Applying Snell's law at 'O'

$$\frac{\sin\theta_0}{\sin\theta_1} = \frac{n_1}{n_0} \rightarrow (1)$$

Applying Snell's law at 'B'

$$n_1 \sin(90 - \theta_1) = n_2 \sin 90$$

$$\cos\theta_1 = \frac{n_2}{n_1} \rightarrow (2)$$

Rewriting equation (1),

$$\sin\theta_0 = \frac{n_1}{n_0}\sin\theta_1$$

$$= \frac{n_1}{n_0}\sqrt{1-\cos^2\theta_1}$$

$$= \frac{n_1}{n_0}\sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$\sin\theta_0 = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} \rightarrow (3)$$

If the medium surrounding the fiber is air, then $n_0 = 1$

$$\therefore \sin\theta_0 = \sqrt{n_1^2 - n_2^2}$$

If θ_i is the angle of incidence of an incident ray w.r.t. the axis of the fiber, then ray will be able to propagate,

if $\quad \theta_i \langle \theta_0$

if $\quad \sin\theta_i \langle \sin\theta_0$

or $\quad \boxed{\sin\theta_i \langle N.A.}$

This is the **condition for propagation.**

Modes of propagation

Light propagates as an electromagnetic wave through an optical fiber. All waves having ray directions above the critical angle will be trapped within the fiber due to total internal reflection. But all such waves do not propagate along the fiber. There are certain ray directions allowed for the propagation. These allowed ray directions or possible number of path of light in an optical fiber is known as modes of propagation. The paths are zigzag paths, except the axial direction. The number of modes that a fiber will support depends on the diameter of the core and wavelength of the wave being transmitted.

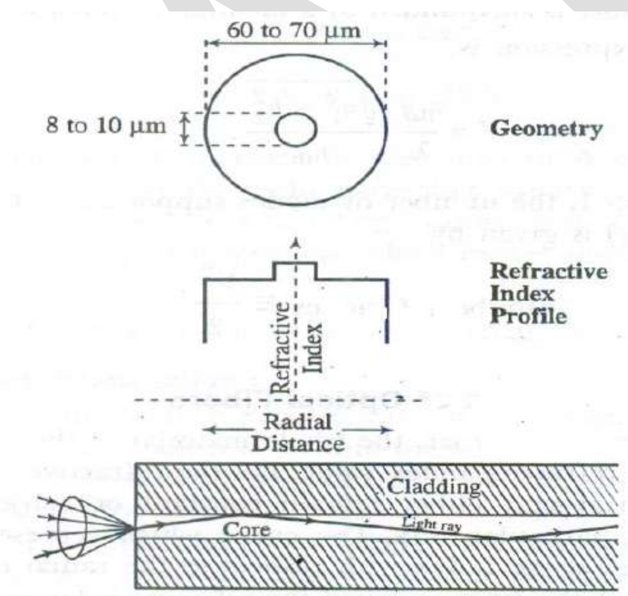
Refractive index (RI) profile

Refractive index profile is a curve which represents the variation of refractive index with respect to the radial distance from the axis of the fiber.

Types of optical fibers:

Depending on the RI profile and number of modes that a fiber can support, there are three types of optical fibers. They are:

1. **Step index single mode fiber:**



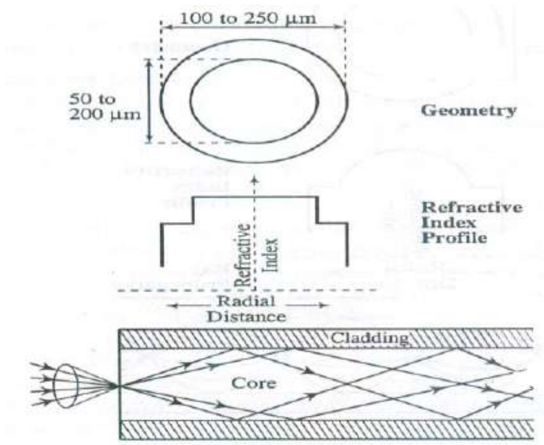
A step index single mode fiber has a core diameter of about 8 to 10 μm and external cladding diameter of 60 to 70 μm. The RI of the core has a uniform value. The cladding also has a uniform RI but slightly lesser than that of the core. The RI of the fiber changes abruptly at the core – cladding interface. Hence it is called a step index fiber. This fiber can support only one mode of propagation along its axis. Hence it is called a single mode fiber.

Due to narrow diameter of the fiber only laser can be used as the source of light with these fibers. There is no intermodal dispersion in the fiber. These are widely used in submarine cable systems.

2. Step index Multi mode fiber:

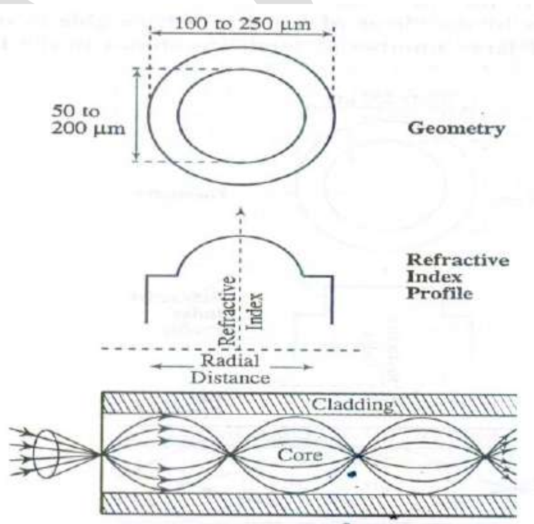
This fiber has a core diameter of 50 to 200 μm and a cladding diameter of 100 to 250 μm. The RI remains uniform in the core and cladding region. But the RI changes abruptly at the core – cladding interface. Because of larger diameter, this fiber allows many modes to propagate through it.

The step index multimode fiber can accept either a laser or LED as source of light. It is used in data links which has lower band width requirements.



3. Graded Index Multimode fiber:

It is a multimode fiber with a core consisting of concentric layers of different refractive indices. Therefore, RI of the core decreases with distance from the fiber axis. The RI of the cladding remains uniform. The RI profile and the modes of propagation are shown in the fig. Such a RI profile causes a periodic focusing of light propagating through the fiber. Either a laser or a LED can be the source for these fibers.



Normalized frequency (V – number):

It is the relation between fiber size, the refractive indices and the wavelength of light propagating through the fiber. It is given by,

$$V = \frac{\pi d}{\lambda}\sqrt{{n_1}^2 - {n_2}^2}$$

Where, $d \rightarrow$ diameter of the core; $n_1 \rightarrow$ RI of the core; $n_2 \rightarrow$ RI of the cladding;

$\lambda \rightarrow$ Wavelength of light.

Since $\sqrt{{n_1}^2 - {n_2}^2}$ = N.A. (numerical aperture), we can write,

$$V = \frac{\pi d}{\lambda} N.A.$$

The number of modes supported by a fiber is given by, $M_N = \frac{V^2}{2}$

Attenuation:

The loss of power suffered by the optical signal as it propagates through the fiber is called attenuation.

The attenuation or fiber loss is due to the following factors:

1. Absorption losses
2. Scattering losses
3. Radiation or bending losses

1. **Absorption Losses:**

The loss of signal strength occurs due to absorption of photons during its propagation. Photons are absorbed by:

a) Impurities in the silica glass of which the fiber is made of.
b) Intrinsic absorption by the glass material itself.

a. Absorption by impurities:

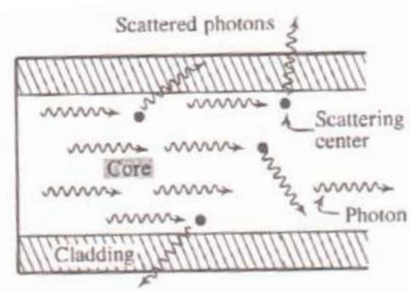
The impurities that are generally present in fiber glass are iron, chromium, cobalt, copper etc. During signal propagation when photons interact with these impurities, the electrons absorb the photons and get excited to higher energy levels. Later these electrons give up their absorbed energy in the form of light photons. But this is of no use, since these photons differ in wavelength and phase.

b. Intrinsic Absorption

The fiber material itself has a tendency to absorb light energy however small it may be. Hence there will be a loss and is known as intrinsic absorption.

2. **Scattering Losses:**

The optical power is lost due to the scattering of photons. This scattering is due to the non- uniformity in the density of the fiber material, which leads to the variation in the RI of the fiber. Structural inhomogenities and defects created in the fiber can also cause scattering. The loss of light energy by scattering is found to be wavelength dependent. It decreases with increase in the wavelength of light to be transmitted through the fiber.

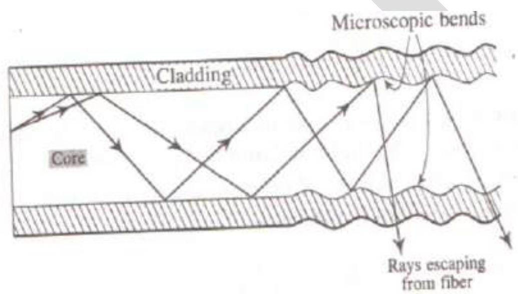


RAYLEIGH SCATTERING
Fig. 8

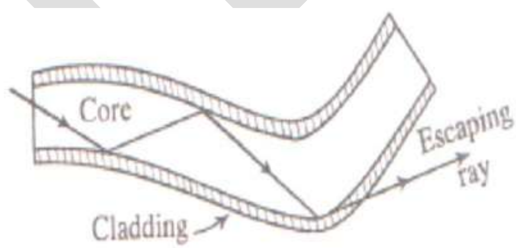
3. **Bending Losses (Radiation Losses):**

Radiation losses occur due to bending of fiber. There are two types of bends

a) Microscopic bends
b) Macroscopic bends



MICROSCOPIC BENDING LOSS



RADIATION LEAKS

Microscopic bends are caused during manufacturing as well as due to the applied stress on the fiber. Macroscopic bending arises during the installation of the fiber. At the point of a bend, light will escape to the surrounding medium due to the fact that the angle of incidence at that point becomes lesser than the critical angle.

To minimize these losses, the optical fiber has to be laid without sharp bends and they should be freed from the external stresses by providing mechanical strength through external coverage.

Attenuation Co-efficient:

Attenuation is the loss of power suffered by the optical signal as it propagates through the fiber. It is also referred as fiber loss.

Attenuation co-efficient or attenuation, $\alpha = -\frac{10}{L}\log(\frac{P_o}{P_i})$ dB/km

Where P_i is the optical power launched at the input and P_o the output power after traveling a distance L km.

Applications of optical fibers:

1. **Fiber Optic Temperature sensors (Phase modulated sensor)**

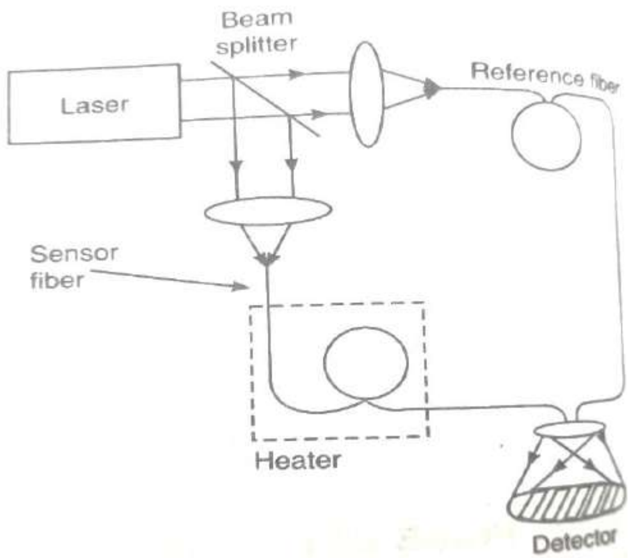
Fiber optic sensors are transducers, which generally consists of light source coupled with an optical fiber and a light detector held at the receiver end.

Principle: This temperature sensor is based on phase variation resulting due to the variation of refractive index of the optical fiber under the influence of temperature.

Construction: Figure shows the single mode fiber sensor arranged in what is known as the Mach Zehnder arrangement. Light source is laser. A beam splitter divides the light into two parts and sends light through the sensing fiber and the reference fiber. Light passing out of the two fiber element is fed to a detector, which measures the difference in phase of the two light waves. Accurate measurements of the temperature may be obtained from these patterns.

Working: Light from the source is divided into two parts by the beam splitter. One part is allowed through sensor fiber, and the other part is passed through the reference fiber. Light rays entering the fibres are coherent and have the same phase. Prior to heating, the optical path lengths of the two fiber elements are same and hence both the outputs will be in phase. When the sensor fiber is subjected to heating, the temperature causes a change in the refractive index of the optical fiber.

Therefore, the light coming out of the two fibers at the other end will have phase difference due to difference in optical path difference caused by heating. When the rays are superposed, they interfere and interference pattern will be observed. As temperature increases, the phase difference between the two outputs increases and is observed as a displacement of the fringe pattern. By determining the fringe displacement, we can determine the magnitude of temperature



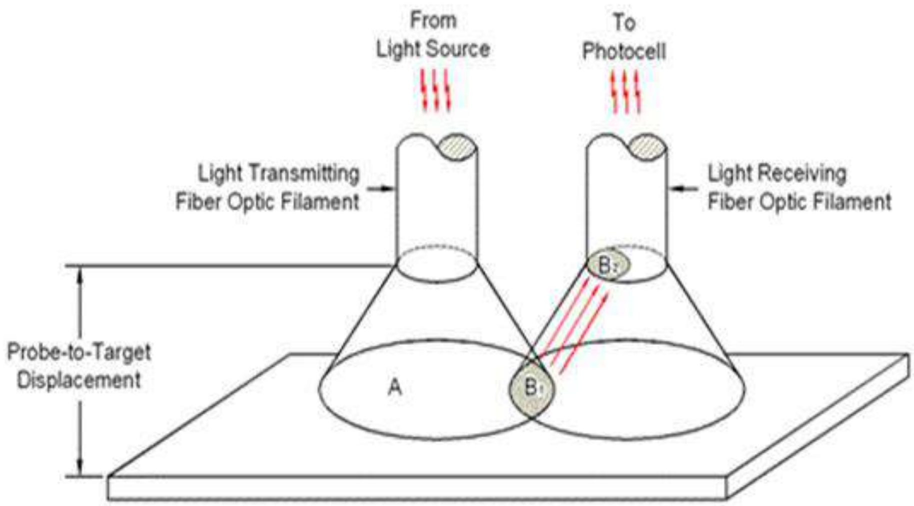
2. **Displacement Sensor**

Principle: It consists of pair of fiber optic elements, one carry light from the source to an object, whose displacement to be measured and the other to receive the light reflected from the object. Displacement of the target is measured with respect to the intensity modulation of the reflected light.

Construction: Two separate optical fibers are positioned adjacent to each other. One of them transmits light coming from a light source. The other fiber receives light reflected from the object under study and passes it onto a photo detector.

Working: Light from the transmitting fiber element is incident on the object under study. The light receiver fiber element is positioned adjacent to the transmitting fiber. If the gap between the object and the fiber element is zero, the light from the transmit fiber would be directly reflected back into itself and little or no light would go into the receiver fiber. When the object moves away, the gap increases and some of the reflected light is captured by the receiver fiber.

As the gap increases, a distance will be reached at which a maximum reflected light will be received. Further increase in the gap will result in a decrease in the light at receiver fiber which reduces the intensity in the signal output from the photo detector. By proper calibration, we can obtain the displacement of the object in terms of strength of the output signal of the photo detector.



Merits and demerits of optical communication:

The advantages of optical fiber communication include the following:

- Large amount of information can be transmitted per unit time in a fiber.
- Low attenuation allows data transmission for longer distances.
- The optical cable is resistance for electromagnetic interference.
- The size of the fiber cable is 4.5 times better than copper wires.
- The cables are lighter, thinner, and occupy less area compared with metal wires.
- Installation is very easy due to less weight.
- The optical fiber cable is very hard to tap because they don't produce electromagnetic energy. These cables are very secure while carrying or transmitting data.
- A fiber optic cable is very flexible, easily bends, and opposes most acidic elements that hit the copper wire.

The disadvantages of optical fiber communication include the following:

- The optical fiber cables are very difficult to merge & there will be a loss of the beam within the cable while scattering.
- The installation of these cables is cost-effective. They are not as robust as the wires. Special test equipment is often required to the optical fiber.
- Fiber optic cables are compact and highly vulnerable while fitting.
- These cables are more delicate than copper wires.
- Special devices are needed to check the transmission of fiber cable.

QUESTIONS

1. Discuss the construction and working of laser in LASER range finder and its application in defense.
2. Define Numerical Aperture and hence derive an expression for numerical aperture in terms of the RIs of core, cladding and the Surrounding.
3. Calculate the number of photons emitted per second for a LASER with power output 10mW given the wave length of fiber 690 nanometer.
4. Explain the construction and working of fiber optic temperature sensor.
5. Enumerate the requisites of a laser system and Describe the construction and working of Semiconductor Laser with a neat sketch and energy level diagram.
6. Calculate the attenuation coefficient for a fiber of length 2 km given the input and output optical power of the fiber 90 mW and 60 mW.
7. Discuss the interaction of radiation with matter and hence explain Laser Action.
8. Discuss the construction and working of optical fiber displacement sensor.
9. Give brief description of application of LASER in Road Profiling, Bridge Deflection and Speed Checker.
10. Define attenuation in fiber with the expression for attenuation coefficient and describe the various fiber losses.
11. Calculate the Numerical aperture and acceptance angle for an optical fiber of RI of core 1.5 and RI of cladding 1.45 placed in water of RI 1.33.

PROBLEMS

1. The average output power of laser source emitting a laser beam of wavelength 632.8nm is 5 mW. Find the number of photons emitted per second by laser source.

Hint:

$\Delta E = h\nu = hc/\lambda$

$N \times \Delta E = 5\times10^{-3} W$

(Ans: $\Delta E = 3.143\times10^{-19}$ J, $N = 1.59\times10^{16}$)

2. A pulsed laser emits photons of wavelength 780nm with 20 mW average power/pulse. Calculate number of photons contained in each pulse if pulse duration is 10ns.

Hint: Energy of each photon $\Delta E = h\nu = hc/\lambda$

Energy, $E = P \times t$

$N X \Delta E = E$

(ANS: $\Delta E = 2.55\times10^{-19}$J, $E = 2\times10^{-10}$J, $N = 7.86\times10^{8}$)

3. A pulse from laser with power 1mW lasts for 10ns .If the number of photons emitted per second is 3.491×10^7, Calculate the wavelength of laser.
Hint: Energy of each photon $\Delta E = h\nu = hc/\lambda$

Energy, E=Pxt

NX $\Delta E = E$

(ANS: $\lambda = 6943.6 \times 10^{-10}$m)

4. The refractive indices of core and cladding are 1.50 and 1.48 respectively in an optical fiber. Find the numerical aperture and angle of acceptance.

Hint: N.A.=$\sqrt{(n_1^2 - n_2^2)}$

N.A= $\sin\theta_o$

(ANS: N.A. =0.244 and $\theta_o = 14.4^o$)

5 An optical fiber has a core material with RI 1.55 and its cladding material has RI 1.50. The light is launched into it in air. Calculate its N.A, and acceptance angle.

Hint: N.A.=$\frac{\sqrt{(n_1^2 - n_2^2)}}{n_o}$

(ANS: N.A= 0.39, $\theta_o = 23^o$)

6. The angle of acceptance of an optical fiber is 30^o when kept in air. Find angle of acceptance when it is in a medium of refractive index 1.33.

Hint: $\sin\theta_o = \frac{\sqrt{(n_1^2 - n_2^2)}}{n_o}$

$\sin\theta_o^I = \frac{\sqrt{(n_1^2 - n_2^2)}}{n_0^I}$

(ANS:$\theta_o = 0.5$, $\theta_o^I = 22^o$)

7. Find the attenuation in an optical fiber of length 500m, when a light signal of power 100mW emerges out of the fiber with a power of 90mW.

Hint: Fiber attenuation, $\alpha = -\frac{10}{L} log_{10}(\frac{P_{out}}{P_{in}})$dB/km

(ANS: $\alpha = 0.915$dB/km)

8.The attenuation of light in an optical fiber is 3.6dB/km.What fraction of its initial intensity remains after i)1km, ii) after 3km ?

Hint: Fiber attenuation, $\alpha = -\frac{10}{L} log_{10}(\frac{P_{out}}{P_{in}})$dB/km

(ANS :α=0.436, α=0.0832)

9. An optical glass fiber of refractive index 1.50 is to be clad with another glass to ensure internal reflection that will contain light traveling within 5^o of the fiber axis. What maximum index of refraction is allowed for the cladding?

Hint : $n_1 sini = n_2 sinr$ (Ans: $n_2 < 1.49$)

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