Unit – V

FIBER OPTICS

Introduction :-

Optical fiber is a very thin, flexible transparent and dielectric medium made up of glass (or) plastic, Which carries light signals from one end to the Other end by total internal reflection.

Structure of optical fiber :-

Optical fiber Consists of 3 parts

1) Core
2) cladding
3) Protecting Cover (or) protecting layer.

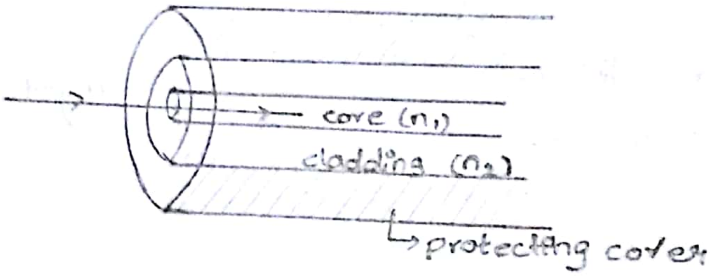


fig : structure of optical fiber

Principle of optical fiber :-

Total Internal reflection :-

If ~~reflectio~~ incident angle is greater than Crictical angle ($i > \theta_c$) the Complete incident light ray reflection back into the Same medium. This phenoum -non is Called as "total Internal reflection".

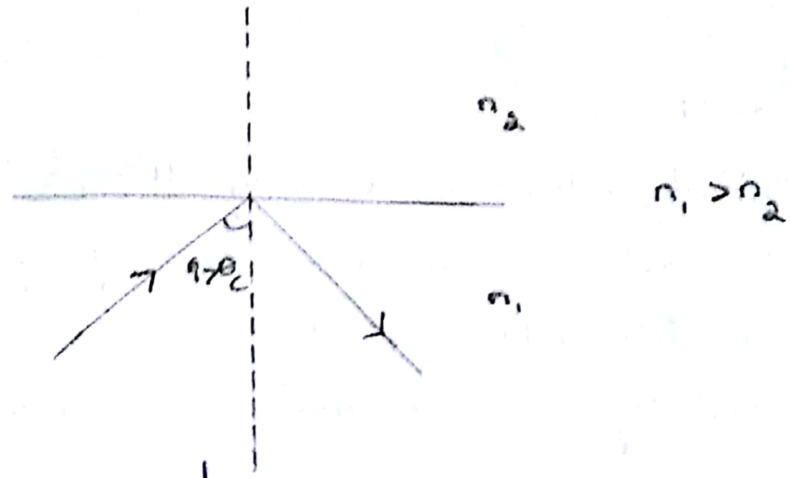


fig : total Internal reflection

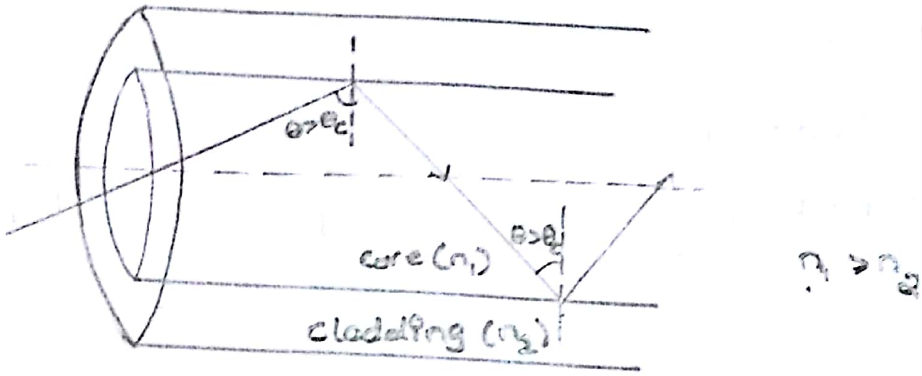


fig : total Internal reflection of light ray in the optical fiber

→ Optical fibers are working based on total Internal reflection principle.

→ The light launched inside the Core through its one end propagate to the other end due to total Internal reflection at the Core - cladding interface. This is the principle of optical fiber.

Conditions :-

Total Internal reflection of light Signal is possible only when.

→ ① Core refractive index (n_1) must be greater than the cladding refractive - Index (n_2)

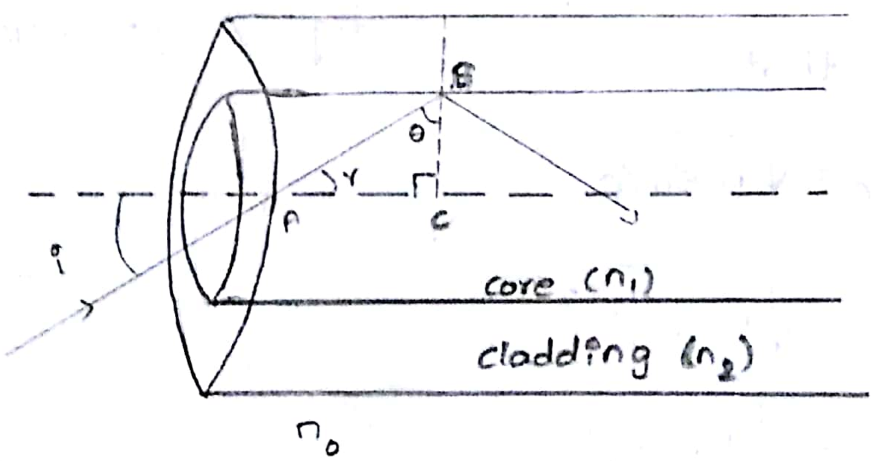
i.e; $\boxed{n_1 > n_2}$

→ ② The incident angle must be greater than the Critical angle at Core - cladding Interface

i.e; $\boxed{i > \theta_c}$

Acceptance angle and Acceptance Cone :-

The maximum Incident angle at which Complete Incident light rays are accepted and propogated through the fiber is Called acceptance angle. It is represented with i_{max} (or) α_{max}



Consider an optical fiber as shown in above figure. Core refractive index is n_1, cladding refractive index is n_2 and Surrounding medium refractive index is n_0.

from Snell's law,

$$\boxed{\mu_1 \sin i = \mu_2 \sin r}$$

apply this principle to the above figure

$$n_0 \sin i = n_1 \sin r$$

$$n_0 \sin i = n_1 \sin(90-\theta) \qquad \left[\because \text{ from } \Delta ABC \quad r = 90-\theta\right]$$

$$n_0 \sin i = n_1 \cos\theta .$$

if $\quad i = i_{max} \Rightarrow \theta = \theta_c$

$$n_0 \sin i_{max} = n_1 \cos\theta_c \quad \text{— ①}$$

from fig: ②

$$n_1 \sin\theta_c = n_2 \sin 90^\circ$$

$$n_1 \sin\theta_c = n_2$$

$$\sin\theta_c = \frac{n_2}{n_1}$$

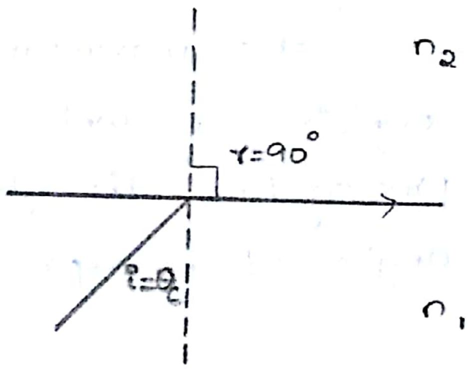


fig ② $\left[\because \sin 90^\circ = 1\right]$

We know that

$$\cos\theta_c = \sqrt{1-\sin^2\theta_c}$$

$$\cos\theta_c = \sqrt{1-\left(\frac{n_2}{n_1}\right)^2}$$

$$\cos\theta_c = \sqrt{\frac{n_1^2-n_2^2}{n_1^2}}$$

$$\cos\theta_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

Substitute this $\cos\theta_c$ value in Eq (1)

$$n_0 \sin i_{max} = n_1 \times \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$n_0 \sin i_{max} = \sqrt{n_1^2 - n_2^2}$$

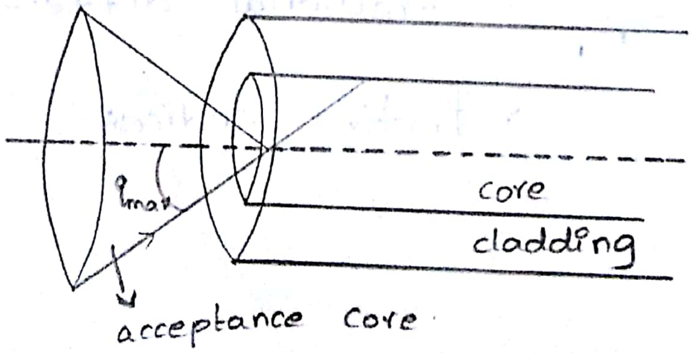
$$\sin i_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

$$\boxed{i_{max} = \sin^{-1}\left[\frac{\sqrt{n_1^2 - n_2^2}}{n_0}\right]}$$

$\therefore$ i_{max} is the acceptance angle of the optical fiber.

Acceptance Cone :-

If we rotate the acceptance angle around the fiber axis it will produce one cone. This cone is known as acceptance cone. light launched into the fiber with in this cone only accepted by the fiber.



Numerical aperture (NA) :-

Sine of the maximum acceptance angle is Called the "Numerical aperture (NA)". Numerical aperture represents the light Collecting Capacity of the optical fiber

$$NA = \sin i_{max} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$

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

Note 1 :- If Surronding medium is air

$n_0 = 1$

$$\boxed{NA = \sqrt{n_1^2 - n_2^2}}$$

Note 2 :-

$$\boxed{NA = n_1\sqrt{2\Delta}}$$

Where $\Delta = \frac{n_1 - n_2}{n_1}$ = fractional difference in refractive Indices.

Types of optical fibers :-

Optical fibers are classified based on the following two factors

I) no. of modes

II) Refractive Index profile.

I) no. of modes :-

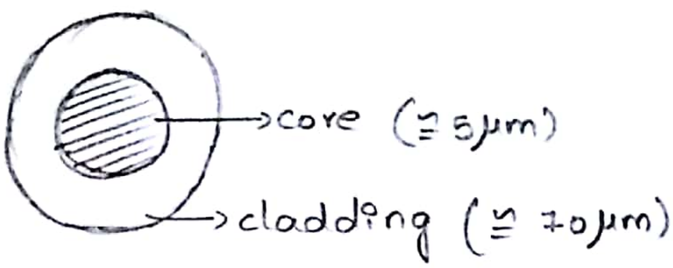
Based on the no. of modes, optical fibers are classified into 2 types.

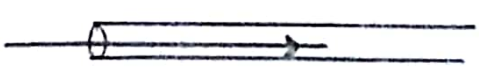
① Single - mode optical fiber

② multi - mode optical fiber.

① Single mode optical fibers:

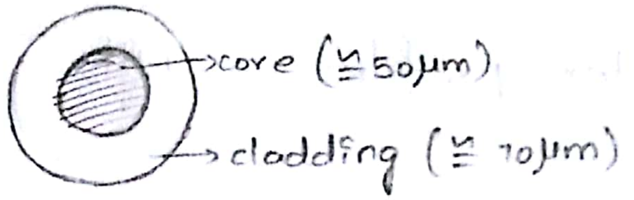
In this case, the diameter of the core is very narrow. Hence it supports only one mode for the light ray transmission. Therefore, this fibers are called as single mode optical fibers

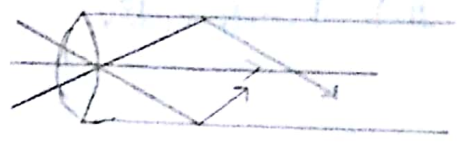




② Multi - mode optical fibers :-

In this fibers, the diameter of the Core is broad Hence it Supports more no. of modes for the light ray transmission. There fore, this fibers are Called as multi-mode optical fiber.



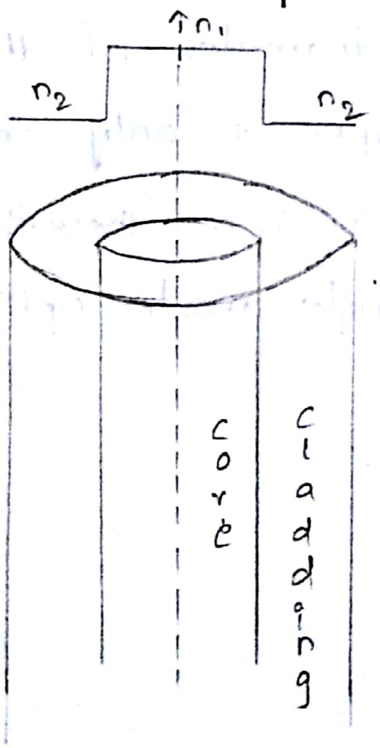


II) Refractive Index profiles :-

Based on refractive Index profile, optical fibers are classified in to 2 types.

1) step - Index optical fibers
2) graded - Index optical fibers.

1) step - Index optical fibers :-



In this fibers, Core refractive Index (n_1) is uniform and cladding refractive index (n_2) also uniform. Core refractive index is slightly greater than the cladding refractive index ($n_1 > n_2$) and the Core refractive Index is suddenly decreasing at Core - cladding interface. At this position the refractive Index profile is in the form of step, Hence this fibers are called as step - Index optical fibers.

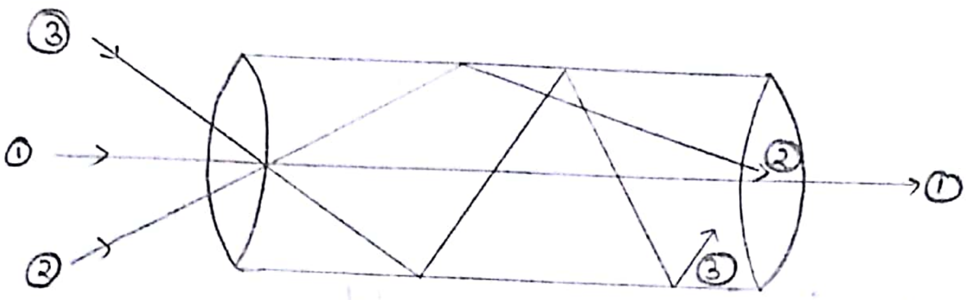


fig :- Signal transmission in step- Index optical fiber

→ In case of step - Index optical fibers, the Signal is transmitted in the form of "Zig - Zag rays" (or) "meridional rays".

→ Signal dispersion and time delay are major draw backs of this fiber.

→ Then step-Index optical fibers are used for short distance Communication.

2) Graded - Index optical fibers:

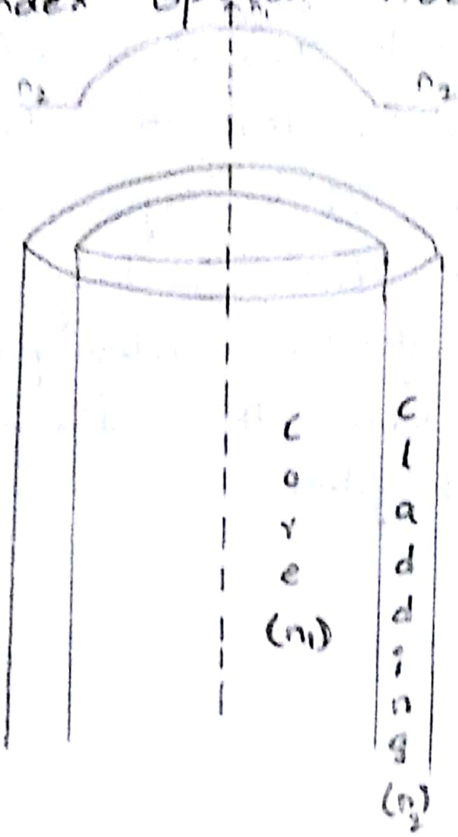


fig :- refractive Index profile.

→ In this fibers, core refractive Index (n_1) is non-uniform, but cladding refractive Index (n_2) is uniform

→ Core refractive Index (n_1) is maximum at its Center, Which is gradually decreasing and It is Equal to cladding refractive Index at core-cladding Interface.

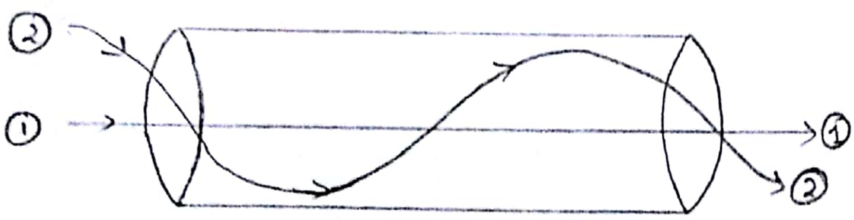


fig : Signal transmission

⇒ In Case of graded - Index optical fibers, the the Signal is transmitted in the form of "skew rays" (or) "Helical rays".

→ Signal dispersion is not there in the graded-Index Optical fibers.

→ These graded-Index optical fibers are useful long distance Communication.

* Difference between step - Index and graded - Index optical fibers :

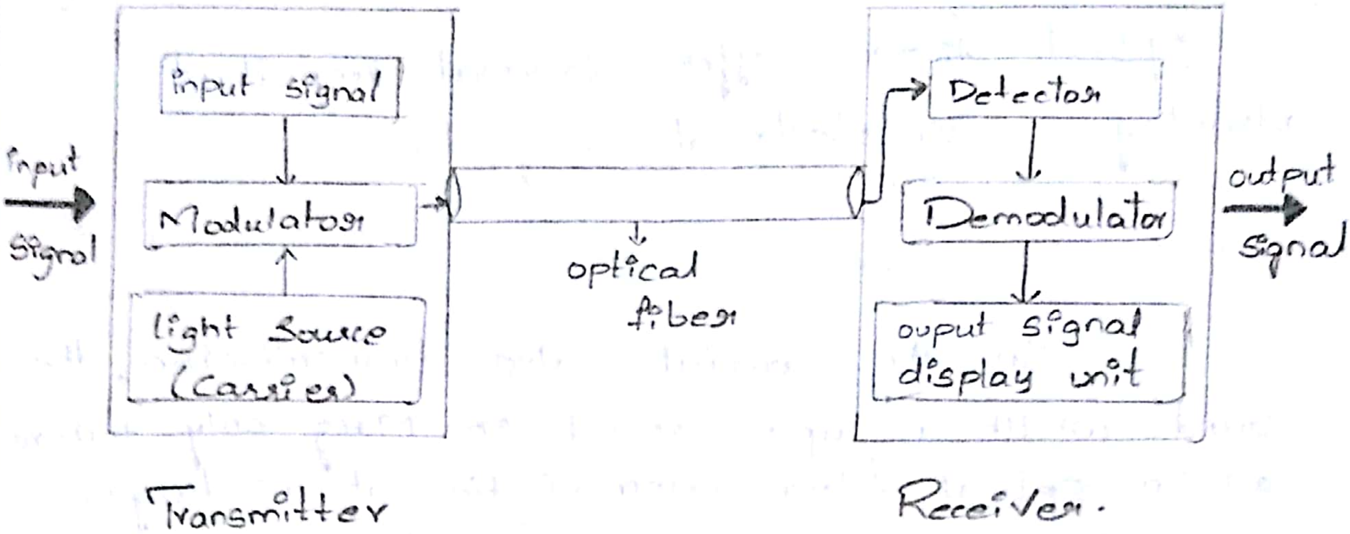
Step-Index O.F's	Graded - Index O.F's
1) In Case of step - Index optical fibers, core and cladding refractive Indices are uniform	1) In Case of graded - Index optical fibers core refractive Index is non-uniform but cladding refractive index is uniform
2) The refractive Index of the Core (n_1) is suddenly changes at Core - cladding interface.	2) The refractive Index of the Core (n_1) is gradually decreasing

Step-Index O.F's	Graded-Index O.F's
3) Signal transmission is in the form of Zig-Zag rays	3) Signal transmission is in the form of skew rays
4) Signal dispersion and time delay are major draw backs of this fibers.	4) Signal dispersion is absent in this fibers.
5) preparation is easy hence these are less Expensive	5) preparation is difficult Hence, these are Costly fibers.
6) These are Suitable for short distance Communi-cation	6) These are Suitable for long distance Communication.
Eg:- LAN (Local area network)	Eg:- Tele Communication

Applications of Optical fibers :-

Optical fibers in Communication :-

optical fibers are used as wave guides in optical Communication Systems.



Optical fiber Communication System mainly Consist of 3 parts.

1) Transmitter
2) Optical fiber
3) receiver.

The transmitter includes modulator and light Source. The input Signal is Converted in to pulses of optical power by modulator. This modulated Optical Signal is launched into the Optical fiber. This Signal is transmitted through the fiber. finally, at the end of the optical fiber the signal is send to the receiver. The receiver contains light detector. This can convert the light signal into electrical current, which is then send to the decoder, which converts the electrical signal into original data.

I-Advantages of optical fibers in Communication :-

Optical fibers offer several important advantages over electrical Hazards.

1) large band with :-

In the Coaxial Cable transmission, the band width is upto around 500 MHz only where as in optical fiber communication it is large as 10^5 GHz. Thus the information carrying capacity is large.

2) light weight and small diameter :-

Since optical fibers are light weight and very small in diameter, the space occupied by the fiber is very small compared to copper cables.

3) low transmission loss :-

Transmission loss is very less compared to the copper wires.

4) Signal Security :-

A transmitted optical signal cannot be drawn from a fiber.

Lack of Cross-talk :-

Since optical fibers are dielectric wave guides, they are free from electro-magnetic interference (EMI)

∴ Cross-talk is not possible in optical fibers even when many fibers are Cabled together.

6) Temperature resistant :-

Optical fibers have high tolerance at Extreme temperature.

7) Electrical Isolation :-

Optical fibers are insulators. Hence, Communication through optical fibers in any Environment do not Cause any problems of Spark

8) low Cost :-

Since optical fibers are made up of Silica, Which is available in large quantity. Hence optical fibers are less Expensive

II) Sensors :-

Optical fibers are Very Useful in Engineering applications as Sensors. Sensors are devices used to monitor the changes in temperature, pressure, displacement, flow rate, liquid level, chemical Composition etc... Then optical fiber Sensors are more Sensitive and reliable.

III) Applications of optical fibers in medicine :-

In the field of medicine, optical fibers are used in "endoscopy". An optical fiber instrum-ent used to see the internal parts of human body is endoscopy.

Attenuation (Loss of signal):-

The amount of optical power loss in the fiber per unit length is known as Attenuation

(or)

Attenuation in optical fiber is defined as the ratio of optical output power to the input power of a fiber for unit length

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

Attenuation or signal losses have 3 main reasons:

→ 1) Absorption loss
→ 2) Scattering loss
→ 3) Bending loss

Absorption loss:-

The presence of impurities like hydroxyl-group (O-H) and the metallic ions like iron, Cr, Ni & Cu ~~[illegible]~~ etc; causes major absorption losses.

Scattering loss:-

The structure and exact composition of the glass may not be the same throughout the fiber and it causes variation in the refractive index of the fiber and leads to scattering losses.

Bending losses:-

whenever a fiber bends from its straight line path, the angle of incidence will be changed, which affects the mode of propagation of light. Hence, it leads to loss of power and these losses are called bending losses.

Fig: loss of signal at fiber bend

LASERS

LASER: Light Amplification by stimulated emission of radiation

Characteristics of LASER radiation:

The most important characteristic of a laser are

→ (1) Laser is highly monochromaticity

→ (2) High directionality.

→ (3) High degree of coherence.

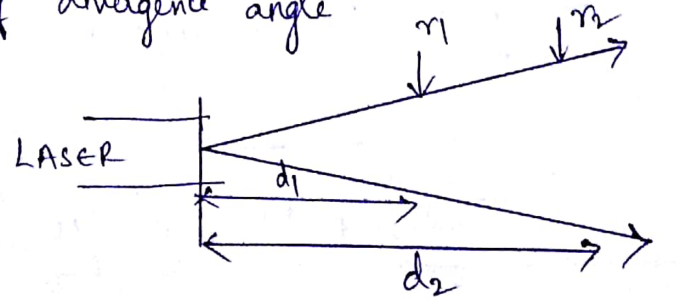
→ (4) High intensity.

(1) High Monochromaticity:- Laser is high monochromatic light, this property is described using a parameter i.e.,

$$\boxed{\xi = \frac{d\nu}{\nu}} = \text{a degree of non-monochromaticity}.$$

for a good stable laser $\xi = 10^{-13}$ is very small value. i.e. The non monochromaticity of a laser is very low from this we can conclude that the laser light consist very high monochromaticity.

(2) High directional: A conventional light source (ordinary light) emit light in all directions due to its spontaneous emission character. But laser light only in single direction, due to its stimulated emission of radiation. The directionality of laser light is expressed interms of divergence angle



The divergence angle

$$\boxed{\Delta\theta = \frac{r_2 - r_1}{d_2 - d_1}}$$

Where r_2 and r_1 are the radius of the laser spots at distance of d_2 and d_1 respectively from the laser source. for a laser beam $\Delta\theta = 0.01$ milliradian, It is very small the laser light has low divergence angle hence, laser light consist high directionality.

(3) High degree of Coherance:

When two light rays are having same phase (or) constant phase difference, then they are said to be coherant. laser beam has high degree of coherance.

Ex: for He : Ne laser $L_c = 600\,km$, $T_c = 10^{-3}$ sec

for Na Lamp $L_c = 3\,cm$ $T_c = 10^{-10}$ sec.

Where $L_c \rightarrow$ coherence length

$T_c \rightarrow$ coherence time.

from above examples laser light consists high coherance.

(4) High Intensity:-

In a laser beam lot of energy is concentrated in a small region. That is more no. of photons are incident at a single point and these photons generates a lot of energy at that point, hence there is high intensity for laser beam.

The no. of photons coming out from a laser per second per unit area is given by

$$\boxed{N = \frac{P}{h\nu \pi r^2} \simeq 10^{22} \text{ to } 10^{34} \text{ photons}/m^2\text{-sec.}}$$

Absorption of radiation:

Consider 2 energy levels of an atomic system 1 & 2. The energy of levels E_1 and E_2 respectively. Let a photon of energy $[E_2 - E_1 = h\nu]$ is incident on the atomic system as shown in following figure.

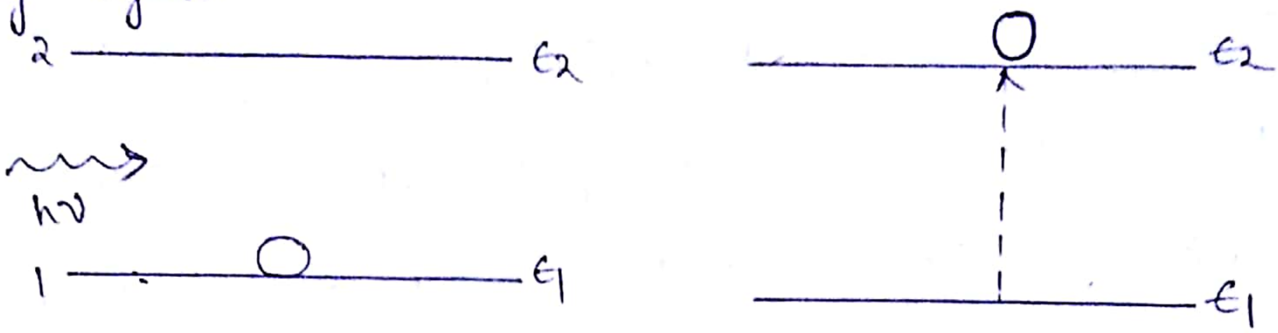


Fig: Absorption of radiation process.

The atoms which are in the ground state absorps the energy from the photon and jumps from ground state to higher energy state. Then this process is known as "absorption of radiation" (or) "stimulated absorption of radiation".

Spontaneous Emission of Radiation:

After absorption of radiation the atoms are reached to excited state E_2. The atoms can remain in state E_2 for a short time known as life time. After lifetime atoms ~~are~~ comes back to its ground state by emitting a photon. This type of emission is called "Spontaneous emission".

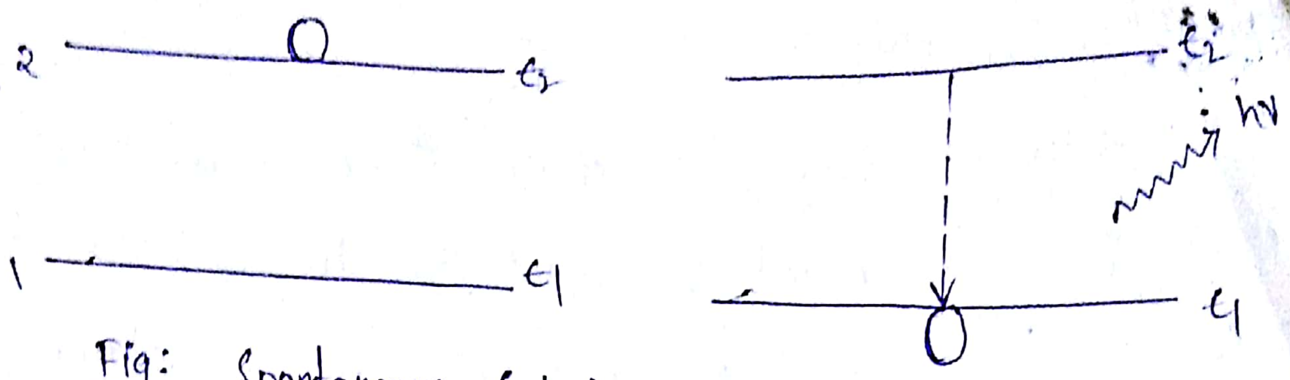


Fig: Spontaneous Emission

Stimulated (Induced) Emission :

Before lifetime (10^{-8} sec) an additional photon is incident on atomic system. The atoms which are in the excited state (E_2) absorb the Energy and quickly come back to the ground state by emitting 2 photons. and these 2 photons move in same direction and with Same phase. This complete process is known as "stimulated emission of radiation"

The emitting light in stimulated emission of radiation consist of high power, high coherance, high directionality and high ~~rate~~ monochromaticity.

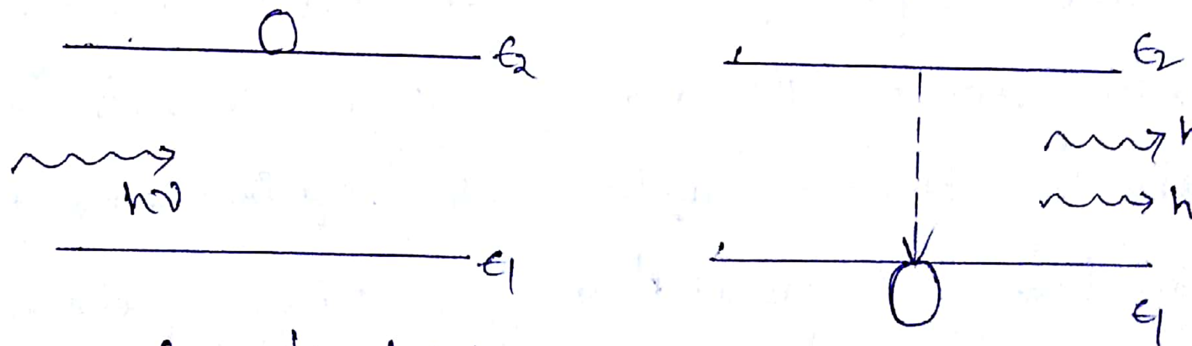


fig: stimulated Emission.

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Difference between Spontaneous emission & stimulated Emission

Spontaneous Emission	Stimulated Emission
(1) Emission of light photon takes place immediately ——— the transition of atom from higher energy level to lower energy level.	(1) Emission of light photon takes place by supplying of additional photon
(2) Incoherant radiation.	(2) High coherant radiation
(3) Less intensity	(3) High intensity.
(4) Less directionality and more angular spread	(4) More directionality and less angular spread.
(5) The emission has a broad spectrum; i.e., It consist many wavelengths	(5) The emission has monochromatic radiation, i.e., It consist single wavelengths.
Ex: Na - lamp, Sunlight, Mercury lamp.	Ex: Laser light

Relation between Einstein's Coefficients

Consider two energy levels E_1 and E_2 of an atomic system such that $E_2 > E_1$. Let N_1 and N_2 be the no. of atoms per unit volume present at the levels E_1 and E_2 respectively. Consider the radiation of frequency $(E_2 - E_1 = h\nu)$ is incident on the atomic system and $u(\nu)$ is the energy density.

→ (i) **Absorption of Radiation :**

The shifting probability of atoms from level 1→2, is given by,

$$P_{12} \propto N_1 u(\nu)$$

$$P_{12} = B_{12} N_1 u(\nu) \longrightarrow (1)$$

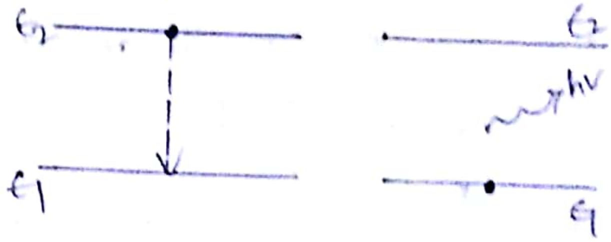
Where "B_{12}" is Einstein's coefficient of absorption of radiation.

→ (ii) **Spontaneous Emission :-**

The shifting probability of atoms from level 2→1 is proportional to no. of atoms present in the "E_2" level i.e.,

$$P_{21} \propto N_2$$

$$P_{21} = A_{21} N_2 \longrightarrow (2)$$



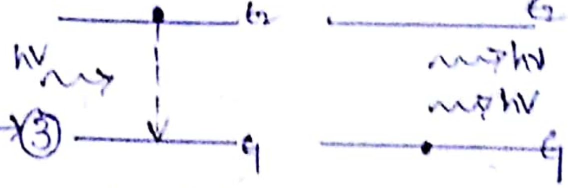
Where "A_{21}" is the Einstein's coefficient of spontaneous emission of radiation.

→ (iii) **Stimulated Emission :-**

The shifting probability of stimulated emission is proportional to the no. of atoms in "E_2" state and energy density of photon i.e.,

$$P_{21} \propto N_2 u(\nu)$$

$$P_{21} = B_{21} N_2 u(\nu) \longrightarrow (3)$$



Where "B_{21}" is Einstein's coefficient of stimulated emission of radiation.

The total shifting probability of atoms from level $2 \rightarrow 1$ is given by

$$P_{21} = B_{21} N_2 u(\nu) + A_{21} N_2 \longrightarrow (4)$$

Under the condition of equilibrium, the no. of atoms absorbing radiation per unit time is equal to no. of atoms emitting radiation per unit time.

$$P_{12} = P_{21}$$

$$B_{12} N_1 u(\nu) = B_{21} u(\nu) + A_{21} N_2$$

$$\left[B_{12} N_1 - B_{21} N_2\right] u(\nu) = A_{21} N_2$$

$$u(\nu) = \frac{A_{21} N_2}{B_{12} N_1 - B_{21} N_2}$$

$$\cancel{u(\nu) = (A_{21}/B_{21})/}$$

$$u(\nu) = \frac{A_{21} \cancel{N_2} / B_{21} \cancel{N_2}}{\frac{B_{12} N_1}{B_{21} N_2} - \frac{B_{21} \cancel{N_2}}{B_{21} N_2}}$$

$$u(\nu) = \frac{(A_{21}/B_{21})}{\left(\frac{B_{12}}{B_{21}}\right)\left(\frac{N_1}{N_2}\right) - 1}$$

According to Boltzmann distribution Law

$$\frac{N_1}{N_2} = \exp\left[\frac{E_2 - E_1}{k_B T}\right] = \exp\left[\frac{h\nu}{KT}\right]$$

$$u(\nu) = \frac{[A_{21}/B_{21}]}{\left[\frac{B_{12}}{B_{21}} \exp\left[\frac{h\nu}{KT}\right] - 1\right]} \rightarrow (5)$$

According to planck's radiation law, the energy density is given by

$$u(\nu) = \frac{8\pi h\nu^3/c^3}{\left[\exp\left(\frac{h\nu}{KT}\right) - 1\right]} \rightarrow (6)$$

Comparing eq^{n}s (5) & (6)

$$\frac{B_{12}}{B_{21}} = 1$$

$$\Rightarrow \boxed{B_{12} = B_{21}} \longrightarrow (7)$$

The probability of stimulated absorption is equal to the probability of stimulated Emission.

$$\boxed{\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}} \longrightarrow (8)$$

The ratio of Einstein's coefficient of spontaneous emission to stimulated emission is directly proportion to the cube of frequency $(\because \nu^3)$

eq^n (7) and (8) represents Relation between Einstein's coefficients.

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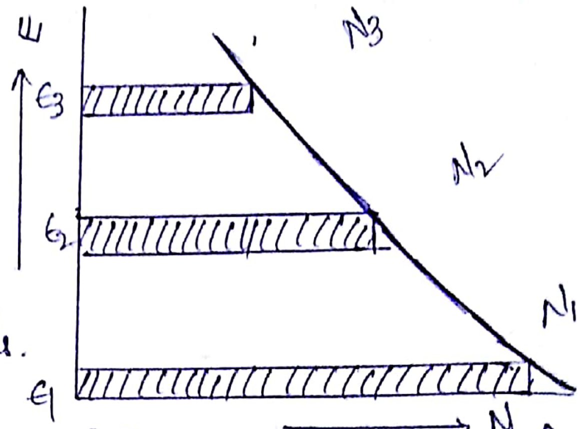
Population Inversion

According to Boltzmann distribution function: The no. of particles (N) at any energy level (ϵ) is given by

$$N = N_0 \exp\left(\frac{-\epsilon}{K_B T}\right)$$

It shows that as the energy of the level increases, the no. of particles in that level decrease.

Consider a 3 level system of energies $\epsilon_1, \epsilon_2, \& \epsilon_3$. ($\epsilon_3 > \epsilon_2 > \epsilon_1$) the no. of atoms in each energy level represented by N_1, N_2, N_3 respectively. Usually $N_1 > N_2 > N_3$ and its graphical representation is shown in following figure.



(Before population inversion)

For laser action to take palace, the higher energy levels should be more populated than the lower energy levels. i.e., $N_2 > N_1$

The process by which the population of particular higher energy state is made more than the population of a particular lower energy state is called as "population inversion".

When system is excited by some means if the no. of atoms in energy state ϵ_2 is made larger compared to the state ϵ_1, we say population inversion is achieved ($N_2 > N_1$). This process is shown in following figure

$N_2 > N_1$.

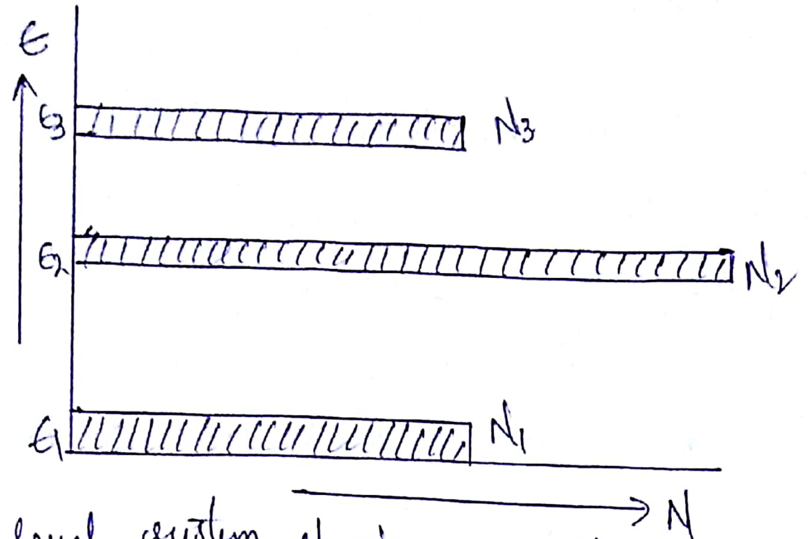
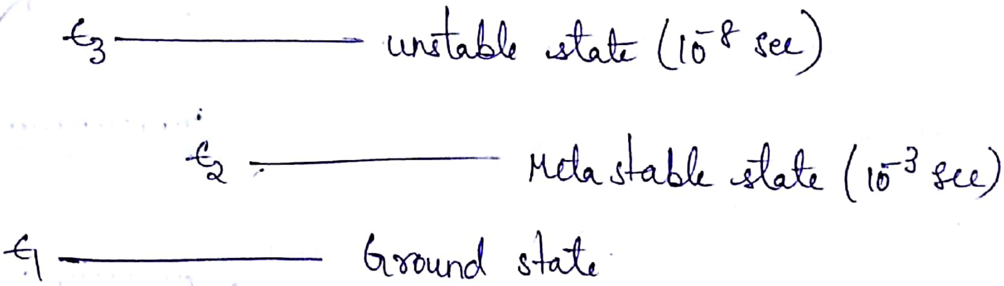


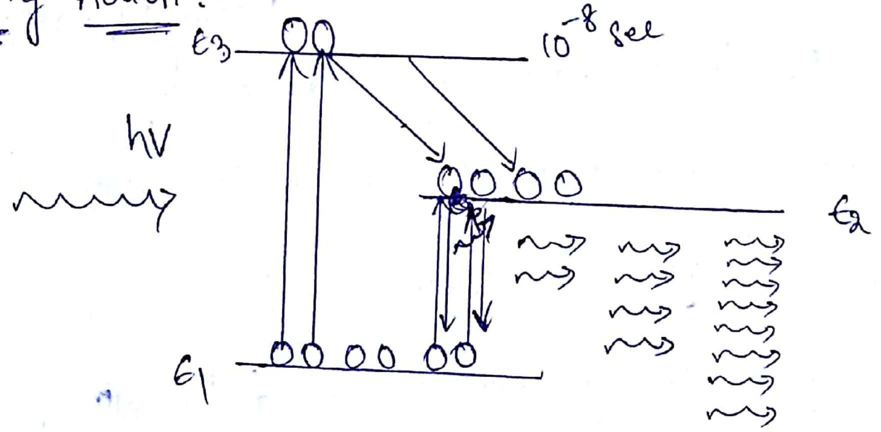
fig:- 3 level system showing population inversion of E_2 with respect to E_1 (After population Inversion)

Metastable state:

The higher energy state of the atoms which is having lifetime morethan 10^{-8} sec is known as "Metastable state".



Lasing Action:



When energy is incident on atomic system, atoms are shifted to higher energy states as shown in fig. Life time of E_3 state is very less (10^{-8} sec only). Hence E_3 atoms will shift to E_2 state. E_2 state is metastable state. Hence, life time is more (10^{-3} sec). After sometime more no. of atoms gathered at E_2 state and population inversion is created between E_1 and E_2 states. first atom lifetime is over in E_2 state then that atom fall down to groundstate by emitting photon. This photon is absorbed by another atom which is present in the E_2 state. Before lifetime atom will fall down quickly by emitting 2 photons. These 2 photons absorbed by another 2 atoms they will fall down to ground state by emitting 4 photons. This process continuous until high intensity laser light is produced. This total process is called as "Lasing action"

The following three things are important for lasing action.

→ 1) active medium
→ 2) population inversion
→ 3) Stimulated Emission.

Types of lasers

Depending upon the active medium, we have different types of lasers, i.e.,

Type	Ex:-
→ Solid state laser	: Ruby laser.
→ Gas laser	: He: Ne laser.
~~→ Semiconductor laser~~	: Ga As laser.

Ruby Laser:

Ruby Laser is a first successful solidstate laser. It was Constructed by "Th. Maiman". It is a three level laser. The experimental arrangement is shown in following fig.

Construction: Ruby ($Al_2O_3 + Cr_2O_3$) is a crystal of aluminium oxide in which some of Al^{+3} ions are replaced by Cr^{+3} ions. When the doping concentration of Cr^{+3} is about 0.05%, the colour of rod becomes pink. The active medium in rubyrode is Cr^{+3} ion. The Ruby rod of length 4cm & 5mm diameter is used and the ends of the rod are highly polished. Both ends are silvered such that one end is fully reflecting and the other end is partially reflecting.

The ruby rod is surrounded by helical xenon flash lamp tube which provides the pumping light to raise the Cr^{+3} ions to upper energy levels. The xenon flash tube which emits Intense pulses, But only a part of this energy is used in pumping Cr^{+3} ion while the rest heats up the apparatus. For this purpose ~~of~~ a cooling arrangement is there as shown in figure.

Working: The energy level diagrams of cromium ion is shown in fig. In the figure, E_1, E_2 and E_3 represent

the energy levels of cr^{+3} ion. In normal conditions all cr^{+3} (7)
ions are in lower energy level E_1. when xenon flash light is incident on the ruby rod, the chromium atoms are excited to upper energy level E_3. This transition is known as pumping transition

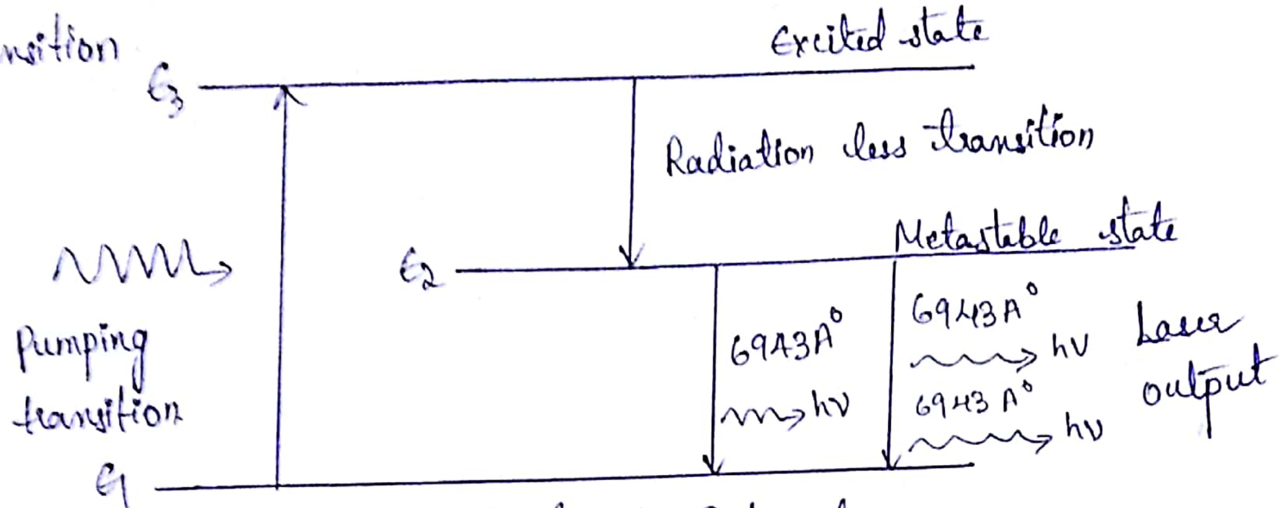


fig: Energy levels of Ruby laser

Due to the collision the excited atoms (ions) lost their energy and decay to metastable state E_2. thus this transition is Radiation less transition. The metastable state has longer lifetime (10^{-3} sec), thus the no. of ions in state E_2 goes on increasing while due to pumping, the no. of ions in state E_1 goes on decreasing. In this way, population inversion is achieved b/w E_2 and E_1

Consider the ion passes spontaneous from the metastable state to ground state, it emits a photon of wavelength 6943A°. This photon travels through the ruby rod and if it is moving parallel to the axis of the crystal, is reflected back and forth by the silvered ends until it stimulated an excited ion in E_2. Now it causes the ion to emit a fresh photon. The excited atom after emitting photon returns to E_1. The process is repeated again and again because the photons repeatedly move along the crystal being reflected from its ends. This results in amplified strong laser beam, of wavelength 6943Å

Advantages

It gives very high power of 100 MW in a single pulse.

Drawbacks

following are the disadvantages of Ruby laser

(1) The laser requires high pumping power.

(2) The efficiency of ruby laser is very small. Here, only the green component of pumping light is utilized while the rest is wasted in the form of heat.

(3) The laser output is not continuous. It gives pulsed laser light.

(4) ~~It~~ The defects due to crystal imperfection also present in this laser.

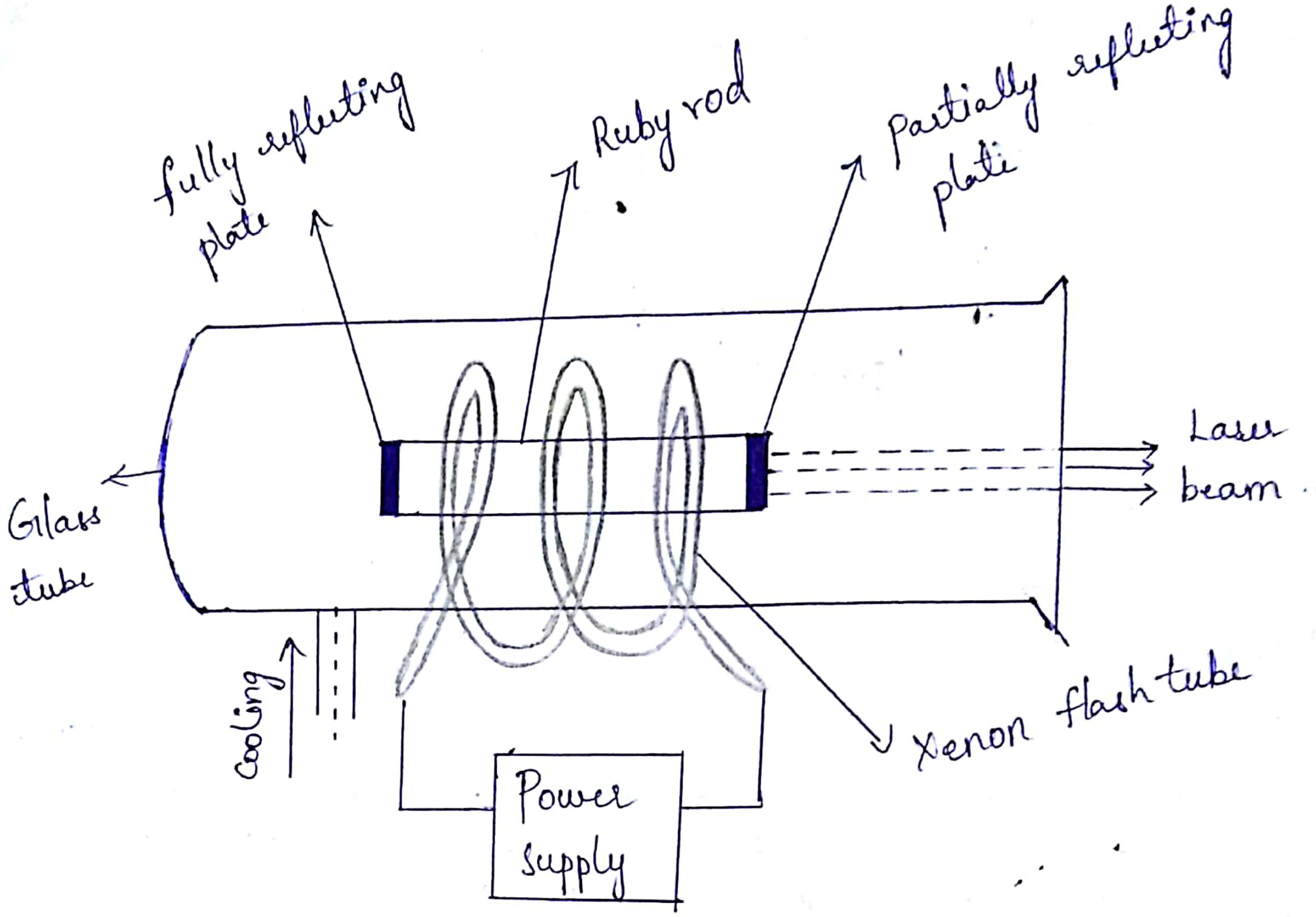


fig: Ruby Laser

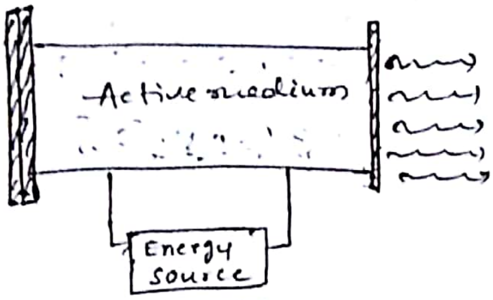
Components of a Laser:-

Laser system consists of 3-important components

→ ① Active medium

→ ② Energy source

→ ③ Optical cavity (or) optical resonator.



Active medium:-

The atomic system (material) which is used to produce laser light is known as active medium.

Energy source:-

Energy source supplies sufficient amount of energy to the active medium by which atoms excited to the higher energy states. As a result population inversion is created in the medium. while atoms shifting to the lower energy level, the emitted photons starts the stimulated emission which leads to laser emission.

Optical cavity:-

The active medium is enclosed in a container(box) one side of the box is closed with fully reflecting mirror and other side is covered with partially reflective mirror. This arrangement is known as optical cavity. These mirrors reflect the photons back & forth in the active medium, these photons enhance the stimulated emission process within the active medium. As a result, we get high-intensity laser light through the partially reflective mirror.

He-Ne Laser [Helium-Neon laser]

The main disadvantage of ruby laser is that the o/p beam is not continuous. For continuous laser beam, gas lasers are used. Using gas laser, light radiation with higher coherance, higher directionality and higher monochromaticity can be achieved.

The first successful gas laser is Helium-Neon laser. It was constructed by "Ali Javan". It is a four level laser.

Construction:-

The experimental arrangement of He-Ne laser is shown in following figure.

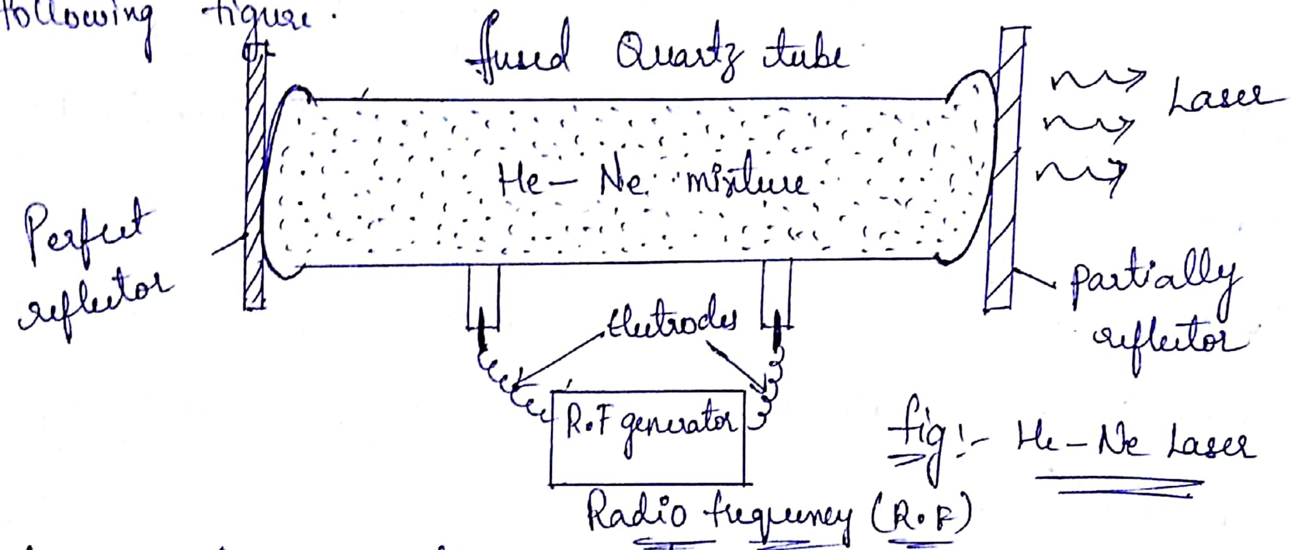


fig:- He-Ne Laser

The gas laser consists of fused quartz tube with diameter of about 1.5cm and 80cm long. This tube is filled with a gas mixture of He and Ne pressure of 1mm of Hg. The ratio of He:Ne gas mixture is 10:1. There is a majority of He atoms and minority of Ne atoms. One end of the tube is covered with the fully reflector and another side is covered with partial reflector. The active medium is excited by a high frequency generator.

Working:

The energy level diagram of He-Ne atom laser is shown in following fig.

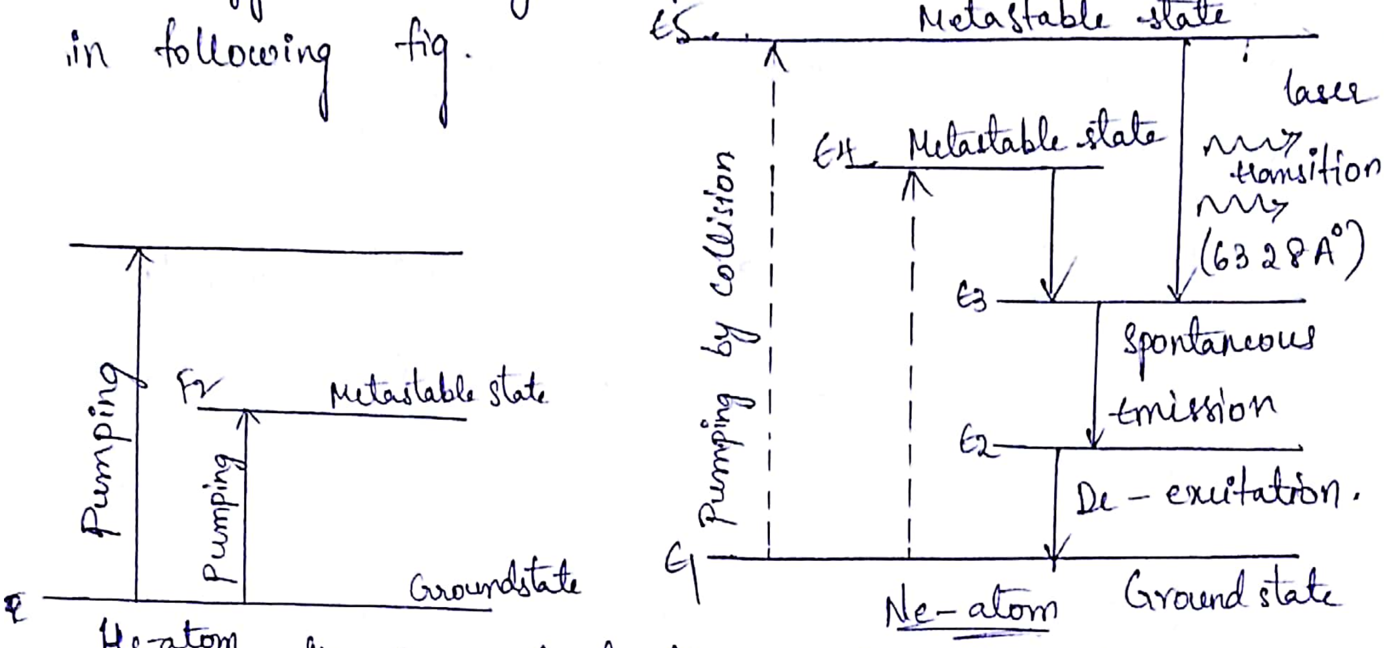


fig: Energy level diagram of the He-Ne Laser

When a discharge passes through the gas mixture, He-Ne atoms are excited to higher energy levels. F_2 & F_3. The excited He-atoms then collide inelastically with Ne-atoms still in groundstate and transfer energy to them, by absorbing this energy. These Ne-atoms are jumped to higher energy states E_3, E_4 & E_5. After collision Helium atoms are jumped to the groundstate (F_0). The higher Ne states E_5 & E_4 are metastable states and have longer lifetimes than E_3. Therefore, a population inversion takes place.

When an excited Ne atom passes from states E_5 & E_4 to E_3. It emits a photon. This photon reflected back and forth by the mirror ends until it stimulates an excited Ne-atom. This process continues till a laser beam builds up in the tube. When the beam becomes sufficiently intense, it will release through the partially silvered end.

Merits.

(1) He-Ne laser is a high efficient laser.

(2) It gives continuous & high power laser light.

(3) It gives high coherent, high directional, high monochromatic and high pure laser light.

Applications of LASERS

Lasers find many applications in the fields of

1. communication
2. computers
3. industry.
4. scientific research
5. Military operation
6. Medicine.

Lasers in industry:

(1) Lasers can be used to blast holes in diamonds and hard steel.

(2) Lasers are used to cut teeth in saws.

(3) Laser can be focussed into a very fine beam resulting in raising the temperature about 1000 K. So, they are used as a heat source.

(4) Laser range finder is used to measure distance for making maps by surveyors.

(5) High power lasers are used for cutting and drilling of metals and non metals such as ceramics, plastics and glass etc.

(6) Micro welding is done with great ease.

(7) Lasers are used to cut a large no. of models and sizes of dresses and suits. and the cut edges are melted by the beam & any fraying is prevented.

(8) CO_2 lasers are used for ceramic and semiconductor scribing.

Lasers in Scientific Research:

(1) Scientists are working on separating isotopes of uranium using laser.

(2) Lasers are used in the field of 3D photography known as Holography.

(3) Astronomers have measured the distance b/w moon & earth using lasers. and they are studying the rotation of earth

(4) Using this, the internal structure of micro organisms and cells are studied

(5) pictures of clouds, wind movements etc can be obtained with the laser beam. This data so obtained can be used in weather forecasting

Lasers in Medicine :

(1) Doctors use the heating action of a laser beam to remove diseased body tissue.

(2) Lasers are used ~~to~~ in opening blocked arteries, removing warts and treating bleeding ulcers.

(3) Lasers are used for elimination of moles and tumors which are developing in the skin tissue.

(4) Lasers are used in opthalmology and dermatology.

(5) the endoscopes are made from optical fibres which are flexible with suitable laser.

(6) CO_2 laser is used in spinal and brain tumor

excision and kidney stone extraction.

(7) Laser doppler velocitymetry is used to measure the blood velocity in the blood vessels.

(8) Laser beam is used for retinal detachment by eyes specialist in opthalmology.

(9) Lasers are used for reconnecting several nerves.

Military Applications:-

→ To destroy enemy aircrafts & missiles
→ for monitoring the remote environments. laser-fluorescences are used.
→ As a war weapon (Laser Guns).

Lasers in computers:-

→ In the LAN, to transfer data from one computer to another
→ In CD-ROMS, during recording & reading the data

Lasers in communication:-

→ In optical fiber communication
→ In spacecrafts & submarines
→ In under water communication and also for studies on variety of atmospheric features.