Laser and Optical Fibers:

LASER: Basic properties of a LASER beam, Interaction of Radiation with Matter, Einstein's A and B Coefficients(derivation of expression for energy density), Laser Action, Population Inversion, Metastable State, Requisites of a laser system, Nd-Yag Laser, Application of Lasers. Numerical problems.

Optical Fiber: Principle and structure, Acceptance angle and Numerical Aperture (NA) and derivation of Expression for NA, Classification of Optical Fibers, Attenuation and Fiber Losses, Applications: Fiber Optic Communication. Numerical Problems. **8 Hrs**

LASER:

LASER is the short form of **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It was invented by American Scientist Maiman in the year 1960.

"A laser is a device that amplifies light and produces a highly directional, high-intensity beam that most often has a very pure frequency or wavelength"

Properties of Laser

1. The laser is highly monochromatic.
   The laser beam is emitted in a very narrow frequency band.
2. Laser light is spatially coherent.
   The laser is highly coherent due to stimulated emission of radiation.
3. Laser light extremely high directionality or unidirectionality.
   The laser beam has very small divergence due to the resonant cavity. Hence light intensity does not decrease as fast with distance as it does in ordinary source of light.
4. The laser beam is extremely bright or intense.
   Light from laser is much brighter than other ordinary sources of light.

Interaction of an electromagnetic wave with matter

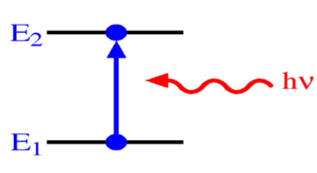
The interaction leads to a transition of the quantum system such as an atom or a molecule from one energy state to another. If the transition is from a higher state to a lower one, the system gives out a part of its energy and if the transition is to a higher state from a lower one, then it absorbs the incident energy.

There are three possible ways through which interaction of radiation and matter can takes place. They are

a. Induced Absorption
b. Spontaneous emission
c. Stimulated emission

a. Induced Absorption:

It is a process in which an atom in the ground state undergoes a transition to the higher energy state by absorbing an incident photon.



The process can be represented as Atom + Photon = Atom *

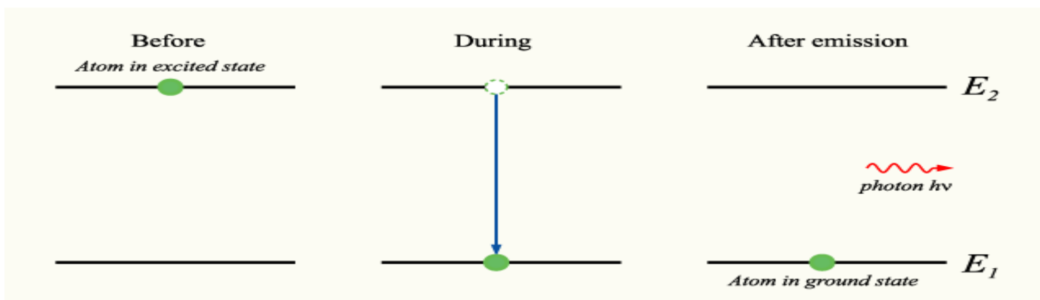
Where Atom* indicates an excited atom

b. Spontaneous Emission:

It is a process in which an atom in the excited state undergoes a transition to the ground state by emitting a photon without any aid of an external agency.

As shown in the figure, consider an atom in the excited state E_2. It makes a transition to the ground state E_1 by the emission of a photon of energy hν. It may be represented as

Atom* = Atom + Photon

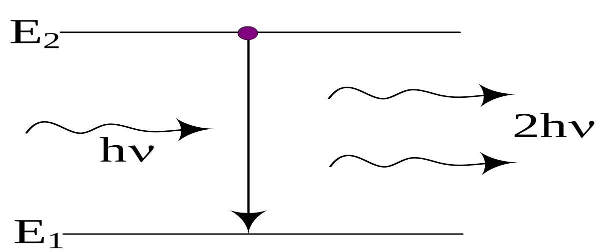


As a result, its energy becomes $E_1 = E_2 - \Delta E$

c. Stimulated Emission:

It is a process in which an atom in the excited state undergoes a transition to the ground state by the influence of a passing photon. During this process, a stimulated photon is emitted along with the incident photon and these photons are found to be coherent.

Atom * + Photon = atom + (Photon + Photon)



Einstein's Coefficients: (Expression for the energy density of photons)

Consider two energy states E_1 and E_2, Let E_1 be the ground state and E_2 be the excited state.

Let N_1 be the number of atoms per unit volume in the energy state E_1 and N_2 be the number of atoms per unit volume in the energy state E_2. Let U_ν be the energy density of radiations.

There are three cases

1. Induced Absorption

The rate of absorption, $R_{12} = B_{12}U_\nu N_1$ **------(1)**

2. Spontaneous emission

The rate of Spontaneous emission $R_{21} = A_{21}N_2$ **------(2)**

3. Stimulated emission

The rate of Stimulated emission **$R_{21} = B_{21}N_2U_v$------(3)**

Where, N_1 = No. of atoms per unit volume in the ground state.

R_{12}= Rate of upward transition.

N_2 =No. of atoms per unit volume in the excited state.

R_{21}= Rate of downward transition.

U_v= Energy Density of radiation.

B_{12}= Einstein Coefficient of induced absorption

A_{21}= Einstein Coefficient of spontaneous emission

B_{21}= Einstein Coefficient of stimulated emission.

Let us assume the system be in thermal equilibrium which means that, the total energy of the system remains unchanged. Under such condition, the no of photons absorbed by the system per second must be equal to the no. of photons it emits per second by both the stimulated and the spontaneous emission process.

At thermal equilibrium

The rate of absorption = Rate of spontaneous emission + Rate stimulated Emission

From, equation (1), (2) and (3), We have

$$\mathbf{R_{12} = R_{21} + R_{21}}$$

$$\mathbf{B_{12}U_vN_1 = A_{21}N_2 + B_{21}N_2U_v}$$

$$\mathbf{B_{12}U_vN_1 - B_{21}N_2U_v = A_{21}N_2}$$

$$\mathbf{U_v\,(B_{12}N_1 - B_{21}N_2) = A_{21}N_2}$$

$$U_v = \frac{A_{21}N_2}{B_{12}N_1 - B_{21}N_2}$$

Dividing each & every term on the RHS by N_2, We get

$$U_v = \frac{A_{21}}{B_{12}\left(\frac{N_1}{N_2}\right) - B_{21}} \qquad \textbf{(4)}$$

According to Boltzmann's law for the distribution function

-: *Boltzmann factor: -*

In a given system the energy level will have many numbers of atoms. The number of atoms in a particular state is referred as population of the state. The population of different energy states of any physical system is related to each other. If we consider two energy states E_1 and E_2 with population N_1 and N_2 respectively and if $E_2 > E_1$ then, Boltzmann factor is the ratio of N_2 / N_1

It is given by $$\frac{N_2}{N_1} = e^{-\left(\frac{E_2 - E_1}{kT}\right)} = e^{-\frac{h\gamma}{kT}}$$

Where k is Boltzmann constant.

$$N_1 = e^{-\left(\frac{E_1}{kT}\right)}$$

$$\Delta E = (E_2 - E_1) = h\nu$$

$$\frac{N_1}{N_2} = \frac{e^{-\left(\frac{E_1}{kT}\right)}}{e^{-\left(\frac{E_2}{kT}\right)}}$$

$$\frac{N_1}{N_2} = e^{-\frac{E_1}{kT}+\frac{E_2}{kT}}$$

$$\frac{N_1}{N_2} = e^{\frac{h\nu}{kT}}$$

Putting the values of N_1/N_2 in equation (4)

$$U_v = \frac{A_{21}}{B_{21}\left(\frac{B_{12}}{B_{21}}\left[e^{\frac{h\nu}{kT}}\right] - 1\right)} \quad (5)$$

According to black body radiation (Planck's) the energy density

$$U_v = \frac{8\pi h v^3}{C^3 \ \left(e^{\frac{hv}{kT}} - 1\right)} \quad (6)$$

Comparing the equation (5) and (6),

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h v^3}{c^3} \quad \& \quad \frac{B_{21}}{B_{12}} = 1 \ \text{ or } \ B_{21} = B_{12}$$

Which is implies that the probability of absorption is equal to stimulated emission;
At thermal equilibrium the equation for energy density is

$$\boxed{U_v = \frac{A}{B}\left(\frac{1}{e^{\frac{hv}{kT}} - 1}\right)} \quad \text{Where} \quad \frac{A}{B} = \frac{8\pi h v^3}{c^3}$$

This is the ratio of
Einstein's A coefficient of spontaneous emission and Einstein's B coefficient of induced emission.

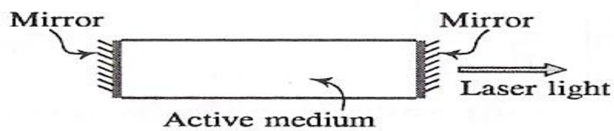
Requisites of a Laser system

The three requisites of a laser system are
(1) An excitation source for pumping action,
(2) An active medium which supports population inversion, and
(3) Laser cavity.

The excitation source provides the appropriate amount of energy for pumping the atoms to higher energy levels. Optical pumping is used in Ruby Laser and electrical pumping is employed in He-Ne laser.

A part of the input energy is absorbed by the active medium in which population inversion occurs at a certain stage. After this stage the medium attains capability to issue laser light.The laser cavity provides the feedback necessary to tap certain permissible part of laser energy from the active medium.

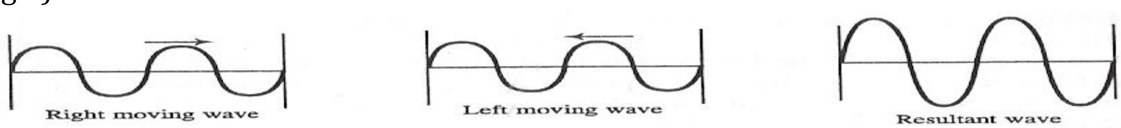
LASER CAVITY



LASER CAVITY
Fig. 1

A Laser device consists of an active medium bound between two mirrors (Fig. 1). The mirrors reflect the photons to &fro through the active medium form a cavity inside which two types of waves exist; one type comprises of waves moving to the right, and the other one to the left (Fig. 2 & 3).

The two waves interfere constructively if there is no phase difference between the two (Fig. 2). But, their interference becomes destructive if the phase difference is π/2.
(Fig.3).



CONSTRUCTIVE INTERFERENCE
Fig. 2

DESTRUCTIVE INTERFERENCE
Fig. 3

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 wavelengths.

i.e. $L = m (\lambda/2)$, where m is an integer > 0, and λ is the wavelength of the laser light inside the material of the active medium.

In such case, a standing wave pattern is established within the cavity and the cavity is said to be resonant at wavelengths, $\lambda = 2L/m$.

Energy states of atoms in Laser

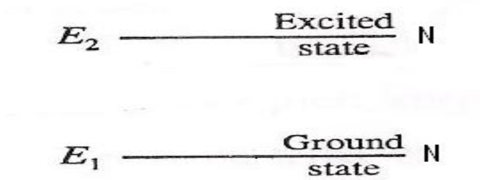
Ground state: It is the lowest possible energy state of an atom which is the most stable state. Atoms can remain in this state for an unlimited time.

Excited state: These are the possible energy states of an atom which are higher than the ground state. Atoms remain in these energy states for a very short time called the lifetime typically of the order of 10^{-8} s to 10^{-9} s.

Metastable State: These are excited states of an atom with relatively large lifetime of the order of 10^{-3}s.

Population Inversion & Metastable state:

Let N_1 be the number of atoms in the ground state E_1. Let N_2 be the number of atoms in the excited state E_2. Under normal conditions the number of atoms in the ground state is always greater than the number of atoms in the excited state.



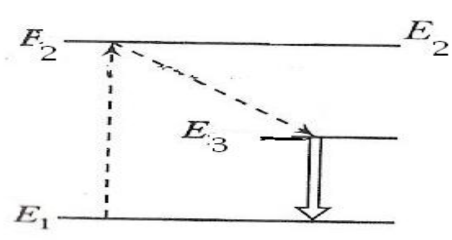
The ratio between these two numbers is given by.

$$\frac{N_2}{N_1} = e^{-\frac{(E_2 - E_1)}{kT}}$$

Since $E_2 > E_1$, then $e^{-\frac{(E_2 - E_1)}{kT}} < 1$ i.e., N2 < N_1 under ordinary condition or at thermal equilibrium.

If by some means the number in the excited state is more than in the ground state. i.e., $N_2 > N_1$ then it is said that population inversion has taken place. This is one of the main criteria for the production of laser ray.

Population inversion is usually achieved when there is an intermediate energy level called metastable state exists, where the electrons will remain for a longer time for about 10^{-3} sec to 10^{-2} sec. This property helps in achieving the population inversion in the following way.



POPULATION INVERSION

Consider three energy levels E_1, E_2 & E_3 of a quantum system which are such that $E_2 > E_3 > E_1$. Let E_3 be a metastable state of the system. Let the atoms be excited from E_1 to E_2 state by supply of appropriate energy from an external source.

Since E_3 is a metastable state, those atoms which get into that state stay over a very long duration, because of which the population of E_3 state increases steadily. Under these conditions a stage will be reached wherein the population of E_3 state overtakes that of E_1, which is known as population inversion.

Once the population of E_3 exceeds that of E_1, the stimulated emission outnumber the spontaneous emissions, and soon stimulated photons, all identical in respect of phase, wavelength & direction, grow to a very large number which buildup the laser light. Hence the condition for laser action is achieved by means of population inversion.

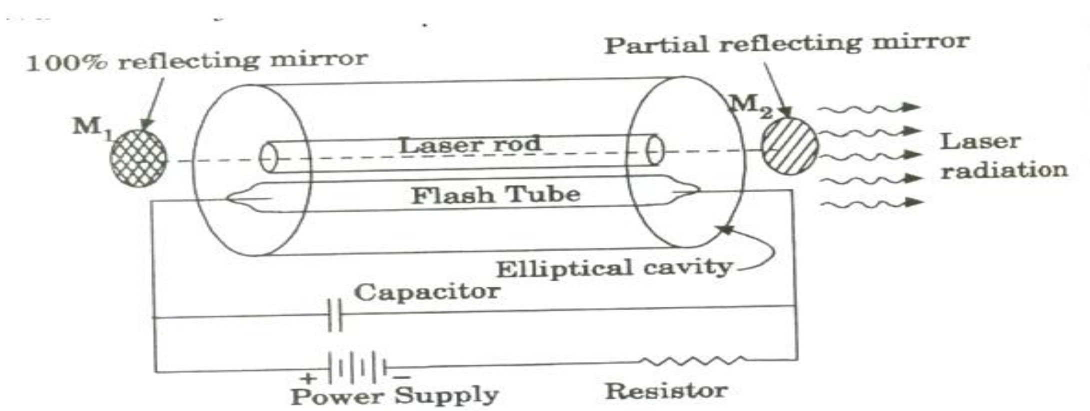
Types of Laser

Based on the active medium they have classified into five categories

I. Solid state laser (Ruby laser)
II. Gas Laser (He-Ne and CO_2)
III. Liquid Laser
IV. Dye and chemical Laser
V. Semiconductor lasers

Nd-YAG LASER:

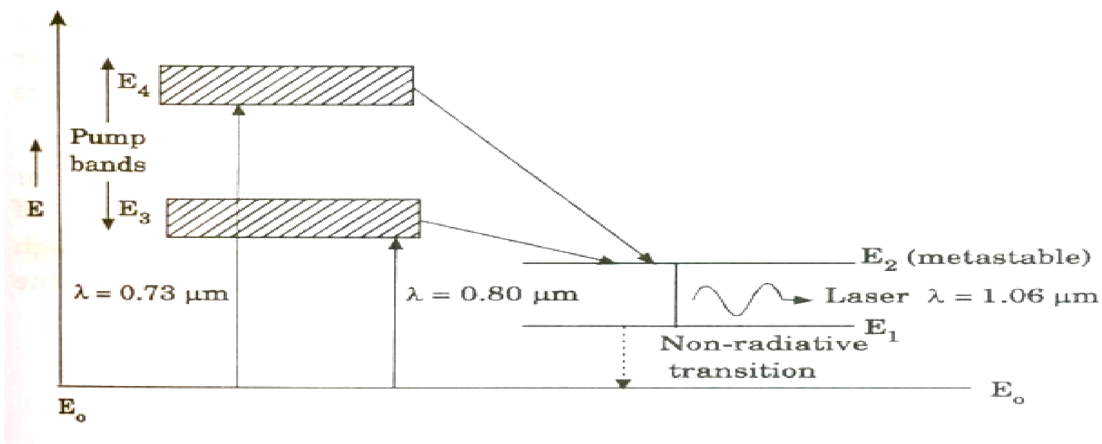
Construction:



Nd-YAG is a solid state laser in which a rare earth metallic ion (Nd ion) is doped in Yttrium aluminum garnet (Y3 Al5 O12), abbreviated as YAG. A few Y3+ ions in the YAG crystal are replaced by Nd3+ ions. Nd3+ ions act as active centers and YAG is the active medium. Nd-YAG lasers operate in both pulsed and continuous mode. Nd-YAG lasers typically emit light with a wavelength of 1064 nm, in the infrared region.

It consists of an elliptically cylindrical laser cavity. The YAG crystal rod is placed inside the cylindrical cavity. The YAG crystal rods are typically of 10cm in length and 1.2cm diameter. The two ends of the rod are polished and silvered. The optical resonator is formed by using two external reflecting mirrors. One mirror (M1) is 100% reflecting while the other mirror (M2) is partially reflecting.

Working:



It is a 4-level laser. When the krypton flash lamp is switched on, by the absorption of light radiation of wavelength 0.73μm and 0.8μm, the Neodymium(Nd^{3+}) atoms are raised from ground level E0 to upper levels E3and E4 (Pump bands). The Neodymium atoms make a transition from E3and E4 energy levels to E2 by non-radiative transition where E2 is a metastable state. The Neodymium ions are collected in the level E2 and the population inversion is achieved between E2 and E1.

An ion makes a spontaneous transition from E2 to E1, emitting a photon of energy hγ. This emitted photon will trigger a chain of stimulated photons between E2 and E1. The photons thus generated travel back and forth between two mirrors and grow in strength. After some time, the photon number multiplies more rapidly. After enough strength is attained an intense laser light of wavelength 1.06μm is emitted through the partial reflector. It corresponds to the transition from E2 to E1.

Characteristics of Nd-YAG Laser:

- The Nd-YAG LASER operates in pulsed and also in continuous wave mode.
- The wavelength of radiation emitted lies in IR- region.
- The efficiency range lies between 0.1% and 1%.

- The pulse rate is considerably high due to high thermal conductivity of YAG crystal.

Applications of Laser:

Industrial application:

The high intensity of laser beam enables to focus in small area. Two lasers Nd-YAG and CO2 are widely used in industries for

- Laser cutting.
- Laser welding.
- Laser drilling.

Medical applications:

- Lasers are used for correcting eye defects and eye surgery.
- CO2 lasers are used in brain and spinal surgery and removal of cancerous cells.
- Dye lasers are used in breaking of kidney stones and gall stones.
- Lasers are used in dentistry and dermatology.

Communication:

- Lasers are used to transmit voice message and television signals.
- Laser beam acts as a source in fiber optic communication.
- Lasers are also used in communication devices such as high speed photo copiers and printers etc.

Measurement of atmospheric pollutants:

- A laser beam is used to estimate the concentration of particulate matter like dust or smoke in the atmosphere.

Lasers in astronomy:

- Radio astronomers have found lasers extremely valuable for amplifying very faint radio signals from space.
- Lasers are used to hear the bursts of light and radiation from stars.

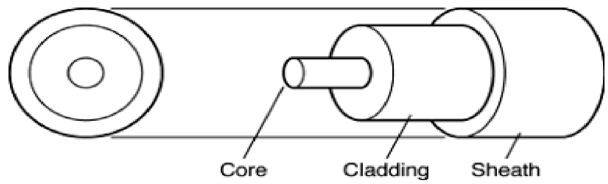
Defence:

- A laser beam can be bounced off a target such as enemy airplane or ship to determine its distance and speed.
- High energy lasers are being used to destroy enemy aircraft and missiles.

Optical Fibers

- ✓ Thin flexible and transparent wire for light propagation.
- ✓ Optical fiber is made from either glass or plastic.
- ✓ Carry data over long distances.
- ✓ At very high speeds.
- ✓ Fiber can be bent or twisted.

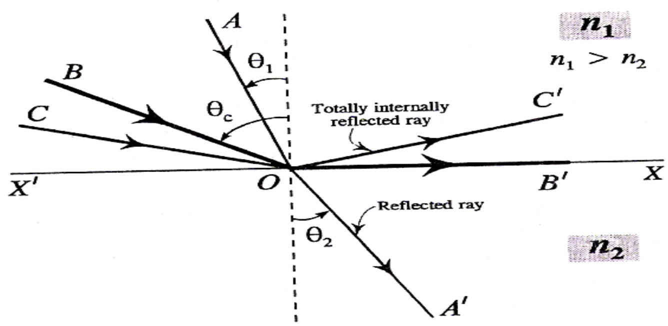
Structure of Optical Fiber:



- ✓ An optical fiber is cylindrical in shape.
- ✓ **Core:** Carries the light signal.
- ✓ **Cladding:** Lower refractive index than the core – to make Total internal reflection.
- ✓ **Polyurethane Jacket (Sheath)**: Hard plastic coating material to protect the cladding. It prevents the scratches that could cause light leakage.

Principle of working of Optical fibers: Total Internal Reflection

Light propagates in optical fibers according to the principle of total internal reflection. When light travels from a denser to a rarer medium, it bends away from the normal. Let a ray AO be incident at O at the interface of the two media with refractive indices. n1and n2 making an angle of incidence θ_1.It gets refracted



TOTAL INTERNAL REFLECTION

along OA^1 making an angle of refraction θ_2.Let OB an incident ray which makes an angle of incidence θ_c. It gets refracted along OB^1 which makes an angle of refraction 90^0 with respect to the normal drawn at the point of incidence. The ray grazes along the interface of two media. Let OC be an incident ray which makes an angle of incidence greater than θ_c., then the light is completely reflected to the same medium along OC^1. The entire incident energy is returned along the reflected light. Hence it is called Total Internal Reflection.

From Snell's law we have, $n_1 \sin \theta_i = n_2 \sin \theta_r$

For the rayAOA^1

$$n_1 \sin \theta_1 = n_2 \sin \theta_2 \text{ is obeyed.}$$

For the rayBOB^1

$\theta_i = \theta_c$ (critical angle) $\theta_r = 90^{\circ}$,

$$\mathbf{n_1 \sin \theta_c = n_2 \sin 90^\circ}$$

$$\mathbf{\sin \theta_c = n_2/n_1}$$

$$\mathbf{\Rightarrow \theta_c = \sin^{-1} (n_2/n_1)}$$

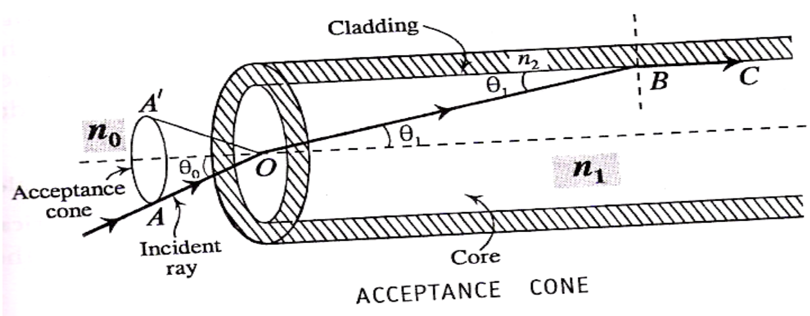
Condition for Total Internal reflection:

1. The ray must travels from denser to rarer medium.
2. Angle of incidence must be greater than critical angle,$\theta_i > \theta_c$

Parameters of optical fibers

1. Acceptance Angle: It is the maximum angle of a ray hitting the fiber core which allows the incident light to be guided by the core.
2. Numerical Aperture (NA) : it is measure of the amount of light rays that can be accepted by the fibers. Or Sine of the acceptable angle is called numerical aperture.

Numerical aperture and Ray propagation in the fiber:



Consider a light ray AO entering the fiber core with an angle θ_0 to the fiber axis. It gets refracted along OB at an angle θ_1 in the core and further proceeds to fall at critical angle of incidence (equal to 90-θ_1) at B on the interface between core and cladding. Since it is a critical angle of incidence, the ray is refracted at 90º to normal i.e., it grazes along BC.

Now it is clear from the figure that any ray that enters into the core at an angle of incidence less than θ_0 will have refractive angle less than θ_1 because of which its angle of incidence (90 - θ_1) at the interface will become greater than the critical angle of incidence, and thus undergoes total internal reflection. If the incident ray is greater than θ_0 at O, the angle of incidence at B is less than the critical angle, because of which it will be refracted into the cladding region and thus will be lost.

Now if OA is rotated around the fiber axis keeping θ_0 fixed, then it describes a conical surface. Only those rays, which are funneled into the fiber within this cone, will only be totally reflected and thus confined within the fiber for propagation. The rest of the incident light rays emerge from the sides of the fiber.

The angle θ_0 is called the waveguide acceptance angle or the acceptance cone half angle, and $\sin\theta_0$ is called the numerical aperture (NA) of the fiber. The numerical aperture represents the light gathering capability of the optical fiber.

Let n_0, n_1 and n_2 be refractive indices of surrounding medium, core of the fiber and cladding respectively.

Now for refraction at point 'O', using Snell's law

$$n_0 \sin\theta_0 = n_1 \sin\theta_1$$

$$\sin\theta_0 = (n_1 / n_0) \sin\theta_1$$

Then $$\sin\theta_0 = (n_1 \sin\theta_1) / n_0 \longrightarrow (1)$$

At the point 'B' on the interface, angle of incidence = $90 - \theta_1$.
Applying Snell's law

$$n_1 \operatorname{Sin}(90 - \theta_1) = n_2 \operatorname{Sin} 90^\circ$$

$$n_1 \operatorname{Sin}(90 - \theta_1) = n_2$$

$$n_1 \operatorname{Cos}\theta_1 = n_2$$

$$\operatorname{Cos}\theta_1 = n_2 / n_1 \longrightarrow (2)$$

Fromeqn (1) $\operatorname{Sin}\theta_0 = \frac{n_1}{n_0}\sin\theta_1$

$$= \frac{n_1}{n_0}\sqrt{\left(1 - Cos^2\theta_1\right)}$$

$$\operatorname{Sin}\theta_0 = \frac{n_1}{n0}\sqrt{1 - \frac{n_2^2}{n_1^2}}$$

Therefore $$\boxed{\operatorname{Sin}\theta_0 = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}}$$

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

$$\text{Sin } \theta_0 = \sqrt{n_1^2 - n_2^2}$$

$$\mathbf{N.A = Sin\ \theta_0 =} \sqrt{n_1^2 - n_2^2}$$

Condition for ray propagation:

If $\theta_i$is the angle of incidence of an incident ray, then the ray will be able to propagate,

If $\theta_i < \theta_0$ or if, $\text{Sin}\theta_i < \text{Sin}\theta_0$ or $\text{Sin}\theta_i < \sqrt{n_1^2 - n_2^2}$

This is the condition for propagation, i.e., $\sin\theta_i <$ N.A.

Numerical Aperture: It is the light gathering capacity of the optical fiber. It is given by

Numerical aperture=NA=Sin $\theta_0 = \dfrac{\sqrt{n_1^2 - n_2^2}}{n_0}$

Angle of acceptance: The angle of incidence θ_0 of light on the core for which the angle of incidence on the core-cladding interface will be critical angle is known as angle of acceptance. It is also known as waveguide acceptance angle.

Fractional index change ($\triangle$):

The fractional index change $\triangle$ is the ratio of the refractive index difference between the core and cladding to the refractive index of core of an optical fiber.

$\therefore \triangle = (n_1 - n_2) / n_1$

V – number:

The number of modes supported for propagation in the fiber is determined by a parameter called V – number. If the surrounding medium is air then the V – number is given by

$$V = \frac{\pi d}{\lambda} \sqrt{n_1^2 - n_2^2} = \frac{\pi d}{\lambda} \text{ (N.A)}$$

Where, d is the diameter of the core, n_1 is the refractive index of the core, n_2 is the refractive index of the cladding. λ is the wavelength of light propagating in the fiber.

If the fiber is surrounded by a medium of refractive index n_0, then the expression is,

$$V = \frac{\pi d}{\lambda} \frac{\sqrt{n_1^2 - n_2^2}}{n_0},$$

For V >> 1, the number of modes supported by the fiber is given by,
Number of modes $\approx V^2/2$

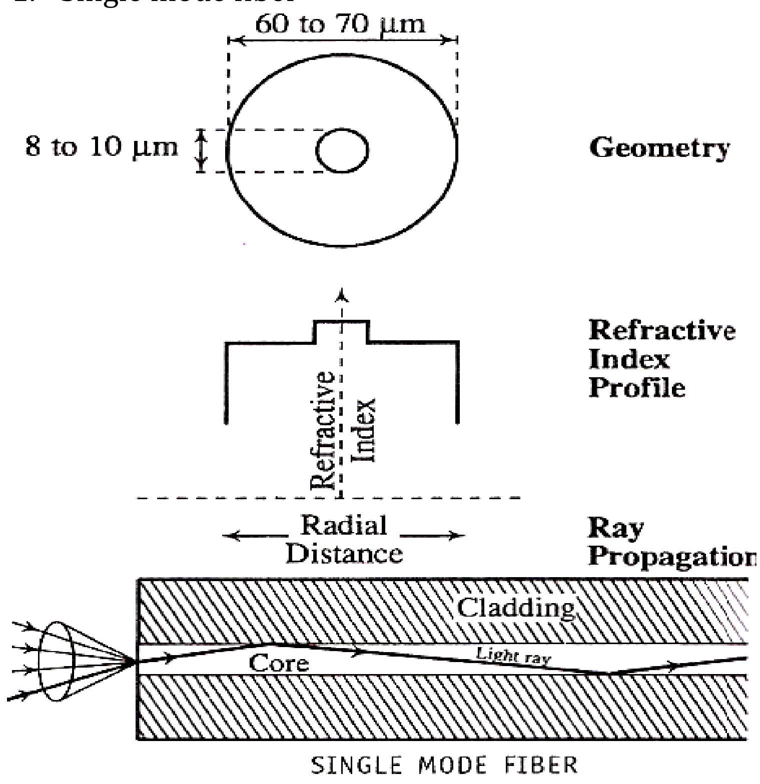
Types of Optical Fibers

Optical fibers are classified into 3 major categories based on the materials used for making optical fibers, number of modes transmitted and the R.I profile of the fibers.

Depending on Refractive Index Profile. Optical fibers are classified into 3 categories namely:

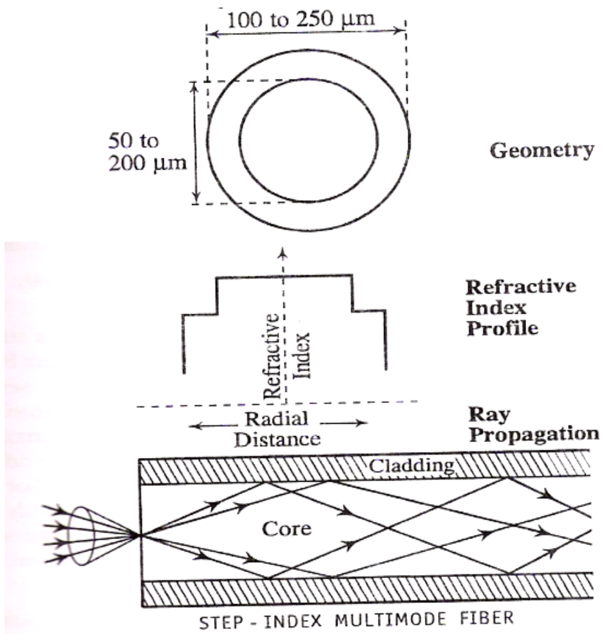
1. Single mode fiber
2. Step index multimode fiber
3. Graded index multimode fiber

1. Single mode fiber



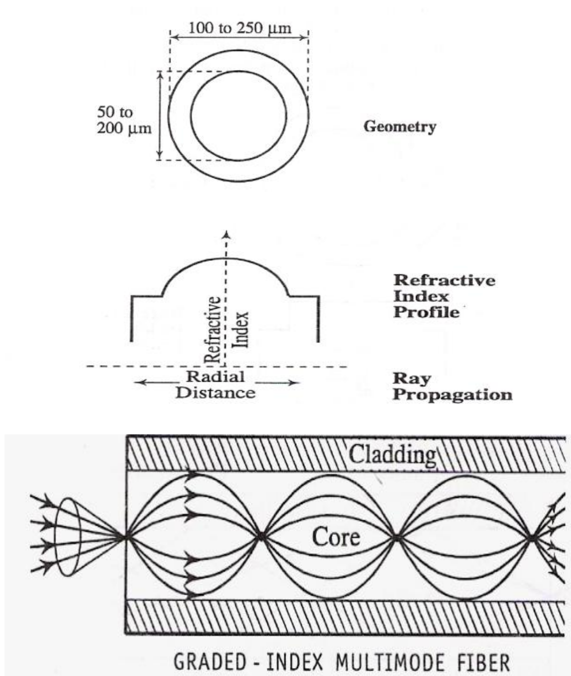
- ✓ Here core and cladding material has uniform refractive index value, but cladding have refractive index little lesser value than that of core.
- ✓ Diameter of the core is 8 to 10 μm.
- ✓ Diameter of the cladding is higher than core (60 to 70 μm).
- ✓ Since the core is very narrow, it can guide just a single mode. Hence it is called single mode fiber.

2. Step index multimode fiber



- ✓ Here core and cladding material has uniform refractive index value, but cladding have refractive index little lesser value than that of core.
- ✓ Diameter of the core is 50- 200 µm.
- ✓ Diameter of the cladding is higher than core (100 to 250 µm).
- ✓ Here the core material has a much larger diameter, which supports propagation of large number of modes.

3. Graded index fiber



- ✓ The special feature of the core is that its R.I value decreases in the radially outward direction from the axis, and becomes equal to that of the cladding at the interface. But the R. I of the cladding remain uniform.
  - ✓ Diameter of the core is 50- 200 μm.
  - ✓ Diameter of the cladding is higher than core (100 to 250 μm).

ATTENUATION (FIBER LOSS)

The power loss suffered by the signal when it propagates through the fiber is called Attenuation.

Types of losses in fiber are:

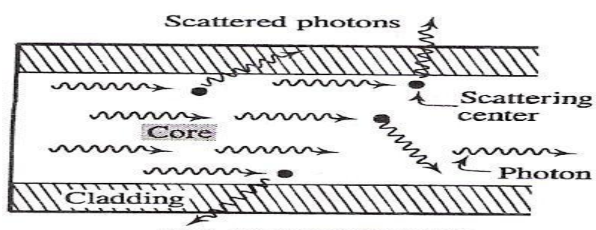
1. Absorption
2. Scattering
3. Radiation loss

1. Absorption loss

a. Absorption by impurities: some of the impurities like Iron, Chromium, Cobalt and Copper are generally present in the glass fiber. When signal propagates through the fiber, a few photons associated with the signal are absorbed by the impurities present in the fiber. This results in power loss.

b. Intrinsic absorption: The absorption that takes place in the fiber material assuming that there are no impurities in it.

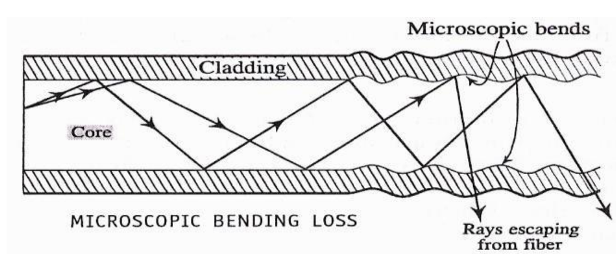
3. Scattering loss:



RAYLEIGH SCATTERING

- ➢ When a signal propagates through the fiber, a few photons associated with the signal are scattered by the scattering objects such as impurities present in the fiber. The dimensions of the scattering objects are very small compared to the wavelength of light.
- ➢ Scattering also occurs due to trapped gas bubbles, unreacted starting materials and some crystallized region in the glass.

3. Radiation loss: It is due to the bending of fibers and it can be explained as follows:



1. Macroscopic bending: They are the bends with radii much larger compared to fiber diameter. It occurs while wrapping the fiber on a spool or turning it around a corner. If the bending is too sharp then the power loss becomes very high.
2. Microscopic bending: It occurs due to the non uniformity in the fibers while manufacturing. Because of this a few modes undergo leakage which results in power loss.

EXPRESSION FOR ATTENUATION CO-EFFICIENT (α)

An optical fiber technology it is expressed α in terms of decibel /Kilometer (dB/Km). hence it follows that

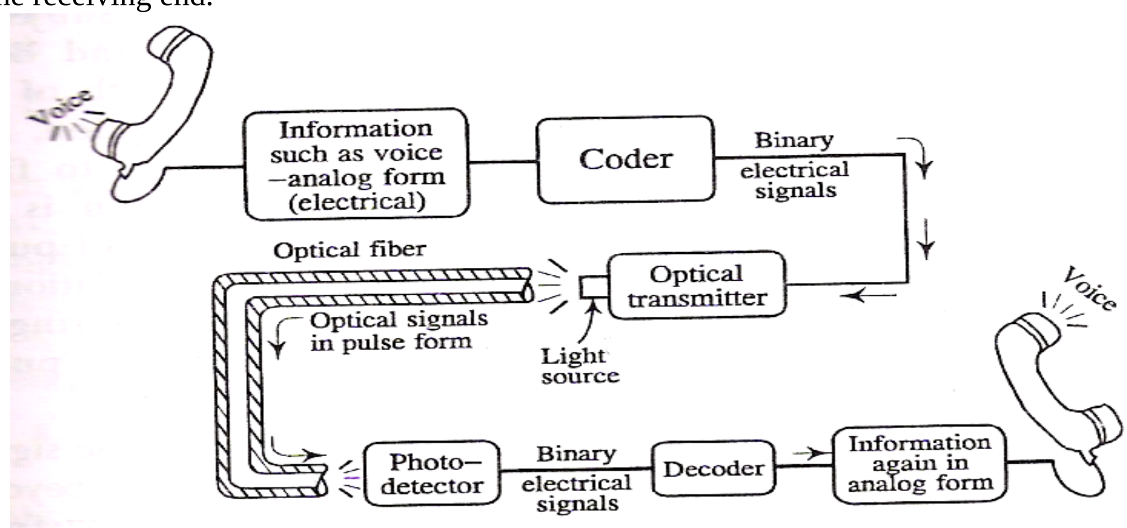
1) The length of the fiber is expressed in Km.
2) The unit of Bel is 10 dB (1 Bel=10 Decibel)

$$\boxed{\alpha = -\frac{10}{L} Log_{10}\left(\frac{P_{out}}{P_{in}}\right) dB/km}$$

Applications: Fiber optic communication:

Point to point Communication system using optical fiber

Optical fiber communication is the transmission of information by propagation of optical signal through optical fibers over the required distance, which involves deriving optical signal from electrical signal at the transmitting end, and conversion of optical signal back to electrical signal at the receiving end.



TYPICAL POINT-TO-POINT FIBER OPTIC COMMUNICATION SYSTEM

Block diagram of Point-to-point Communication:

A simple point-to-point communication system using optical fibers is shown in figure.

1. The voice is fed into the telephone, which gets converted into electrical signal.
2. The analog electrical signal is fed into a coder, which converts it into binary data.
3. The binary data comes out of the coder as electrical pulses.
4. These pulses are converted into optical signal by modulating the light emitted by an optical source through an optical transmitter.
5. The optical signal is then fed into optical fiber, through which the signal propagates by means of total internal reflection.
6. As the signal propagates it is subjected to attenuation and delay distortion. This is compensated by an optical repeater which converts the distorted optical signal into electrical signal. This electrical signal is sent back to the optical transmitter.
7. The optical signal is received by the photo detector, where it is transformed into pulses of electrical signals (binary data).
8. These pulses are fed into decoder which converts the sequence of binary data into analog electrical signal.
9. This analog electrical signal gets converted into voice through telephone.

Applications of optical fibers:

1. ***Sensing device:*** Optical fibers can be used as sensing devices where as they can sense parameters like pressure, voltage or current.
2. ***Data Link:*** In data transfer systems we can make use of optical fibers where the information will be in a secured form.
3. ***Local Area networks:*** Optical fibers provide more efficient communication facilities in the local area networks.

Advantages of optical communication system:

1. Optical fibers can carry very large amounts of information in either digital or analog form.
2. The materials used for making optical fibers are silicon dioxide and plastic, both of which are easily available at low cost.
3. Because of the greater information carrying capacity by the fibers, the cost/meter/channel for the fiber would be lesser than that for the metallic cable.
4. Because of their compactness, and lightweight, fibers are much easier to transport.
5. The optical fibers are totally protected from interference between different communication channels, since no light can enter a fiber from its sides. Thus the purity of the signals traveling inside the fiber remains unaffected because of which no cross talk takes place.
6. The signals generated from radio and telecommunications stations, or from some electronic equipments, or sometimes radiation from lightning, or sparking, tend to cause disturbance in the metallic cable but cannot do so for the fiber cable.
7. There is no energy radiation from a fiber. Hence the possibility of information tapping by detecting the leaky radiation is ruled out.
8. Fiber communication system is easily compatible with the electronic system.
9. Since the signal is optical, no sparks are generated as it could be in the case of electrical signal. Hence it leads to protection from corrosive and flammable environments.

Limitations of optical communications systems:

1. Splicing (joining two fibers) is a skilful task, which if not done precisely, the signal loss will be so much that it is virtually a break in the communication line. The optic connectors that are used to connect (splicing) two fibers are highly expensive.
2. While system modification is made, or because of accidents, a fiber may suffer line break. Operations required re-establishing the connections are highly skilful and time consuming.
3. Though fibers could be bent to circles of few centimeters radius, they may break when bent to still smaller curvatures. Also for small curvature bends, the loss becomes considerable.
4. Fibers undergo expansion and contraction with temperature that upset some critical alignments, which lead to loss in signal power.