UNIT - IV

1. LASERS

§ Introduction:

The word "LASER" is an acronym for "Light Amplification by Stimulated Emission of Radiation". The basic principle in LASER is the phenomenon of "Stimulated Emission of Radiation" suggested by Albert Einstein in 1917. In 1954 Charles H. Townes and his co-workers put this prediction of Einstein to practical use.

The first laser was developed by T.H. Maiman in the year of 1960 (Ruby laser). After that in the year 1961, Ali Javan and his associates developed He-Ne laser. Developments in semi conductor technology led to the fabrication of solid state laser in 1962 by Hall and his co-workers.

LASER is a device which can produce high intense, highly monochromatic coherent light in a narrow parallel beam.

Characteristics of Laser :-

The important characteristics of laser are :

1). Highly Monochromatic (Monochromaticity)

2). Highly Directional (Directionality)

3). Highly Intensive &

4). Highly Coherent (Coherence)

①. Highly Monochromatic :- (Monochromaticity)

Laser is highly monochromatic compared to the other conventional light sources. For example, the beam of a He-Ne gas laser is a very pure red colour. It is said to be nearly monochromatic (or) nearly single coloured. Near monochromaticity is a unique property of laser light which says that it consists of light of almost a single colour/wavelength.

Perfect monochromatic light can not be exist, but, laser light is many times more monochromatic than the other sources.

②. Highly Directional :- (Directionality)

All conventional light sources emit light in all possible directions as shown in fig (a).

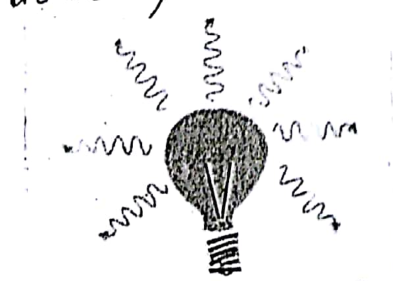


Fig (a): Conventional Source

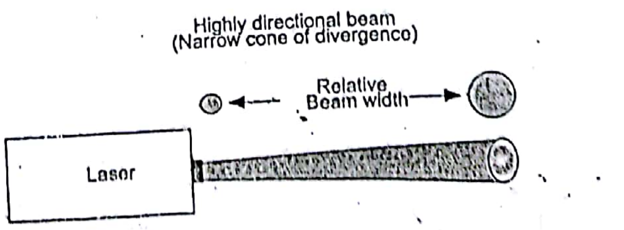


Fig (b): Directionality of laser light

Fig (6) shows that the highly directional nature of light produced by a laser.

Directionality is the characteristic of laser light that causes it to travel in a single direction.

Laser is highly directional which can be expressed in terms of divergence. The degree of divergence (spread) of laser for laser spots of radii r_2 and r_1 for distances D_2 & D_1 from the laser source can be given by

The divergence

$$\Delta\theta = \frac{(r_2 - r_1)}{(D_2 - D_1)} \longrightarrow (1)$$

③. Highly Intensive :-

A lot of energy is concentrated in a small region due to low divergence and highly coherence of laser. Hence, there is a enormous intensity in laser beam (i.e., highly intensive)

④. Highly Coherent :- (Coherence)

Laser is highly coherent because two waves in laser beam maintain high spatial coherence and temporal coherence.

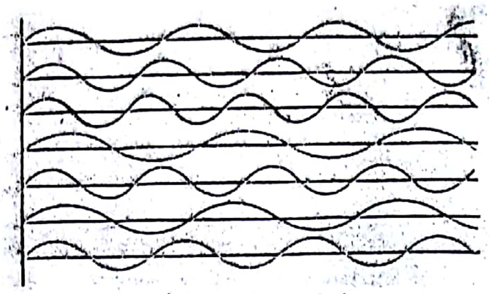


Fig.(a): Incoherent light waves

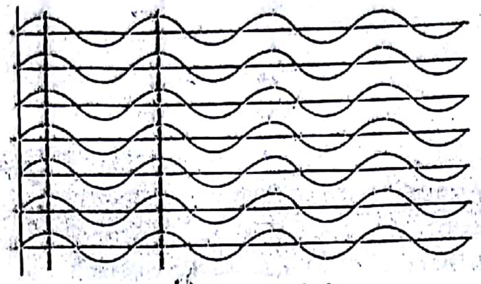


Fig.(b) Coherent light waves

§ Atomic Excitation :- (Interaction of radiation with Matter)

An electron in an atom revolves around the nucleus in descrete orbits. Unless it absorbs some amount of energy by any means, the atom will be in ground state(or) stable state.

When sufficient energy is given to the atom in the ground state, then electrons of that atom absorbs energy (photons) and are excited to a higher energy levels. Now, the atom is said to be in an "Excited State".

In this state the atom can not stay for a long time; because, excited state is always an unstable state. After a little time (10^{-8} sec) it comes down to the ground state by emitting a photon of EM radiation.

EINSTEIN COEFFICIENTS :-

Stimulated Absorption :-

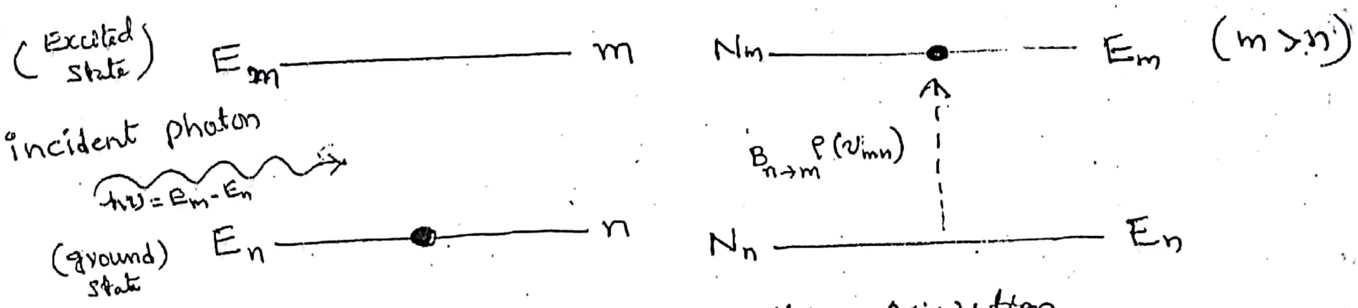


fig 1(a). Before Absorption (b). Absorption

Consider two energy states E_m and E_n of an atom. "E_n" represent ground state of the atom and "E_m" represent the excited state of the atom respectively.

If a photon of energy equal to $E_m - E_n = h\nu$ is incident on the atom in the ground state, then the atom in the ground state, absorbs that energy and gets excited to state 'E_m' as shown in fig.

This transition is known as "stimulated absorption" (or) "induced absorption".

$$\therefore \quad E_m - E_n = h\nu \quad \text{(or)}$$

$$\boxed{\nu = \frac{E_m - E_n}{h}} \longrightarrow (1)$$

is the frequency of the incident photon.

The probability of occurence per unit time of this absorption transition $n \to m$ depends upon the properties of the states m and n, and is proportional to the spectral energy density $\rho(\nu_{mn})$. (i.e., $\rho(\nu_{mn}) \to$ the rate at which photons of frequency 'ν' fall on the atom).

$\therefore$ Hence, the number of absorption transitions (or) the number of atoms excited is given by, (or the probability of stimulated Absorption N_{Ab}).

$$N_{Ab} \propto \rho(\nu_{mn}) \quad \text{(or)}$$

$$N_{Ab} = B_{n\to m} \cdot \rho(\nu_{mn}) \longrightarrow (2)$$

If at any time there are "N_n" atoms in the state 'n', the no. of such transitions per second is

$$\therefore \boxed{N_{Ab} = N_n B_{n\to m} \, \rho(\nu_{mn})} \longrightarrow (3)$$

($\because$ Ab $\to$ stands for Absorption)

Here, $N_n \to$ is number of atoms in ground state 'n'

$\rho(\nu_{mn}) \to$ is the spectral energy density

$B_{n\to m} \to$ is the proportionality constant and is called

" Einstein's coefficient of absorption".

Spontaneous emission :-

Suppose the atom is in higher (excited) state 'm'. The life-time of the excited state is usually very small ($\approx 10^{-8}$ sec).

So, the atom jumps to the lower energy state 'n', emitting a photon of frequency "ν". This is known as "spontaneous emission" of radiation.

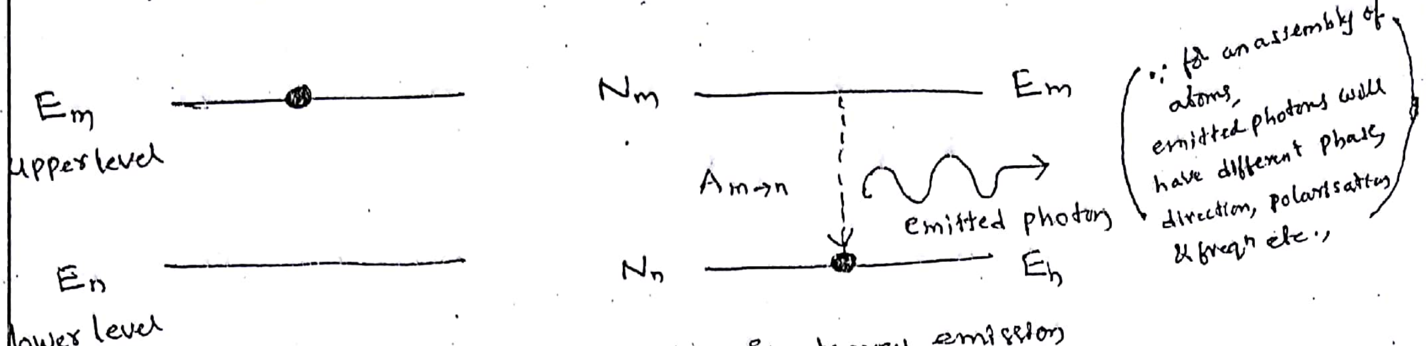


fig 2 (a). Before emission · (b). Spontaneous emission

When there is an assembly of atoms, the radiation emitted spontaneously by each atom has a random direction and random phase. So the emission is "incoherent".

The probability of spontaneous emission is independent of the spectral energy density $\rho(\nu_{mn})$, and depends only on the number density of atoms 'N_m' (i.e., no. of atoms in excited state) and is determined by the properties of states 'm' and 'n'.

Hence $N_{sp} \propto N_m$ (or)

$$\therefore \boxed{N_{sp} = N_m A_{m\to n}} \longrightarrow (4)$$

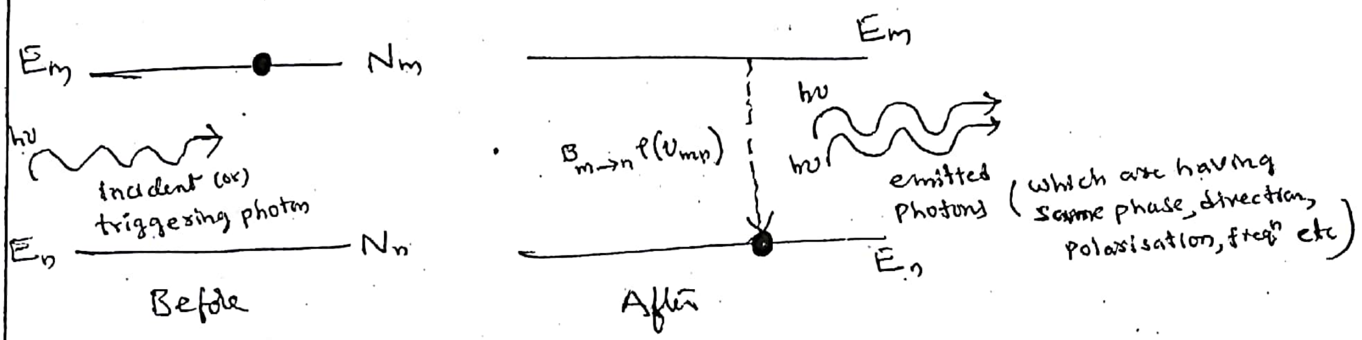
(∵ Sp → stands for spontaneous emission)

Here, $A_{m\to n}$ is a proportionality constant and is called the "Einstein's coefficient of spontaneous emission".

Stimulated (induced) emission :- (Working principle of Laser)

When a photon of energy "$h\nu = E_m - E_n$" hits the atom which was in excited state (E_m), before it undergo spontaneous emission, then the atom is forced and it may jump to a lower energy state, by emitting an additional photon of the same frequency. Now, two photons instead of one move on.

This is known as "stimulated (or) induced emission of radiation" and is shown in fig(3).



Fig(3) : Stimulated Emission process

The most important property of this radiation is, that "it is coherent".

i.e., the direction of propagation, energy, phase, and state of polarisation of the emitted photons is exactly the same as that of stimulating (or incident / triggering) photon.

The probability of stimulated emission is proportional to the spectral energy density.

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i.e., $N_{st} \propto \rho(\nu_{mn})$ (or)

$$N_{st} = B_{m\to n} \cdot \rho(\nu_{mn}) \longrightarrow (5)$$

If at any time there are "N_m" atoms in the state "m",

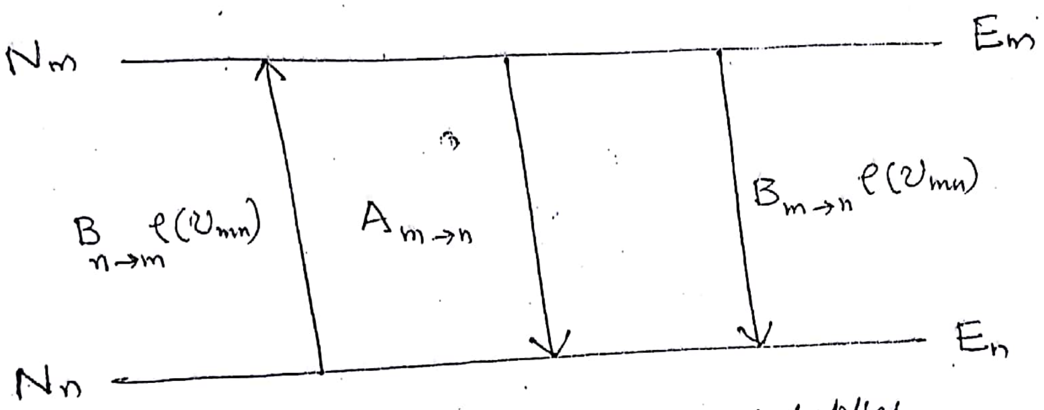
then we have,

$$\boxed{N_{st} = N_m B_{m\to n} \rho(\nu_{mn})} \longrightarrow (6)$$

($\because$ st → stands for Stimulated Emission)

Where, N_m → is density of atoms in excited state

$B_{m\to n}$ → is proportionality constant and is called "Einstein's coefficient of stimulated emission"



Fig(4): Einstein transition probabilities

Under thermal equilibrium condition, we can write

$$N_{Ab} = N_{sp} + N_{st} \longrightarrow (7)$$

substituting eq^n's (3), (4) & (6) in above eq^n, we get

$$N_n B_{n\to m} \rho(\nu_{mn}) = N_m A_{m\to n} + N_m B_{m\to n} \rho(\nu_{mn})$$

(or)

$$\left[N_n B_{n\to m}\,\rho(\nu_{mn})\right] = N_m\left[A_{m\to n} + B_{m\to n}\,\rho(\nu_{mn})\right] \quad \text{(or)}$$

$$\frac{N_n}{N_m} = \frac{\left[A_{m\to n} + B_{m\to n}\,\rho(\nu_{mn})\right]}{\left[B_{n\to m}\,\rho(\nu_{mn})\right]} \longrightarrow (8)$$

The equilibrium distribution of atoms among different energy states is given by Boltzmann's law according to which

$$\frac{N_n}{N_m} = e^{(E_m - E_n)/KT} = e^{h\nu_{mn}/KT} \longrightarrow (9) \quad (\because E_m - E_n = h\nu_{mn})$$

substituting in eqn (8), we get

$$e^{h\nu_{mn}/KT} = \frac{\left[A_{m\to n} + B_{m\to n}\,\rho(\nu_{mn})\right]}{B_{n\to m}\,\rho(\nu_{mn})} \quad \text{(or)}$$

$$B_{n\to m}\,\rho(\nu_{mn})\,.\,e^{h\nu_{mn}/KT} = A_{m\to n} + B_{m\to n}\,\rho(\nu_{mn}) \quad \text{(or)}$$

$$B_{n\to m}\,\rho(\nu_{mn})\,.\,e^{h\nu_{mn}/KT} - B_{m\to n}\,\rho(\nu_{mn}) = A_{m\to n} \quad \text{(or)}$$

$$\rho(\nu_{mn})\left[B_{n\to m}\,e^{h\nu_{mn}/KT} - B_{m\to n}\right] = A_{m\to n} \quad \text{(or)}$$

$$\rho(\nu_{mn}) = \frac{A_{m\to n}}{B_{n\to m}\,.\,e^{h\nu_{mn}/KT} - B_{m\to n}} \longrightarrow (10)$$

(or)

$$\bar{\rho}(\nu_{mn}) = \frac{A_{m\to n}}{B_{m\to n}\left[\frac{B_{n\to m}}{B_{m\to n}} \cdot e^{h\nu_{mn}/kT} - 1\right]} \quad \text{(or)}$$

$$\therefore \rho(\nu_{mn}) = \frac{\left(\frac{A_{m\to n}}{B_{m\to n}}\right)}{\left(\frac{B_{n\to m}}{B_{m\to n}}\right) \cdot e^{h\nu_{mn}/kT} - 1} \longrightarrow (11)$$

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

$$\rho(\nu_{mn}) = \frac{8\pi h\nu^3}{c^3} \cdot \frac{1}{\left(e^{h\nu/kT} - 1\right)} \longrightarrow (12) \quad \text{(or)}$$

$$\therefore \rho(\nu) = \frac{\left(\frac{8\pi h\nu^3}{c^3}\right)}{\left(\frac{1}{1}\right) \cdot e^{h\nu/kT} - 1} \longrightarrow (13)$$

Comparing equations (11) & (13)

Einstein coefficients are related by the equations,

$$\frac{A_{m\to n}}{B_{m\to n}} = \frac{8\pi h\nu_{mn}^3}{c^3} \quad \text{(or)}$$

$$\therefore \boxed{A_{m\to n} = \frac{8\pi h \upsilon_{mn}^3}{c^3} \cdot B_{m\to n}} \longrightarrow (14)$$

and $\frac{B_{n\to m}}{B_{m\to n}} = 1$ (or)

$$\therefore \boxed{B_{n\to m} = B_{m\to n}.} \longrightarrow (15)$$

Population Inversion :-

We know that stimulated emission process is the key to produce a laser light. For stimulated emission the condition is " More number of atoms should be present in the excited state (E_2) compared to the lower energy state (E_1)." This situation is known as " population Inversion".

Here, population → means, No. of atoms occupying an energy state

Inversion → means, opposite to the normal situation (Normally most of the atoms are present in the ground state E_1)

Let us consider a "γ" level system in which energy states $E_1, E_2, \ldots E_\gamma$ and populations of these energy levels are $N_1, N_2, \ldots N_r$ respectively. According to Boltzmann distribution law, the population of a given energy state can be expressed as

$$\therefore \boxed{N_r = N_0 \, e^{\frac{-E_r}{K_B T}}} \longrightarrow (1)$$

(E_r → energy of excited state)

where $r = 1, 2, 3, \ldots\ldots$

Here, N_0 → is the population of ground state

T → is the temperature

& K_B → is the Boltzmann's constant ($K_B = 1.38 \times 10^{-23}$ J/K)

The normal population distribution as a function of energy level is shown in fig (a).

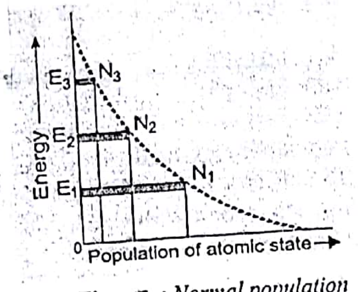


Fig. a : Normal population distribution

$(N_1 > N_2)$

From the above fig (a), it is clear that, the population in each energy level decreases exponentially with increase of energy level.

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From fig (a) it is also observed that, the population of atoms N_1 in the lower energy state E_1 is more than the population of atoms N_2 in the higher energy state E_2 (i.e., $N_1 > N_2$).

The process of making $N_2 > N_1$ is known as " population Inversion".

PUMPING :- The process of achieving population inversion is known as " Pumping" process.

Metastable State :- Inorder to achieve population inversion, we must have an energy state, which has long life time. This type of state is called a " Metastable state".

The life time of metastable state is 10^{-3} sec ($>>>>>>> 10^{-8}$ s)

" " Excited state is 10^{-8} sec

ACTIVE SYSTEM :- A system in which population inversion is achieved is known as " Active System". The active system (medium) may be solid, liquid or a gas.

Eg :- Silica base glasses, He-Ne gas mixture, Nitrogen, CO_2, GaAs are some examples of active medium.

Types of Lasers :-

Depending on the nature of active medium we have 4 types of lasers.

They are :

1). Solid state laser

Eg: Ruby laser (6943 A°) (or) (694.3 nm)

Nd-YAG and glass (1.064 μm)

Alexandrite (700 – 800 nm)

2). Liquid laser

Eg: Organic dye (300 – 1000 nm)

3). Gas laser

Eg: He-Ne (632.8 nm)

Argon ion (450 – 520 nm)

Nitrogen (337 nm)

CO_2 (10.6 μm)

4). Semiconductor laser

Eg:- Ga Al As diode laser (750 – 900 nm)

In Ga AsP diode laser (1100 – 1600 nm)

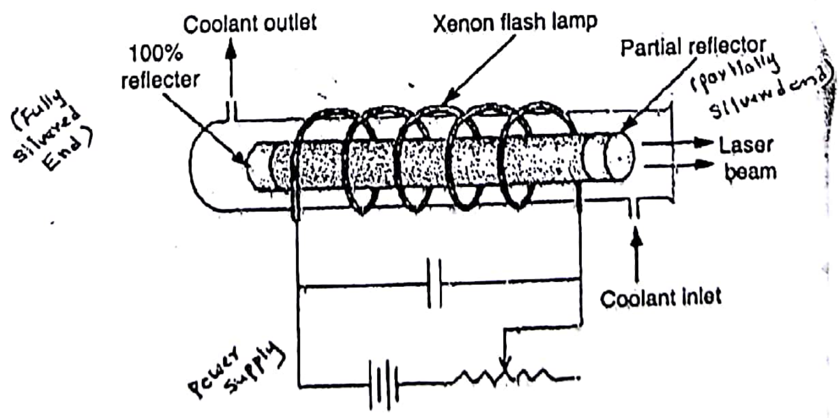
RUBY LASER :-

(L.Q)

Imp. This was the first laser developed by T. Maimann. Ruby belongs to the family of gems. It is basically Al_2O_3 crystal containing about 0.05% of Chromium atoms. The colour of ruby rod crystal depends on the concentration of Chromium atoms. Otherwise Al_2O_3 is transparent. (Ruby rod pink or red)

Al^{3+} ions in the crystal lattice are substituted by Cr^{3+} ions. Here, Cr^{3+} ions constitute active centers, i.e., laser action takes place in Chromium energy levels. The aluminium & Oxygen atoms are inert.

Construction :- The schematic diagram of a ruby laser is shown in fig (1).



Fig(1.) : Ruby Laser

Ruby rod is taken in the form of a cylindrical rod of about 10cm in length and 1cm is diameter. Its ends are grounded & optically polished such that the end faces are optically plane & exactly parallel and also $\perp^R$ to the axis of the rod.

One face is silvered to achieve 100% Reflection while the opposite face is partially silvered. These two silvered faces act as optical resonating cavity.

The rod is surrounded by helical photographic xenon flash lamp. It produces high intense flashes of white light whenever activated by a power supply. The system which gets heated due to pumping radiation is cooled with the help of coolant, circulated around the ruby rod.

Working :-

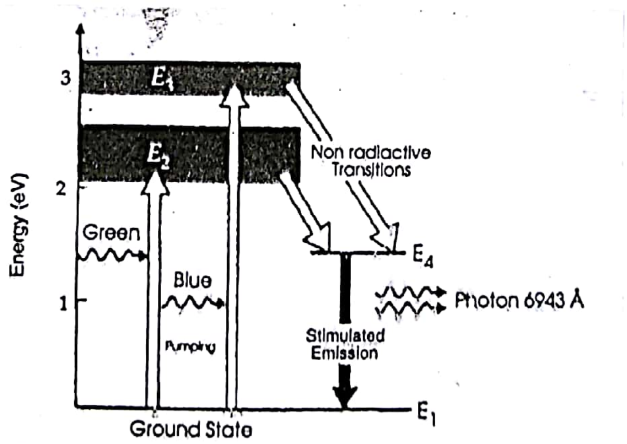


Fig. (2·) : Energy levels and transitions in a ruby laser

Ruby Laser is a three level laser system. The energy levels of Cr^{3+} ions in Al_2O_3 lattice are shown in fig(2). The excited energy levels of Cr^{3+} ion are not single energy levels. They are a band of energies.

When power is switched on, xenon flash lamp produces very high intense white radiation for a few seconds. The atoms in the ground state E_1 absorbs green and blue components of white radiation & get excited to one of the energy levels in E_2 and E_3 respectively.

Since life time of atoms in excited states E_2 & E_3 is very small, excited atoms are quickly deexcited to either E_4 & E_1. But, from selection rules probability of tansition from E_2 (or E_3) to E_4 is more when compared to probability of transition from E_2(or E_3) to E_1. The transition from E_2(or E_3) to E_4 is a non-Radiative transition.

Since E_4 is metastable state, the excited Cr^{3+} ions are accumulated in the state. If pumping occurs at faster time/rate, the population at the level E_4 exceeds that of ground level E_1 in shorter time. Therefore, the state of population inversion gets established between E_4 and E_1. After some time Cr^{3+} ions are spontaneously de-excited to ground level E_1, with the emission of a photon of wavelength 6943 A° (red). The emitted photons which are moving along the axis of ruby rod, are repeatedly reflected by mirrors and enhance the stimulated emission process. When the beam develops sufficient intensity, it emerges out of the partially silvered mirror.

Drawbacks :-

1>. The xenon flash lasts for a few milli seconds. However, laser does not operate throughout this period. Therefore, the output of laser beam is not continuous, but occurs in the form of pulses of μsec duration.

2>. The efficiency of ruby laser is very poor.

3>. The ruby laser requires greater excitation energy (high pumping power) to achieve (create) population inversion.

Applications :-

1>. Distance measurement using "pulse echo" technique.

2>. Used for drilling high quality holes

3>. In military, used as target designators

4>. Used in general research applications

* * *

Helium - Neon (He-Ne) Laser :-

Imp

He-Ne laser was the first successful gas laser built by Ali Javan & his co-workers in 1961. As the name implies the active medium is a mixture of He and Ne gas. He-Ne laser is continuous laser; where as Ruby laser is a pulsed laser.

Construction :-

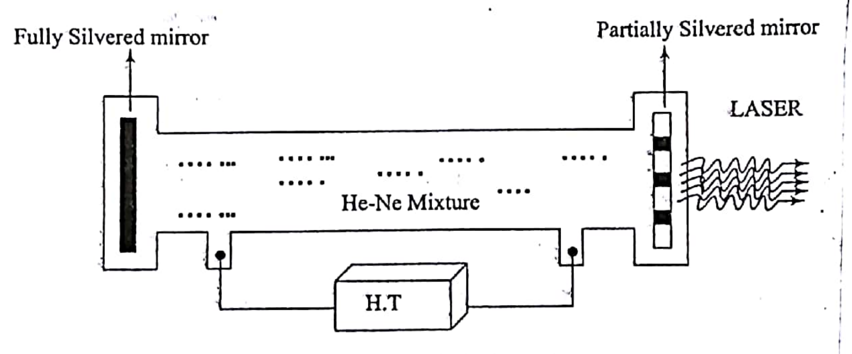


Fig. (1). *Schematic of He–Ne Laser*

The Schematic diagram of He-Ne laser is shown in fig (1). The gas mixture of He-Ne in the ratio of 10:1 is enclosed in a discharge tube at a pressure of 1mm of Hg (~300Pa). Silvered mirrors are provided at the ends of the discharge tube, in which one is fully silvered and the other one is partially silvered. A high voltage R.F generator is connected to the discharge tube.

Working : (Energy level Diagram)

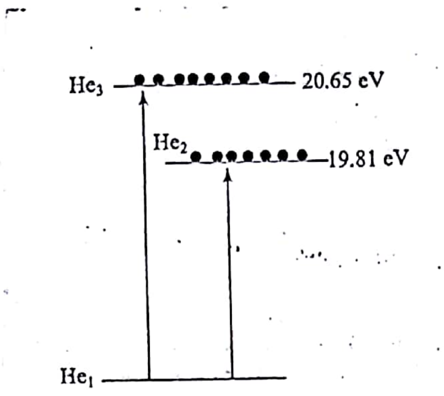


Fig. 2 Energy level diagram of Helium

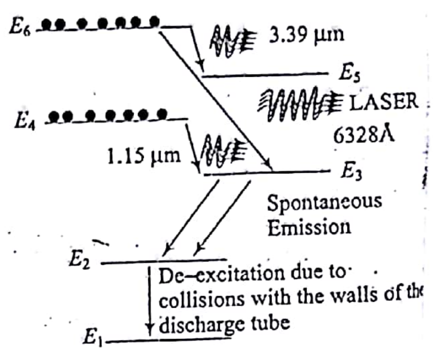


Fig. 3 . Energy level diagram of Neon

The energy level diagrams of He and Ne are as shown in fig (2) & (3). When the discharge is passed through the He-Ne mixture, the He atoms absorb the energy from the discharge and are excited to the energy levels He_3 & He_2 whose energies are 20.65eV and 19.81eV.

The excited He atoms make elastic collisions with Ne atoms and transfer the energy to the Ne atoms. Hence, Ne atoms are excited to the metastable states E_6 & E_4 which are close to He_3 & He_2.

After a short time, population inversion is achieved between the metastable states E_6 & E_4 and lower energy states E_5 & E_3.

The possible transitions are:

$E_6 \rightarrow E_5$ of wavelength 3.39 μm

$E_6 \rightarrow E_3$ of wavelength 6328 A°

$E_4 \rightarrow E_3$ of wavelength 1.15 μm

From the above 3 transitions, a mixture of wavelengths will be obtained. To obtain laser output of 6328 A°, the discharge tube is made with quartz which absorbs the wavelengths 3.39 μm & 1.15 μm. Neon atoms in E_3 take a fast spontaneous emission to energy state E_2 and then de-excited to the ground state.

Applications:-

1). Very widely used in laboratories

2). Used widely in metrology in surveying etc.,

3). He-Ne laser can be scanned across the surface to read barcodes, special characters & other symbols.

4). Used for OCR (Optical Character Recognition)

5). Used in 3D recording of objects called Holography.

* * *

Applications of Lasers :-

Lasers can have the following applications :

1. In communication :

(i). In optical fibre communication, because of its high band width.

(ii). In spacecrafts and submarines because of high directionality

(iii). In underwater communication and also for studies on variety of atmospheric features.

2. In Computers :-

(i). In the LAN, to transfer data from one computer to another.

(ii). In CD-ROMS, during recording and reading the data

3. In Industry :-

(i). To blast holes in diamonds and hard steel.

(ii). To cut teeth in saws, drill eyes in surgical needles, and test the quality of material

4. In Scientific Research:-

(i). To seperate isotopes from a radioactive element

(ii). In holography, for construction & reading the holograms.

5. In Military Applications:-

(i). To destroy enemy aircrafts and missiles

(ii). As a war weapon; hence, named as death weapon

6. In Medicine:-

(i). In opening blocked arteries, reconnecting severed nerves, removing warts, and treating bleeding ulcers.

(ii). To elemenate moles, and tumours which are developing in the skin tissue.

(iii). In the treatment of liver cancer.

* * *

Problems:-

1. Energy gap of a semiconductor is 3eV. Calculate the wavelength of emitted photon.

Sol:- Given data,

Energy gap E_g = 3eV (or)

$= 3 \times 1.602 \times 10^{-19}$ J

$\approx 4.806 \times 10^{-19}$ J

planck's const (h) = 6.625×10^{-34} J-sec

velocity of light photon (c) = 3×10^{8} m/s

∴ Energy gap $E_g = h\nu = \frac{hc}{\lambda}$ → ①

∴ Wavelength of emitted photon $\lambda = \frac{hc}{E_g}$

$$\lambda = \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{4.806 \times 10^{-19}} \text{ m (or)}$$

$\lambda \approx 4.135 \times 10^{-7}$ m (or)

∴ $\boxed{\lambda = 4135 A^{\circ}}$ → ② (Ans)

② Calculate the wavelength of emitted radiation from GaAs which has a band gap of 1.44eV.

Imp

Sol:- Given data,

Energy gap E_g = 1.44eV (or)

$= 1.44 \times 1.602 \times 10^{-19}$ Joule

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$h = 6.625 \times 10^{-34}$ J-s

$c = 3 \times 10^{8}$ m/s

$\therefore \; E_g = h\nu = \frac{hc}{\lambda} \longrightarrow (1)$

$\therefore \; \lambda = \frac{hc}{E_g}$

$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{1.44 \times 1.6 \times 10^{-19}}$

$\approx 0.862 \times 10^{-6}$ m

$\therefore \; \boxed{\lambda = 0.862 \, \mu m} \longrightarrow (2)$

* * * *

(3). Calculate the relative population in the laser transition levels in a ruby laser in thermal equilibrium. The wavelength of the ruby laser light is 6943 at 300K.

Sol:- We have,

the relative population, according to Boltzman's law

$\frac{N_1}{N_2} = e^{(E_2-E_1)/K_BT} \approx e^{h\nu/K_BT} \longrightarrow (1)$

Here, $N_1 \rightarrow$ No. of atoms per unit vol. in ground state (E_1)

$N_2 \rightarrow$ " " in metastable " (E_2)

Given data,

$\lambda = 6943 A^{\circ}$ (or)

$= 6943 \times 10^{-10}$ m

$c = 3 \times 10^{8}$ m/sec

$\therefore \nu = \frac{c}{\lambda} = \frac{3\times 10^{8}}{6943\times 10^{-10}} = 4.32\times 10^{14}$ Hz.

K_B (Boltzmann const) $= 1.38\times 10^{-23}$ J/K

$T = 300K$, $h = 6.626\times 10^{-34}$ J-sec

Now, eqn (1) becomes

$$\frac{N_1}{N_2} = e^{(6.626\times 10^{-34} \times 4.32\times 10^{14}) / 1.38\times 10^{-23} \times 300}$$

$$\approx e^{69.16} \Rightarrow \frac{N_2}{N_1} = e^{-(69.16)} \approx 8\times 10^{-31} \text{ (Ans)}$$

$$= 1.06\times 10^{30}$$

$\therefore$ Relative population $\left(\frac{N_1}{N_2}\right) = 1.06\times 10^{30}$ (Ans)

* * * *

LECTURE PLAN

ENGINEERING PHYSICS

BECF181T30/CBSPH18T30

B.E. / B. Tech.

(ECE, EIE, Mechatronics, EEE, CSE&IT)

(2020 -21 / I SEMESTER)

UNIT III – PHOTONICS

- solid-state laser (Nd-YAG laser)

Delivery mode	• Black board/ PPT
Key lecture points	• Nature of components of Nd:YAG laser • Characteristics of Nd:YAG laser • Description on working set up (with diagram) • Explanation on working with energy level diagrams • Applications.
Conclusions	• Nd-YAG laser uses a solid Nd-YAG rod as active medium • Laser transition occurs between electronic levels in solid state lasers • Four level solid state laser • Optical pumping is employed for solid state lasers
Questions	• Differentiate between various pumping systems • Give the significance of meta-stable states • Essential components of Nd-YAG laser set up

Credits	Exam	Marks		Total
		UI	UE	
4	3Hrs	40	60	100

Objectives

- To understand the components of Nd-YAG laser
- To understand the working of Nd-YAG laser

Outcomes

Student will be able to explain

- Solid state Four level lasers
- Optical pumping
- Meta stable states and population inversion
- Electronic transitions

Pre requisites

Basic knowledge on

- Spontaneous and stimulated emissions
- Laser components

Terms used

- Nd-YAG rod
- Xenon flash lamp
- Elliptical cavity
- Four level laser
- Reflective mirrors

Nd-YAG LASER

[Neodymium doped Yittrium Aluminium Garnet Laser]

Why Y A G?

YITTRIUM ALUMINIUM GARNET [YAG]

- Garnets [$X_3Y_2(SiO_4)_3$] are group of silicate minerals [gem stones and abrasives]

  X sites - Divalent cation $(Ca, Mg, Fe, Mn)^{2+}$

  Y sites - Trivalent cation $(Al, Fe, Cr)^{3+}$

- YAG is a synthetic garnet made using aluminium in the place of Si
- High optical quality
- YAG can be polished to a good optical finish
- High thermal conductivity for easy extraction of the heat generated

Lab created YAG Gem
https://www.jtv.com/library/gemopedia/yag

CHARACTERISTICS

❖ **ACTIVE MEDIUM : Neodymium [Nd^{3+} ions] doped YAG**

- Size of Nd^{3+} ions are almost same as Y^{3+} ions
- Some of the Y^{3+} ions (1%) are replaced by Nd^{3+} ions on doping
- Nd^{3+} ions act as active centers in the active medium
- Active centers are those atoms or molecules which involve in absorption and emission transitions during pumping processes.

Nd:YAG laser rod 0.5 cm in diameter

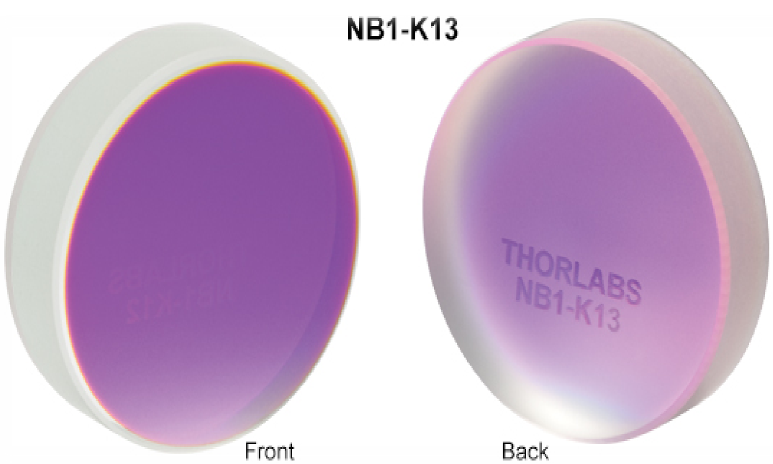
❖PUMPING MECHANISM : Optical Pumping

- Pumping Source : Xenon Flash Lamp
- Photons from the flash of flash lamp excite Nd^{3+} ions to higher excited levels
- Population inversion is created

Customized Xenon flash lamps
https://gbondtech.com/product-categories/laser-crystal-xenon-lamps/

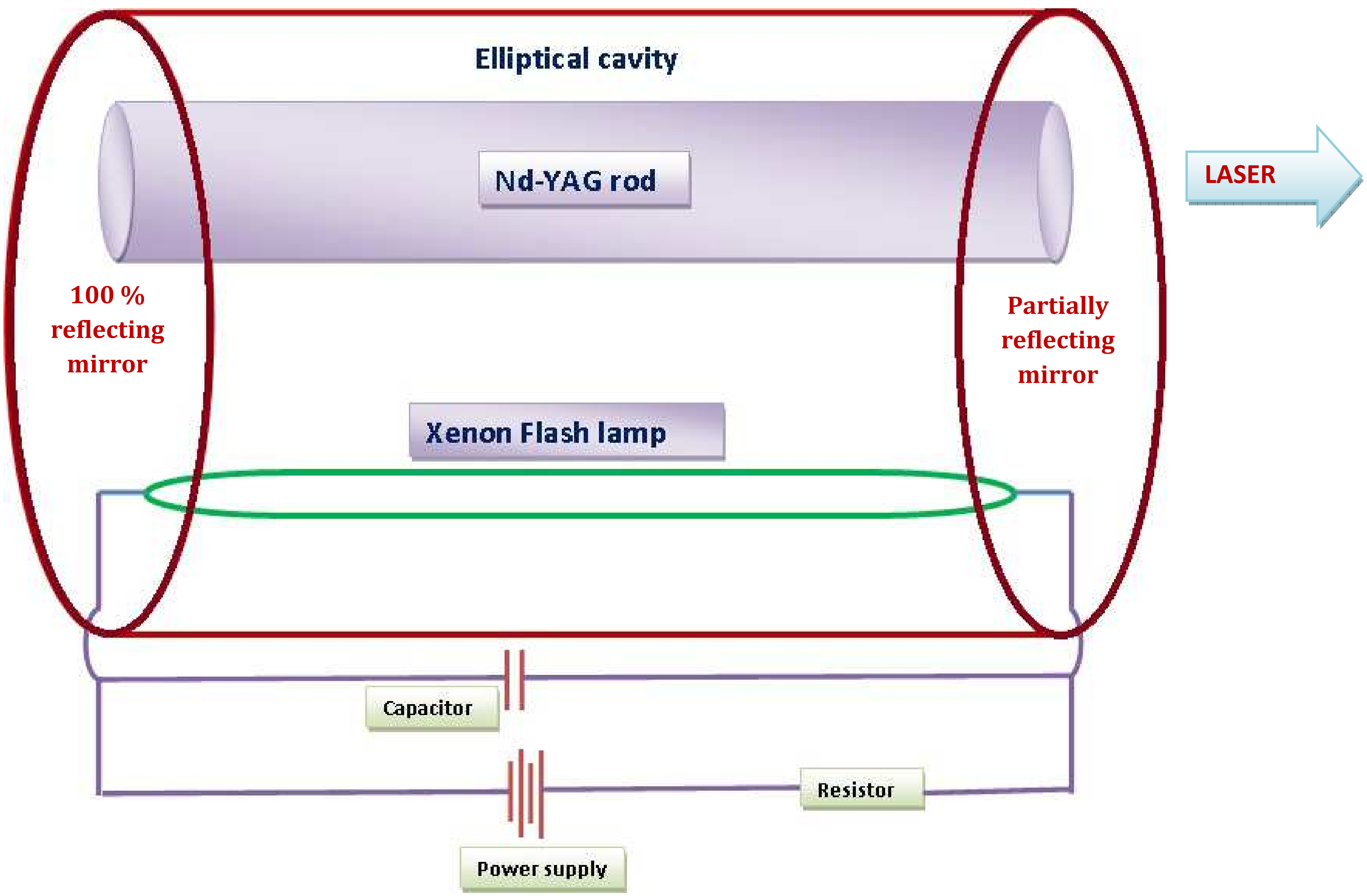
❖REFLECTIVE MIRROR SET UP

- The ends of Nd-YAG rod are fitted with suitable reflective mirrors
- One mirror gives 100% reflection
- The other mirror gives partial reflection



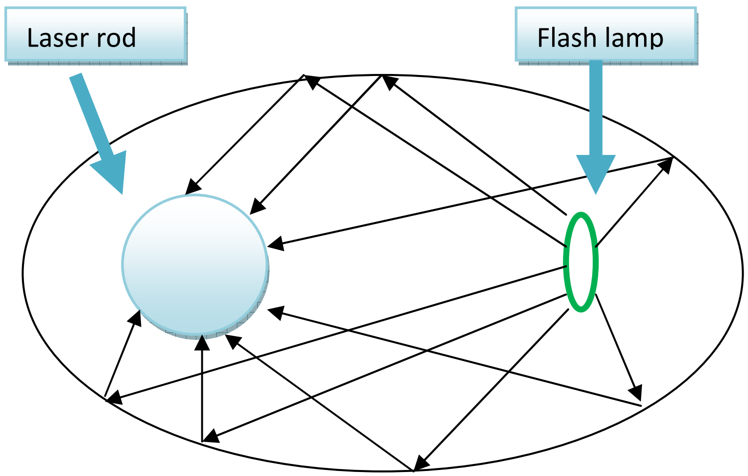
Mirrors for Nd-YAG lasers
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=3793

SCHEMATIC SET UP



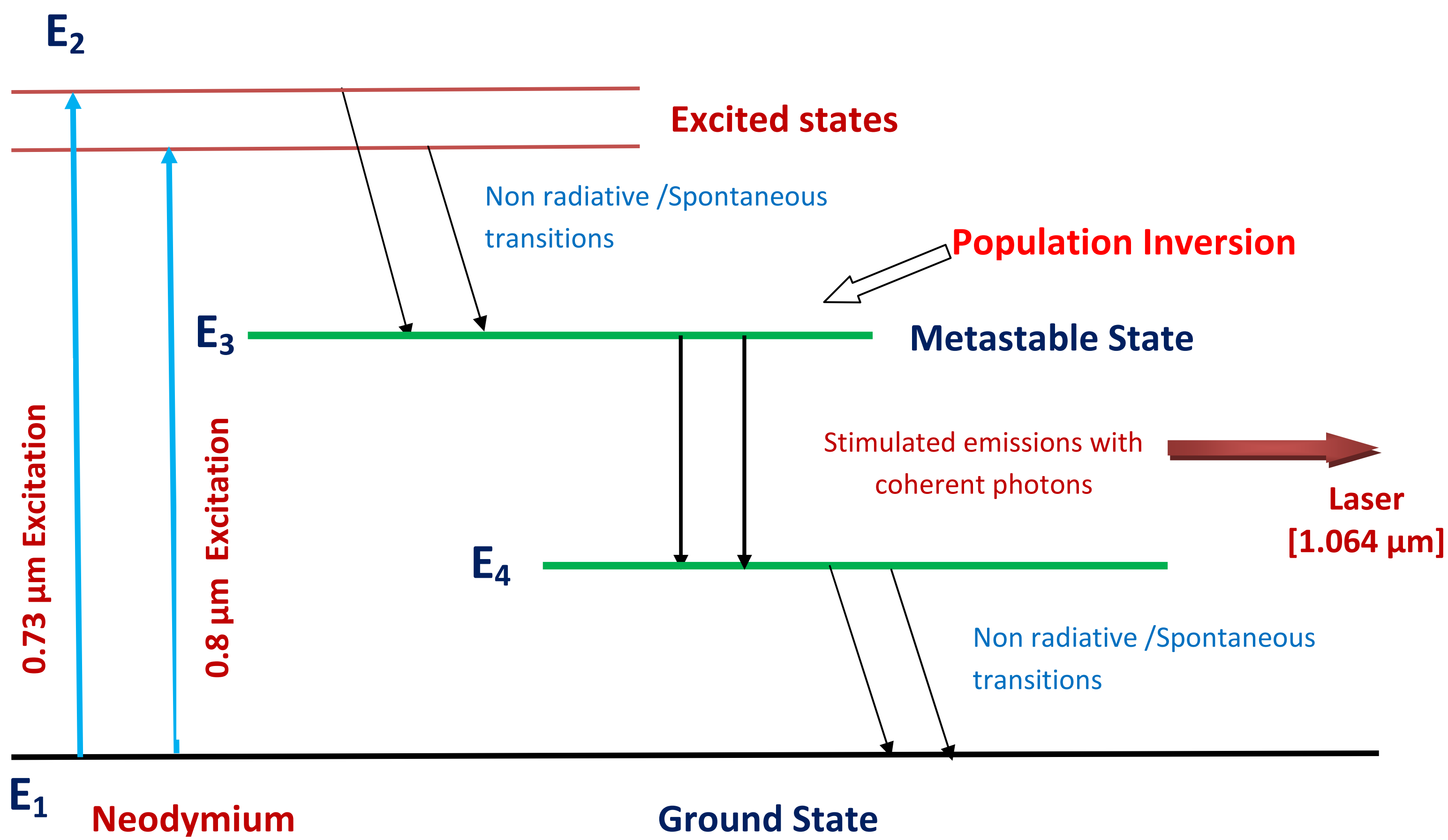
ELLIPTICAL CAVITY

- The elliptical cavity is a hollow casing and whose inner surface is coated with reflective coating
- At one of the focal point of elliptical cavity, Nd-YAG rod [active medium] is placed
- At another focal point a Xenon flash lamp is fixed
- This arrangement focus all the light on the laser rod [Nd-YAG rod]



WORKING OF LASER

ENERGY LEVEL SCHEME



WORKING OF LASER

- When the flash lamp gives flash, the Nd^{3+} ions are excited to higher levels
- These levels are highly unstable and the excited ions make a non-radiative transition to meta stable states
- Population inversion takes place in meta stable levels
- Stimulated emission is induced in the meta stable levels by spontaneously emitted photons
- Coherent photons are released in stimulated emission
- These photons are suitably multiplied by resonant cavity [laser rod attached with mirrors] and finally released as laser beam at 1.064 µm [IR region] through partial windows.

APPLICATIONS

- Nd:YAG lasers are used in ophthalmology
- In oncology, Nd:YAG lasers can be used to remove skin cancers
- Nd:YAG dental lasers are used for soft tissue surgeries in the oral cavity,
- Nd:YAG lasers are used in manufacturing for engraving, etching and metal surface enhancement processes.
- The Nd:YAG laser is the most common laser used in military as laser rangefinders.

COURSE TEACHER

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SCSVMV

Semiconductor Diode Laser

Definition:

It is specifically fabricated p-n junction diode. This diode emits laser light when it is forward biased.

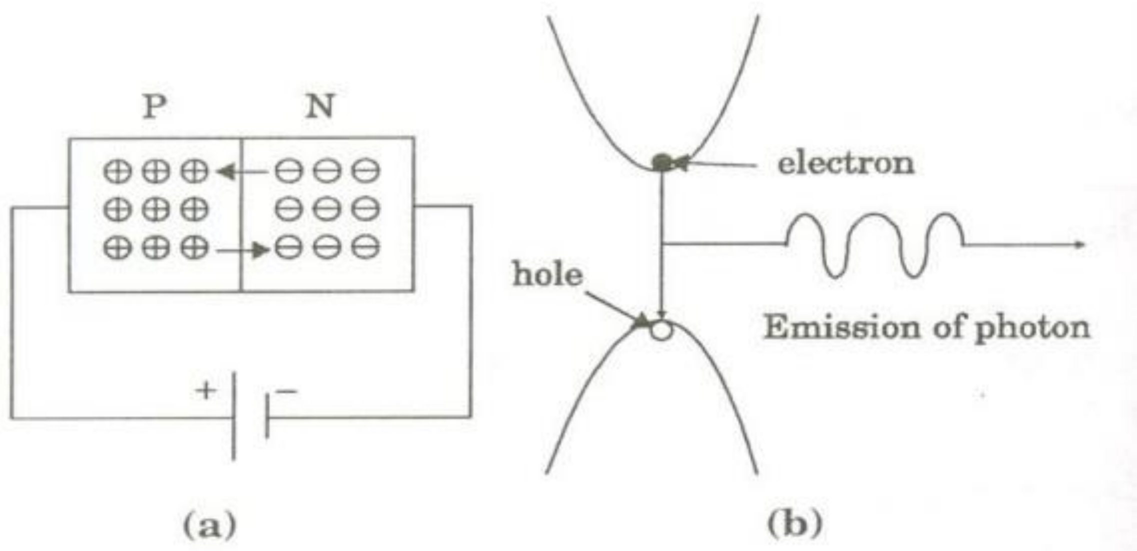
Characteristics:

- Type: It is a solid state semiconductor laser.
- Active medium: A PN junction diode made from single crystal of gallium arsenide is used as an active medium.
- Pumping method: The direct conversion method is used for pumping action
- Power output: The power output from this laser is 1mW.
- Nature of output: The nature of output is continuous wave or pulsed output.
- Wavelength of Output: gallium arsenide laser gives infrared radiation in the wavelength 8300 to 8500 A

Principle:

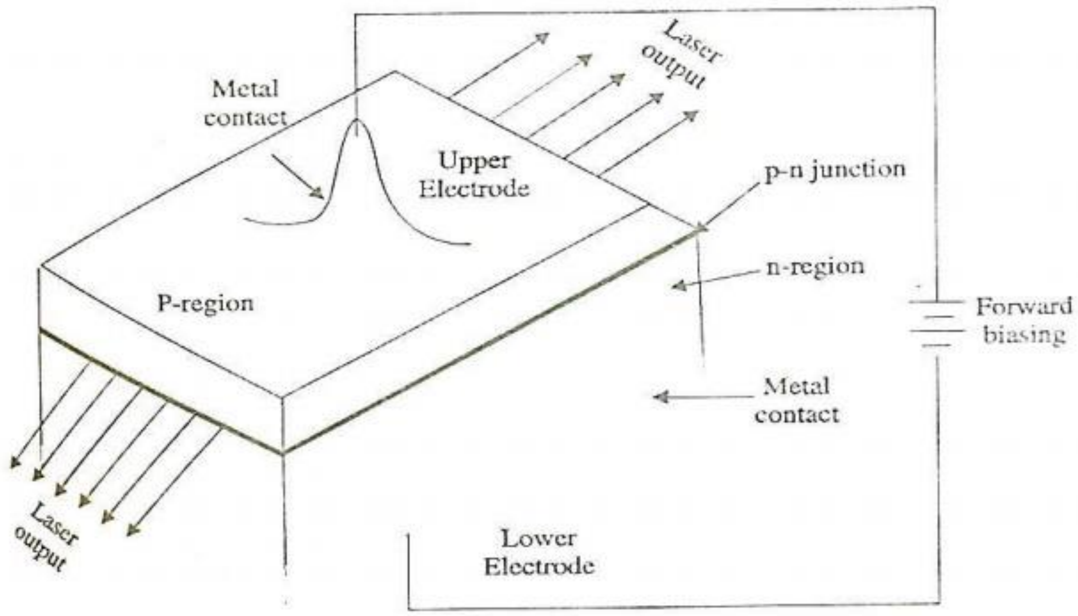
When a p-n junction diode is forward biased, the electrons from n – region and the holes from the p- region cross the junction and recombine with each other.

During the recombination process, the light radiation (photons) is released from a certain specified direct band gap semiconductor like Ga-As. This light radiation is known as recombination radiation. The photon emitted during recombination stimulates other electrons and holes to recombine. As a result, stimulated emission takes place which produces laser.



Construction:

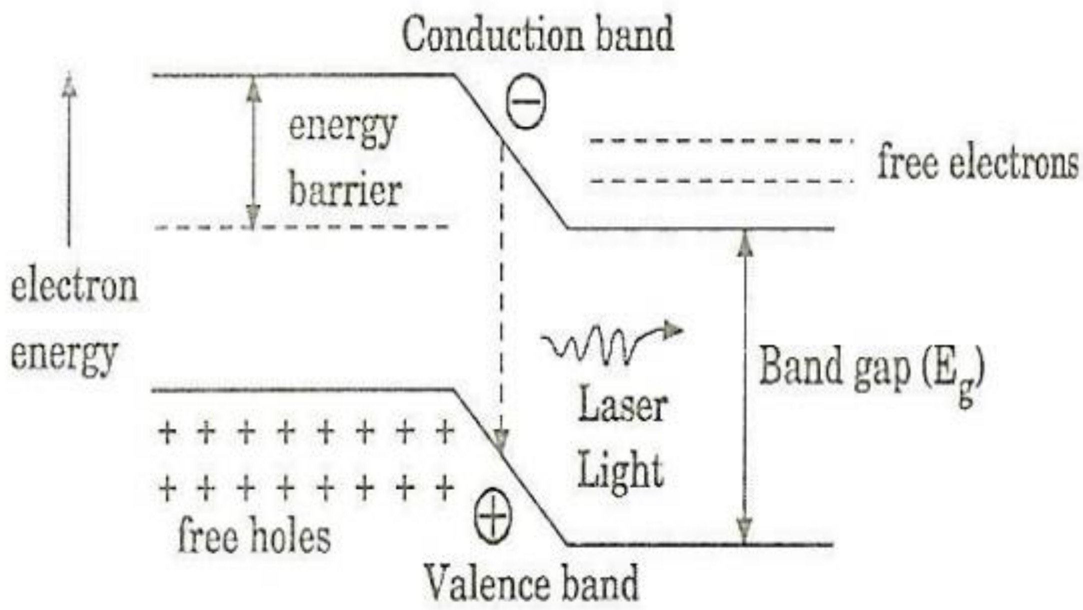
Figure shows the basic construction of semiconductor laser. The active medium is a p-n junction diode made from the single crystal of gallium arsenide. This crystal is cut in the form of a platter having thickness of 0.5μmm.



The platelet consists of two parts having an electron conductivity (n-type) and hole conductivity (p-type). The photon emission is stimulated in a very thin layer of PN junction (in order of few microns). The electrical voltage is applied to the crystal through the electrode fixed on the upper surface. The end faces of the junction diode are well polished and parallel to each other. They act as an optical resonator through which the emitted light comes out.

Working:

Figure shows the energy level diagram of semiconductor laser.



When the PN junction is forward biased with large applied voltage, the electrons and holes are injected into junction region in considerable concentration. The region around the junction contains a large amount of electrons in the conduction band and a large amount of holes in the valence band. If the population density is high, a condition of population inversion is achieved. The electrons and holes recombine with each other and this recombination's produce radiation in the form of light. When the forward – biased voltage is increased, more and more light photons are emitted and the light production instantly becomes stronger. These photons will trigger a chain of stimulated recombination resulting in the release of photons in phase. The photons moving at the plane of the junction travels back and forth by reflection between two sides placed parallel and opposite to each other and grow in strength. After gaining enough strength, it gives out the laser beam of wavelength 8400 A . The wavelength of laser light is given by

$$E_g = h\nu = h\frac{c}{\lambda}$$

$$\lambda = \frac{hc}{E_g}$$

.

Advantages:

1. It is very small in dimension. The arrangement is simple and compact.
2. It exhibits high efficiency.

3. The laser output can be easily increased by controlling the junction current
4. It is operated with lesser power than ruby and CO_2 laser.
5. It requires very little auxiliary equipment
6. It can have a continuous wave output or pulsed output.

Disadvantages:

1. It is difficult to control the mode pattern and mode structure of laser.
2. The output is usually from 5 degree to 15 degree i.e., laser beam has large divergence.
3. The purity and monochromacity are power than other types of laser
4. Threshold current density is very large ($400A/mm^2$).
5. It has poor coherence and poor stability.

Application:

1. It is widely used in fiber optic communication
2. It is used to heal the wounds by infrared radiation
3. It is also used as a pain killer
4. It is used in laser printers and CD writing and reading.

UNIT - 3

OPTICAL FIBERS

OPTICAL FIBER :- Optical fiber is a very thin and flexible medium having a cylindrical shape consisting of three sections :

(i) the core ,
(ii) the cladding and
(iii) the outer jacket (or) buffer (or) protection sheet

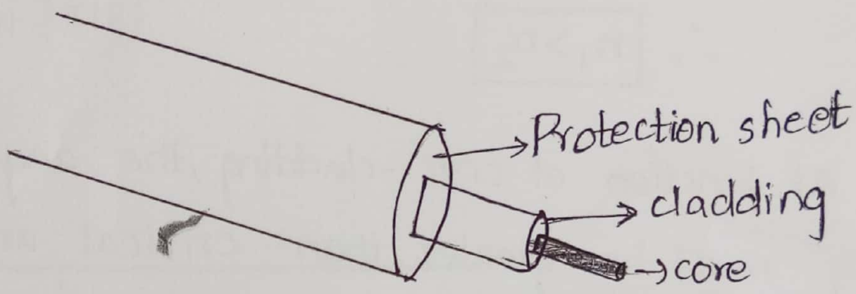


Fig :- Structure of an optical fiber.

Core ;-

- It is inner part of optical fiber
- Made with glass / plastic material
- It has high refractive index
- Carries the signals through it

Cladding :-

- It is surrounding glass material of core.
- It has less refractive index than core .

Outer Jacket :

- It is outermost surrounding of core and cladding.
- It protects optical fiber from erosion , contaminations etc.

WORKING PRINCIPLE OF OPTICAL FIBER :-

Optical fiber works on the principle of total internal reflection. When light launches at one end of core. It can propagate to second end due to total internal reflection at core and cladding interface.

Total Internal Reflection can occurs only under two conditions :-

① The refractive index of core "n_1" must be slightly greater than the refractive index of cladding "n_2"

$\therefore$ $\boxed{n_1 > n_2}$

② At junction of core-cladding, the angle of incidence "θ_i" must be greater than critical angle "θ_c".

$\therefore$ $\boxed{\theta_i > \theta_c}$

BASIC PRINCIPLE OF OPTICAL FIBER :-

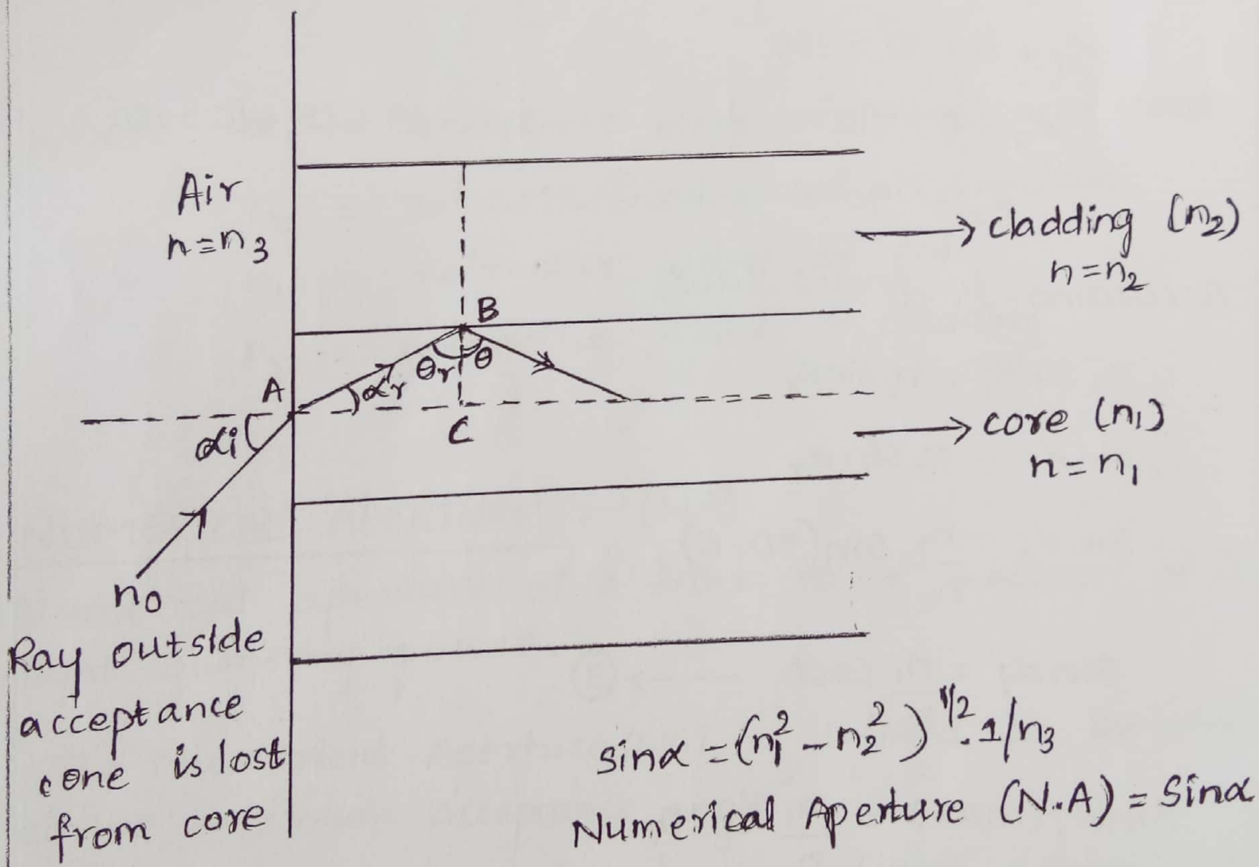
Optical fibers are the waveguides though which electromagnetic waves of optical frequency range can be guided through them to travel long distances.

An optical fiber works on the principle of total internal reflection [TIR].

Total internal Reflection :- When a ray of light travels from a denser medium into a rarer medium and if the angle of incidence is greater than the critical angle then the light gets totally reflected into the denser medium.

ACCEPTANCE ANGLE :-

→ All right rays falling on optical fiber are not transmitted through the fiber. Only those light rays making $\theta_i > \theta_c$ at the core-cladding interface are transmitted through the fiber by undergoing TIR [Total internal reflection]. For which the angle of incidence, the refraction angle is greater than 90° will be propagated through total internal reflection [TIR].



$$\sin\alpha = (n_1^2 - n_2^2)^{1/2} \cdot 1/n_3$$

$$\text{Numerical Aperture (N.A)} = \sin\alpha$$

→ There by Acceptance angle is defined as : The maximum angle of incidence to the axis of optical fiber at which the light ray may enter the fiber so that it can be propagated through TIR (Total internal reflection).

→ Consider the optical fiber with core refractive index 'n_1' and cladding refractive index "n_2". Light is incident on the axis of optical fiber at an angle "θ_1". It can produce an angle of refraction "θ_2".

→ The relationship at the interface is given by snell's law as,

$$\sin\theta_c = \frac{n_2}{n_1} \longrightarrow (1)$$

From ΔABC,

$$\alpha_r + \theta + 90^\circ = 180^\circ$$

$$\alpha_r + \theta = 90^\circ \qquad \because \angle A + \angle B + \angle C = 180^\circ$$

$$\alpha_r = 90^\circ - \theta \longrightarrow (2)$$

According to snell's law,

$$n_1 \sin\theta_i = n_2 \sin\theta_r$$

$$n_0 \sin\alpha_i = n_1 \sin\alpha_r$$

$$\sin\alpha_i = \frac{n_1}{n_0} \sin(90-\theta)$$

$$\sin\alpha_i = \frac{n_1}{n_0} \cos\theta \longrightarrow (3)$$

$$\sin\alpha_i(max) = \frac{n_1}{n_0} \cos\theta_c$$

$$\sin^2\theta_c + \cos^2\theta_c = 1$$

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

$$\sin\alpha_i(max) = \frac{n_1}{n_0}\sqrt{1-\sin^2\theta_c}$$ from, $\sin\theta_c = \frac{n_2}{n_1}$

$$\sin\alpha_i(max) = \frac{n_1}{n_0}\sqrt{1-\left(\frac{n_2}{n_1}\right)^2}$$

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

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

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

where α_i = acceptance angle (or) acceptance cone

n_0 = refractive index of air medium

n_1 = refractive index of core

n_2 = refractive index of cladding.

NUMERICAL APERTURE :- (NA)

→ Numerical aperture of a fiber is a measure of its light gathering power.

→ "The Numerical Aperture (NA) is defined as the sine of the maximum acceptance angle".

→ The light gathering ability of optical fibers depends on two factors i.e,

- Core diameter
- NA (Numerical aperture)

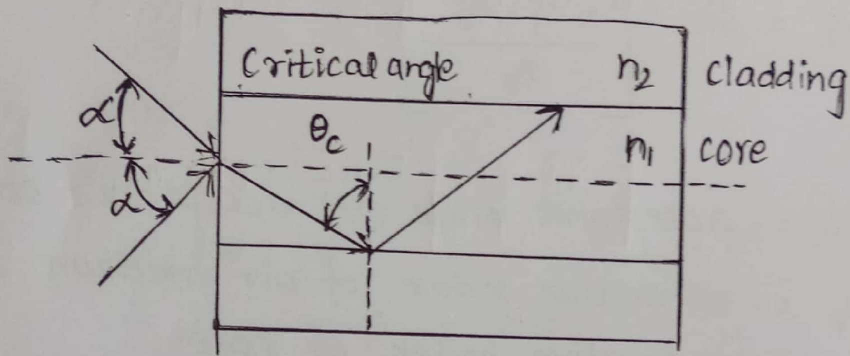
→ Numerical aperture (A) is defined as sine of the acceptance angle.

i.e, $NA = \sin\theta_A$

i.e,

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

→ The efficiency of optical fiber is expressed in terms of NA; it is called as figure of merit of optical fiber.



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

Full Acceptance angle $= 2\alpha$

$$NA = \sin\left[\alpha_i(max)\right]$$

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

$$NA = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} \longrightarrow (1)$$

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \longrightarrow (2)$$

$\Delta \rightarrow$ change in refractive index, relative (or) fractional refractive index.

$$\Delta = \frac{(n_1+n_2)(n_1-n_2)}{2n_1^2}$$

If $n_1 \simeq n_2$

$$\Delta = \frac{2n_1(n_1-n_2)}{2n_1^2}$$

$$\Delta = \frac{n_1-n_2}{n_1} \longrightarrow (3)$$

From (2),

$$2n_1^2\Delta = n_1^2 - n_2^2$$

$$n_1^2 2\Delta = n_1^2 - n_2^2$$

Taking root on Both sides,

$$n_1\sqrt{2\Delta} = \sqrt{n_1^2 - n_2^2} \longrightarrow (4)$$

Substituting (4) in (1),

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

$$NA = \frac{n_1\sqrt{2\Delta}}{n_0}$$

$$NA = \frac{n_1\sqrt{2\Delta}}{n_0}$$

where, $n_0 = 1$ due to refractive index of air

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

ACCEPTANCE CONE :-

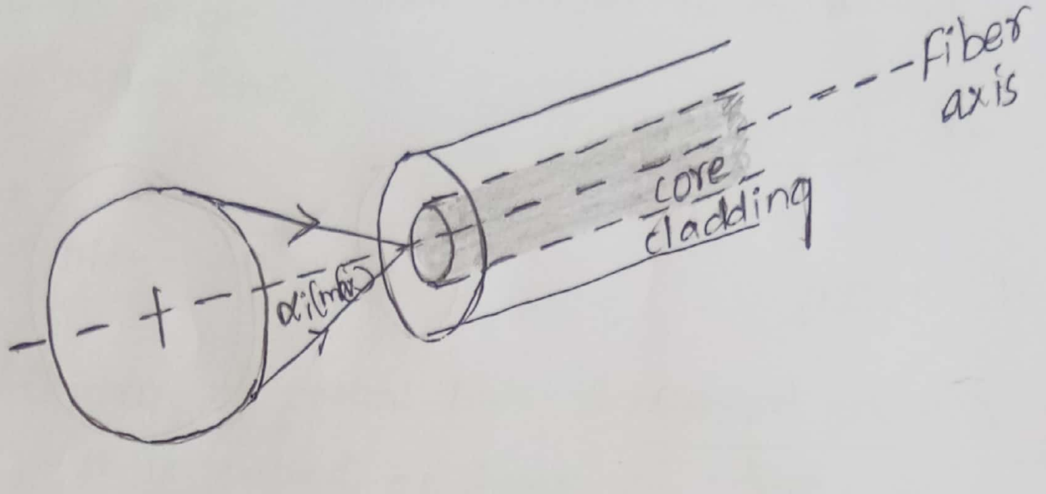


Fig: Acceptance cone obtained by rotating the acceptance angle about the fiber axis.

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

→ This maximum angle is called acceptance angle or the acceptance cone half-angle. Rotating the acceptance angle about the fiber axis as shown in figure, one gets the acceptance cone of the fiber. Light launched at the fiber end within this acceptance cone alone will be accepted and propagated to the other end of the fiber by total internal reflection. Larger acceptance angles make launching easier.

TYPES OF OPTICAL FIBERS :-

We use different types of optical fibers far different.
Applications Ex : for hospitality [mostly use single mode OF]
for communication [mostly use multi mode]

Optical fibers can be classified based on,
(i) Modes
(ii) Refractive Indices of core
(iii) Material

Types of optical fibers based on modes :-

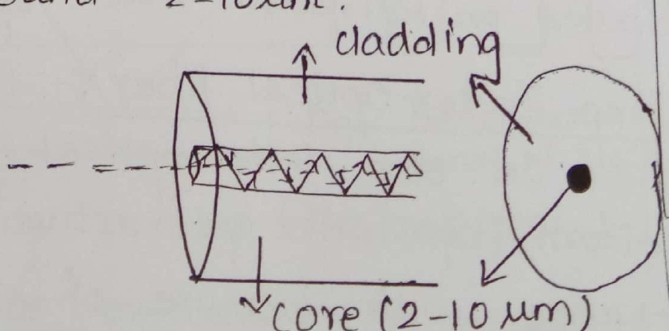
The way of propagation of light by total Internal reflection is called "mode".

Based on mode, optical fiber classified as,
(i) Single mode optical fibre
(ii) Multi mode optical fibre

(i) Single mode Optical fibrer/fiber :-

The optical fiber, which supports only single way of propagation of light through it, that is "single mode O.F".

Single mode consists of :-
→ Less diameter of core around 2-10 µm.
→ Less numerical aperture
→ Less attenuation
→ Low signal dispersion



→ High band width

→ Usefull for longer distances communication with higher data.

(ii) Multi-mode optical fibers :-

The optical fiber, which supports more than one, way of propagation of light through it that is "multimode optical fibre".

Multimode optical fiber consists :-

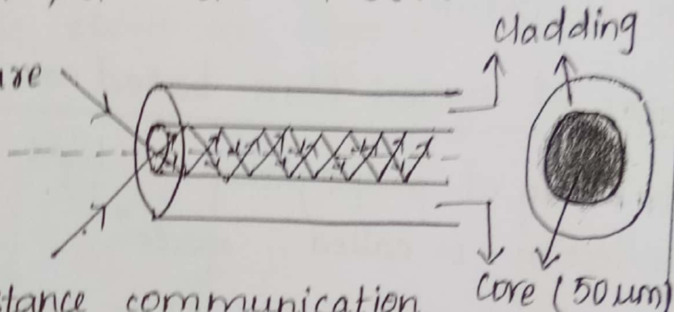
→ Larger diameter of core, size around 50 μm

→ High numerical aperture

→ High attenuation

→ High signal dispersion

→ Useful for shorter distance communication



Types of optical fiber based on Refractive Indices :-

The ratio between light speed (velocity) in vaccum and light speed in substance/matter is called Refractive index.

$$\text{Refractive index} = \frac{\text{Light velocity in vaccum}}{\text{light velocity in substance}}$$

Based on Refractive Index optical fiber classified as,

(1) Step Index Optical fiber :-

In step index optical fiber, the entire core has uniform (constant) refractive index. It does not change with increase of radius from central axis of core.

→ Cladding refractive index also constant.

→ The refractive index is slightly greater than cladding refractive index.

→ This change of refractive indices between core and cladding is, in the form of step. Hence it is called "step index optical fibre".

Transmission of signal (or) propagation of light rays In step index optical fiber :-

The signal is sent through fiber, in the form of light pulses (⎍⎍⎍) representing 0's and 1's. If this propagation is through multimode fiber. One pulsed signal travels along fiber axis and another pulsed signal travels in zig-zag (merid. motion/ manner. Due to longer path of propagation. It reaches to Reciever's end with same time delay, as shown in figure.

The rays (signals) recieved at Reciever's end at different times and pulse gets broadened is called "Intermodal dispersion".

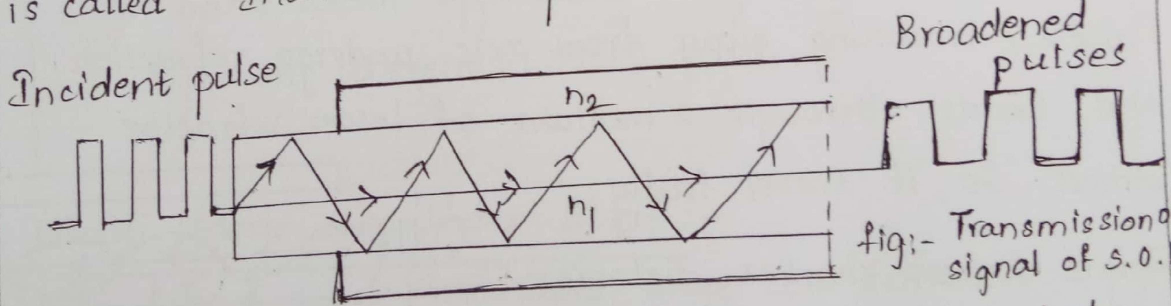


fig:- Transmission of signal of S.O.F

This is the problem occuring in step index optical fiber, this difficulty can be overcomed by manu-

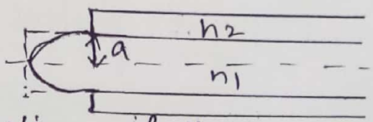
-facturing of graded index optical fiber

(2) <u>Graded Index Optical fibre :-</u>

In graded index optical fiber, the refractive index of core gradually decreases with increase of radius of core from central axis.

→ But cladding refractive index is constant. At central axis core has maximum refractive index.

→ At core-cladding interface, the refractive index of core matches with cladding constant refractive index.

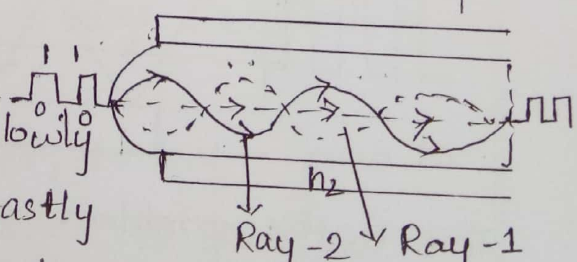


<u>Transmission of signal (or) propagation of light rays in Graded Index optical fiber :-</u>

Let us consider signal pulse travelling through graded index fiber in two different paths 1 & 2, as shown in figure.

→ Pulse 1, travelling away from axis undergo refraction through a medium of higher refractive index, so it travels slowly.

→ Pulse 2, travelling away from axis undergo refraction and bends through a medium of lesser refractive indices. So, it travel fastly.



Ray 1 travels shorter distance - slowly

Ray 2 travels longer distance - fastly

Hence both pulses reach other end simultaneously.

Types of step Index fiber / Graded Index fibre :-

(i) Single Mode step Index fiber :-

The variation of the refractive index of a step index fiber as a function of distance can be mathematically represented as longitudinal cross-section.

NOTE: Mode of propagation : It is defined as the number of paths available for the light ray to transfer through the optical fiber.

Structure :-

(i) Core diameter : 8 to 12 μm, usually 8.5 μm

(ii) Cladding diameter : Around 125 μm

(iii) Sheath diameter : 250 to 1000 μm

(iv) Numerical Aperture (NA) : 0.08 to 0.15 usually 0.10

Performancce characteristics :-

(i) Band width : Greater than 500MHZ km.

(ii) Attenuation : 2 to 5 dB/km

(iii) Applications : These fibers are ideally suited for high band width applications using single mode injection coherent (LASER) sources.

(ii) Multi Mode step Index fibers :-

→ These fibers have reasonably large core diameters and large NA to facilitate efficient transmission to incoherent (or) coherent light sources.

→ These fibers allow finite number of modes.

→ Normalised frequency (NF) is the cut off frequency, below which a particular mode cannot exist. This is related to NA, Radius of the core, and wave length of light as NF=2/λa(NA), where,

a = radius of core

Structure :-

(i) Core diameter : 50 to 200 μm

(ii) Cladding diameter : 125 to 400 μm

(iii) Sheath diameter : 250 to 1000 μm

(iv) Numerical apesture (NA) : 0.16 to 0.5

Perfomance Characteristics :-

(i) Band width : 6 to 50 MHZ km

(ii) Attenuation : 2.6 to 50 dB/km

(iii) Applications : These fibers are ideally suited for limited band width and relatively low cost applications.

(iii) Multi Mode Graded Index fibers :-

→ In case of graded index fibre, the refractive index of core is made to vary as a function of radial distance from the centre of the optical fiber.

→ Refractive index increases from one end of core diameter to center and attains maximum value at the centre. Again refractive index decreases as moving away from center to towards the other end of the core diameter.

-> The refractive index variation is represented as,

$$n(r) = n_1 (1-2\Delta)^{1/2} = n_2$$

-> The number of modes is given by the expression 'N'

$$N = 4.9[d(NA)/\lambda^2]$$

$$N = 4.9\left[\frac{d\,(NA)}{\lambda^2}\right]$$

where, d = core diameter
NA = Numerical aperture
λ = wavelength of radiation

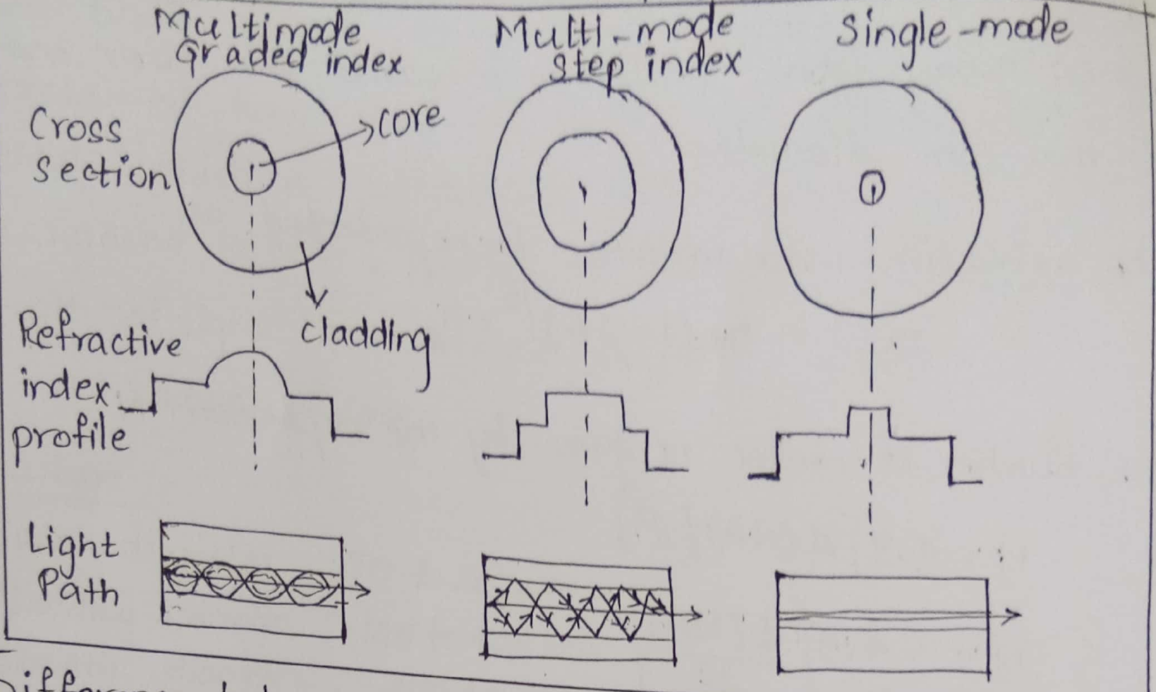
Structure :-

(i) Core diameter : 30 to 100 µm
(ii) Cladding diameter : 105 to 150 µm
(iii) Sheath diameter : 250 to 1000 µm
(iv) N.A : 0.2 to 0.3

Performance characteristics :-

(i) Band width : 300 MHz km to 3 GHz km.
(ii) Attenuation : 2 to 10 dB/Km
(iii) Applications : These are ideally suited for medium to high band width applications using incoherent and coherent multimode sources.

Fig:- Refractive Index and propagation in these modes.



Difference between Step Index and Graded Index fibers :-

Step Index	Graded Index
→ Refractive Index (R.I) is uniform throughout except at one stage.	→ Refractive index (R.I) varies gradually with radial distance.
→ Single and multimode propagations exist.	→ It is multi mode fiber.
→ Used for short distance applications	→ Used for long distance applications.
→ Attenuation losses are of the order 100 dB/km.	→ Attenuation losses are of the order 10 dB/km.
→ Meridional rays propagation takes place.	→ Skew rays propagation takes place.
→ Easy to manufacture.	→ Difficult to manufacture.

ATTENUATION IN OPTICAL FIBERS :-

Attenuation is the loss of optical power as light signal travels along the fiber.
The signal attenuation is defined as the ratio of optical Input power to optical output power.

The following equation defines signal attenuation as a unit of length,

$$\text{Attenuation } \alpha = \frac{-10}{L} \log_{10}\left[\frac{P_{out}}{P_{in}}\right]$$

(or)

$$\text{Attenuation } \alpha = \frac{10}{L} \log_{10}\left[\frac{P_{in}}{P_{out}}\right]$$

L = length/km

P_{in} = optical power input

P_{out} = optical power output

→ Attenuation is measured in terms of decibles (dB).
→ Attenuation in fibers is caused by absorption, scattering, bending & coupling losses.

(1) **Absorption losses :-**

Absorption losses causes due to conversion of optical power into another energy form such as Heat, by molecules of using material.

Absorption of light in fiber is classified into ② types;

① Intrinsic absorption

2. Extrinsic Absorption.

Intrinsic Absorption:-

→ Intrinsic absorption is caused by basic fiber material.

→ In pure glass type fibers, Si-O atoms of glass are absorbents.

→ This absorption loss is negligible due to "no impurities in fibers.

Extrinsic absorption:-

→ Extrinsic absorption is caused by impurities of fibers.

→ Impurities such as iron, nickel and chromium are introduced into the fiber during fabrication.

→ Impurtie ions/molecules makes electronic transition between one energy level to another.

→ If the amount of impuaities is reduced, then fiber attenuation is reduced.

(2) Scattering losses :-

Scattering of light occurs mainly because of in-homogenetics in fibers. When light interacts with density fluctuations within fiber. Then propagation of light changes. Hence, it leads to loss of optical power. These density fluctuations (or) inhomoge-netics (or) microscopic variations

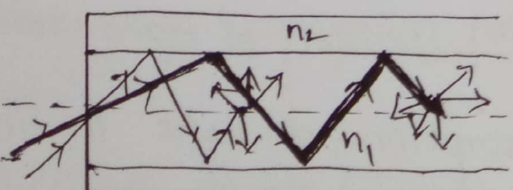


fig: Scattering losses.

are produced when optical fibres are manufactured. The scattering losses of light depends on wavelength.

(3) <u>Bending losses :-</u>

Bending losses causes due to bends of optical fiber from it's straight line path,

Bending loss is classified into ② types:

(i) Micro bending

(ii) Macro bending

<u>Micro bending loss :-</u>

→ Micro bending is a small-scale distortion.

→ It is causes / caused by imperfections in fibers, due to external sources.

→ An external force deforms fiber surroundings also causes. The small bends in fiber. By these micro (small) bends. The mode of propagation of light changes. Hence losses occurs.

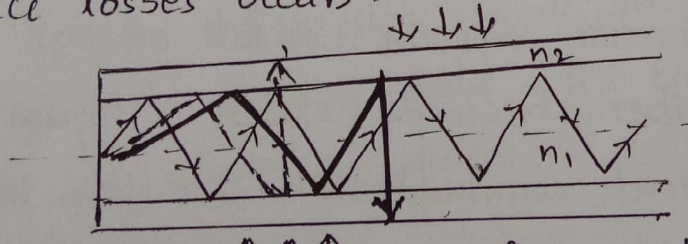


fig:- Microbending losses.

<u>Macrobending loss :-</u>

Macro bend losses are observed when a fiber bend's radius of curvature is large compared to fiber diameter macrobending is great source of loss in fibers.

Macrobending losses are reduced by operating at shortest possible wavelength.

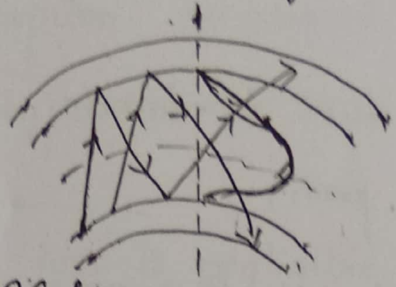


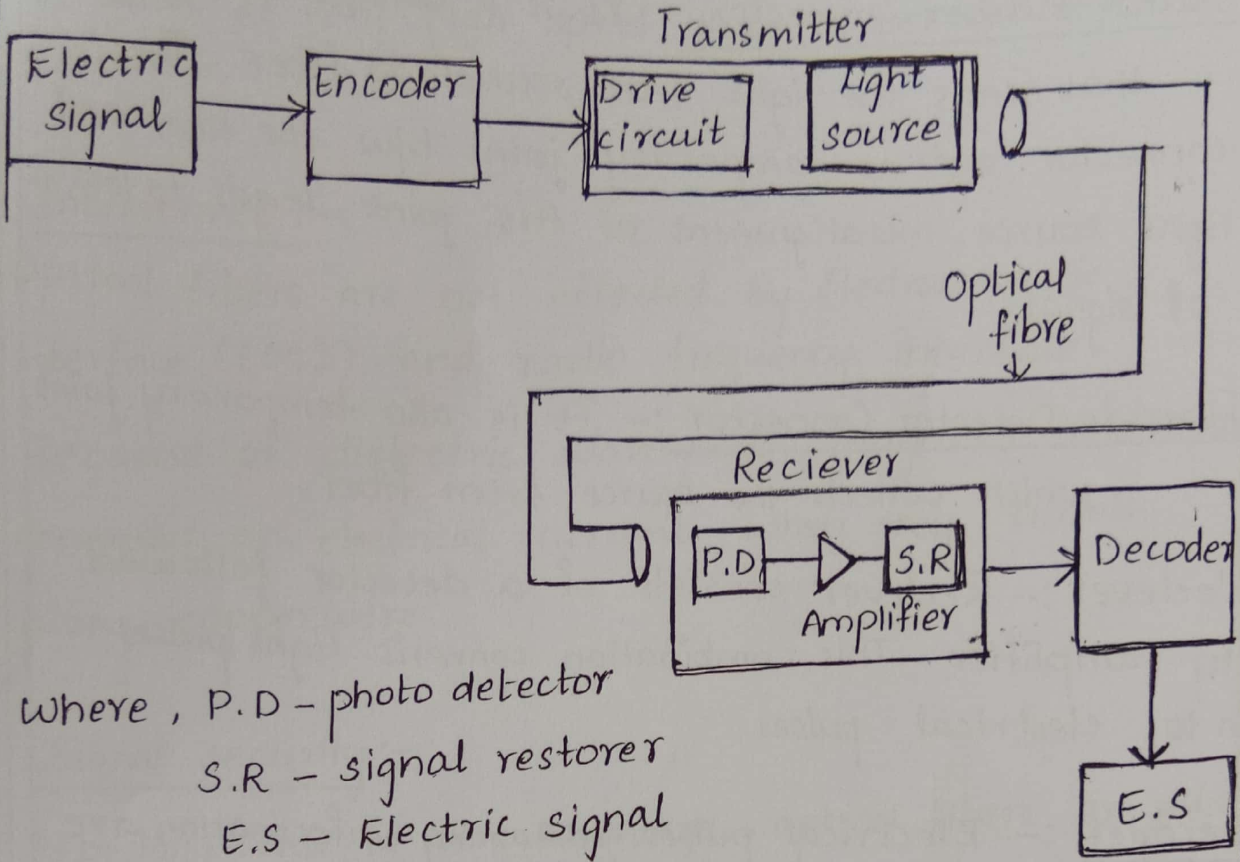
fig:- Macrobending losses

Coupling losses :-

For long distance communication, when the optical fibers are interconnected. Losses could occur due to mechanical misalignment. These losses are coupling losses. Coupling losses also occurs in coupling of optical fibers with the transmitter and reciever, as well as when core, cladding surface is not perfectly smooth.

*** Fiber Optics Communication system :-

Fiber optics communication system consists of transmitter, optical fiber, Reciever, shown in figure, Optical fiber is an ideal communication medium by systems that require high data capacity, fast operation and to travel long distances with a minimum number of repeaters.



where, P.D – photo detector
S.R – signal restorer
E.S – Electric signal

Analog information — Continuous

Digital information (discrete) — 1 0 1 0

<u>Encoder</u> :- It is an electronic system that converts the analog information signals, such as voice of telephone user, in to binary data. The binary data consists of series of electrical pulses.

<u>Transmitter</u> :- Transmitter consists of a driver which is a powerful amplifier along with light source. The output of amplifier feeds to light source, which converts electrical pulses in to light pulses.

Source to Fiber connector :- It is a special connector that sends the light from sources to fiber. The connector acts as temporary joint b/w the fiber and light source, misalignment of this joint; leads to loss of signal.

Fiber to Detector Connector :- It is also temporary joint, which collects the source from fiber.

Reciever :- Reciever consists of a detector followed by amplifier. This combination converts light pulses in to electrical pulses.

Decoder :- Electrical pulses containing information are fed to the electronic circuit called decoder.
Decoder converts binary data of electrical pulses in to analog information signals.

ADVANTAGES OF FIBER OPTIC COMMUNICATION :-

The fiber optic communication system has more advantages than conventional electrical communication system those are given below.

(1) Bandwidth :-

Optical fibers have much greater bandwidth than metal cables for optical fibers communication bandwidth around 10^5 GHz. But metal cable it has 500 MHz only. Hence optical fibres transmits large amount of data at very high speed than copper stable|cable system.

(2) Interference :-

Optical fibers are not affected by Electromagnetic interface (EMI) and radio frequency interface. Because of dielectric waveguide, magnetic field lines generates an electrical current when they travels along copperwire.

(3) Signal security :-

Especially due to this advantage, optical fibers are using in military and space applications and cross talk is not possible (or) negligible, even when many fibers abled together.

(4) Small size and weight :-

Optical fibers are very small in diameters. The space occupied by these are small compared to metallic cables. The weight of cables are also less than copper cables.

(5) Low signal loss :-

The signal loss is very less compared to best copper conductor. Hence for long distance communications fibers are prefered. The signal loss is around 0.2 dB/Km^{-1} only.

(6) Low cost :-

Optical fibers are made of silicon which is available in abudance. Optical fibers are less expensive.

(7) Spark less :-

The communication through fiber, even in electrically hazardous environment do not cause any fear of spark..

(8) flexibility and Ruggedness :-

optical fiber cable structure are flexible, compact and extremely rugged and long life also.

***APPLICATIONS OF FIBER OPTICS :-

In sensors :-

Sensor devices used to measure the physical quantities such as displacement, temperature, pressure, flow rate liquid level, chemical compositions etc.

Optical fiber sensors can be divided into ② categories.

Intrinsic (or) active sensors :-

In these sensors, the quantity to be measured acts directly on the fiber itself. The fiber itself acts as a transducing element and modifies the light passing through it. It means "Light does not leaves the fiber".

Intrinsic sensors are used to ~~produce~~ - measure strain, pressure, temperature.

Extrinsic (or) Passive Sensors :-

→ In this type of sensors, the quantity to be measured acts directly on the transducing material which modifies the light. This modified light collected through another fiber to reach the detector to sense the modification. In this light takes place outside the fiber.

→ The major benefit of extrinsic optical fiber is ability to reach otherwise inaccessible places.

→ Extrinsic optical fiber sensor are used to measure vibration, rotation, displacement, velocity, acceleration etc.

In Medicine :-

→ Optical fibres are frequently used in endoscopy treatment for visualize internal portion of human body.

→ optical fiber are using in keyhole surgeries.

→ optical fiber are using in ophthalmology treatment to correct the defects in vision.

→ Fibers are used in cardiology to do heart surgeries.

→ They are also used in Nephrology treatment, to brust the stone in kidneys.

→ Fibers are using in laproscopic surgery.

In Industry:-

→ Optical fibers are used to examine the places where one cannot reach such as to examine welds, nozzles and combustion chambers inside jet aircraft engines etc.

→ To measure inside temperature of electrical transformers.

→ To examine welds, cuttings, leakages etc. in industries.

In Communication System:-

Optical fibers are used in Tele communications such as,

1) Cable Television
2) CCTV surveilance
3) Voice Telephones
4) Remote monitoring

Optical fibers are vital for computer networking applications such as stores the data, transmits data etc

In other Applications:-

→ There are used as hydrophones for sonar applications.

→ optical fibres are used for military & mining applications.

→ They are also used for robotics.