* **Hall angle:-** Denoted by "θ_H"

$$\tan\theta_H = \frac{E_H}{E_x}$$ E_x field is in along x.

$$\theta_H = \tan^{-1}\frac{E_H}{E_x}$$

$$E_x = \frac{J}{\sigma}, \quad E_H = \frac{V_H}{d} = \frac{JBd/nq}{d}$$

$$E_H = JB/nq$$

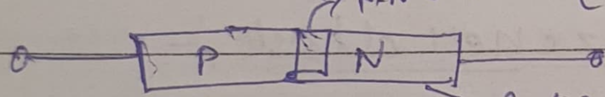
$$\theta_H = \tan^{-1}\frac{JB/nq}{J/\sigma} \Rightarrow \theta_H = \tan^{-1}\frac{B\sigma}{nq},$$

$$\theta_H = \tan^{-1}(R_H\sigma) \quad \{R_H = 1/nq\} \quad \{\mu_H = R_H\sigma\}$$

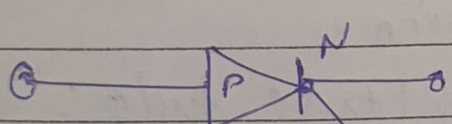
$$\theta_H = \tan^{-1}(\mu_H B)$$

* **I-V characteristic of P-N Junction:-** simple p-n junction.

P-N junction { called depletion layer }

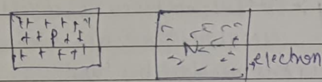


Poles terminals

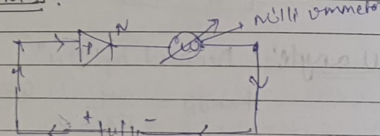


Junction

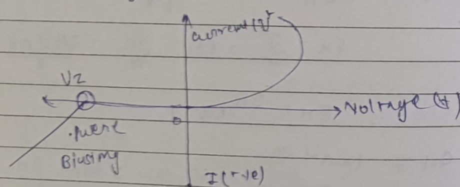
* Semi conductor :- (1) Intrinsic (pure) -> Ge, Si
(2) Extrinsic -> P-type (trivalent holes)
-> N-Type
(Pentavelent extra electron)



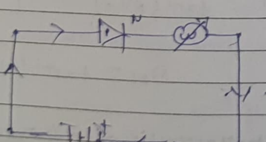
(1) Forwarded Bias :-



In graph (I-V graph) make their current (I)+



(II) Reversed Biasing



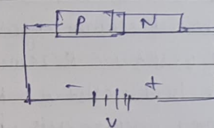
* I-V characteristic of zener diode :-

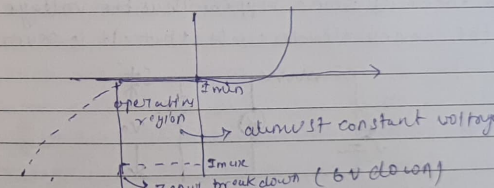
1. operates in breakdown region.
2. also called constant voltage diode :- make constant voltage along terminal y

here
doping level is very high due to which P-N Junction becomes narrow and electron pass easily g.

* used in reversed bias in forword works as same as P-N-Junction.

* Reversed bias :





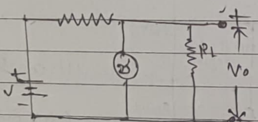
* Advantage of zener diode :- (1) Less expensive than other diode
(2) Ability to shift voltage
(3) Easily compatible and obtainable across systems.
(4) High performance standered
(5) Protection from over voltage
(6) Ability to regulate and stabilize circuit voltage.
(7) Greater control overflowing current.
(8) Usable in smaller circuits.

* working :- The junction of zener diode thin and So strong electric field is produced even when a low reverse bias voltage is applied an increase the temprature. the forbidden energy gap reduces and the zener breakdown now begins to occure

at a low voltage at the zener voltage, the resistance of diode falls and the reverse current suddenly increases when the reverse voltage is withdrawn the junction of diode regains back to original state.

* **Use of zener diode as a voltage regulator:-** The value of supply voltage v and resistance R are chosen such that diode current remains with a define limit and the diode operates in the break down region, the potential diff across the load resistance R remain constant even if the supply voltage or load resistance R is changed.

The supply voltage v is obtained from the d.c. power which contains some ripples. Thus the voltage v is applied on the zener diode such that it is reverse bias.



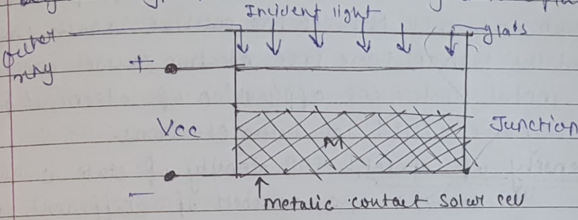
* **Solar cells:-** The solar cells are semiconductor junction devices which are used for junction devices which are used of converting optical radiation into electrical energy. The generated electric voltage is proportional to the intensity of incident light. Due to their capability of generating voltage they are called photovoltaic or solar cells.

A solar cell is PN junction device with no voltage applied directly across the junction this convert power into electrical.

* **Construction:-** The cell is a P-N junction diode with doped semiconductor the solar cells are made from semi-conductor material like silicon.

The top p-type layer is made very thin so that the light radiation may penetrate to fall on junction.

The doping level of P doped semiconductor is very high. P-type material surrounded by a nickel plated ring



Solar cell

* **Working:-** when a photon of light energy collids with the valance electron either in P-type or N type material it impart half of the energy to electron to leave it atom. As a result free electron and holes are generated on each side of junction in P type material the newly genrated electron are minority carrier here electrons move freely across the junction with no applied bias.

* **Advantage:-** (1) The solar cell is self genration device. it doesn't require any external power device.
(2) It is pollution free energy conversion system.

---

* **Bloch Theorem:-** Bloch's theorm states that solution to the schrodinger equation in a periodic potential take the form of a plane wave modulated by a periodic function.

Bloch function:- $\boxed{\psi_r = e^{ikr} \cdot u(r)}$

$\boxed{\psi(r) = e^{ikr} u(r)}$

r → position
ψ → wave function
u → periodic function
k → crystal momentum vector
e → Euler's number
i → imaginary unit

* **Free electron Theory of metal:-** All metals contain large number of free electrons which move free through the positive ionic core of the metals. Since these free electron causes conduction in metal under the application of electrical field, They are called conduction electrons.

* **Density of states:-** The density of state is essentially the number of different states at a particular energy level that electron allowed to occupy.

The density of state in semi-conductor equals to number of states per unit energy and unit volume

$$g(E)\,dE = \frac{\#\,\text{state}}{\text{volume}}\,dE$$

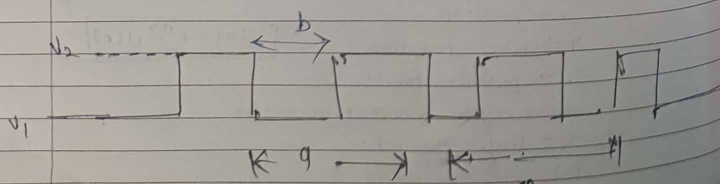
$$g(E) = \frac{4\pi(2m)^{3/2}\sqrt{E}}{h^3}$$

* **Kronig penny model:-** It is simplified model for an electron in one dimensional periodic potential.

The possible states that the electron can occupy are determined by schrodinger equation and the e⁻ density of states or it is strongly simplified one-D quantum mechanical model for a crystal.

$$-\frac{\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V(x)\psi = E\psi$$

In the case of Kronig penny model the potential V(x) is periodic square wave.



K-P model

Unit - IV Laser

Laser is an acronym for light Amplification by stimulated emission of radiation. It is a device to produce a strong, monochromatic collimated and highly coherent beam of light and depends on phenomenon of.

(1) Laser beam produces coherent light in same phase and of same frequency while ordinary light source such as incandescent lamp source produces incoherent light.

(2) Laser beam is highly monochromatic while ordinary light sources spread over a wavelength range 100Å to 1000Å.

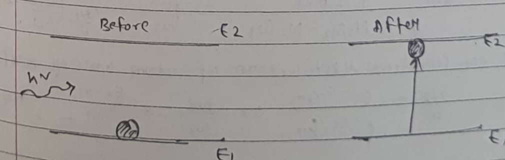
(3) Laser beam is extremely intense while the intensity of ordinary light sources decrease rapidly with distance.

(4) Laser beam doesn't diverge while ordinary light source highly diverge.

* **Absorption of radiation:-** If an atom is initially in lower state it can rise to higher state by absorption quantum of radiation of frequency ν given by

$$\nu = \frac{E_2 - E_1}{h}$$

where E_1, E_2 are energies of atom in state respectively this process known absorption of radiation.



* **Spontaneous emission:-** let's consider atom initially in higher excited state with higher energy in inherent unstable, hence atom in excited state does not stay for longer time and it jumps to lower energy state emitting a photon

Unit - IV Laser

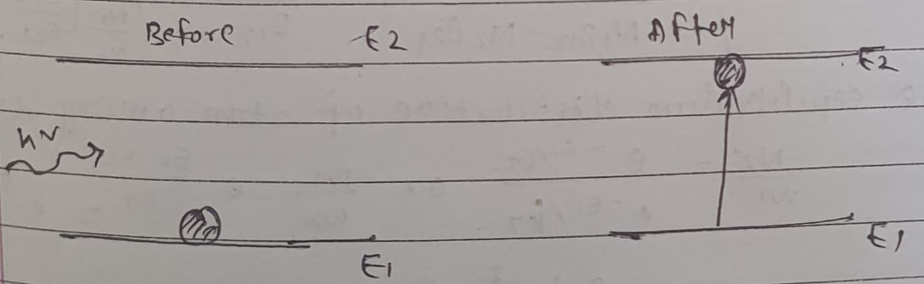
Laser is an acronym for light Amplification by stimulat emission of radiation. it is a device to produce a strong, monochromat collimated and highly coherent beam of light and depends on phenomenon of.

(1) Laser beam produces coherent light in same phase and of same frequency while ordinary light source such as incandes lamp source produces incoherent light.
(2) Laser beam is highly monochromatic while ordinary light sources spread over a wavelength range 100Å to 1000Å.
(3) Laser beam is extremely intense while the intensity of ordinary light sources decrease rapidly with distance.
(4) Laser beam doesn't diverge while ordinary light source highly diver

* **Absorption of radiation:-** If an atom is initially in lower it can rise to higher state by absorption quantam of radiation of frequency ν given by

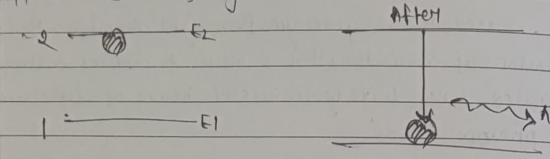
$$\nu = \frac{E_2 - E_1}{h}$$

where E_1, E_2 are energies of atom in state respectively this process known absorption of radiation.

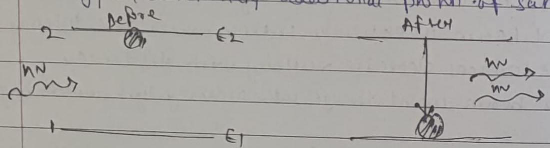


* **Spontaneous emission:-** let's consider atom initially in higher excited state with higher energy in inherent unstable, hence atom is excited state does not stay for longer time and it jumps to lower energy state emitting a photo

of frequency ν. this is spontaneously emission of radiation if there is an assembly of atoms.



* **Stimulated (Induced) emission**:- According to einstein, an atom in an excited energy states may, under the influence of electromagnetic field of photon of frequency ν incident upon it, jumps to a lower energy state, emitting additional photon of same (ν).



* **Relation between spontaneous and stimulated emission**:-

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

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

$$N_1 P_{12} = N_2 P_{21}$$

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

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

The equilibrium distribution of atom among different

$$\frac{N_2}{N_1} = \frac{e^{-E_2/kT}}{e^{-E_1/kT}} \quad \text{or} \quad \frac{N_1}{N_2} = e^{\frac{E_2 - E_1}{kT}} = e^{h\nu/kT}$$

$$u(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{h\nu/kT} - 1}$$

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

Date :

* **Laser**:- A device that produces a controlled ray of very powerful light that can be used as a tool or laser is light amplification by the stimulated emission of radiation.

A laser is created when electron in the atoms in optical material absorb the energy form an electrical current or a light. that extra energy "excites" electrons enough to move from a lower-energy orbit to a higher-energy orbit around the atom's nucleus.

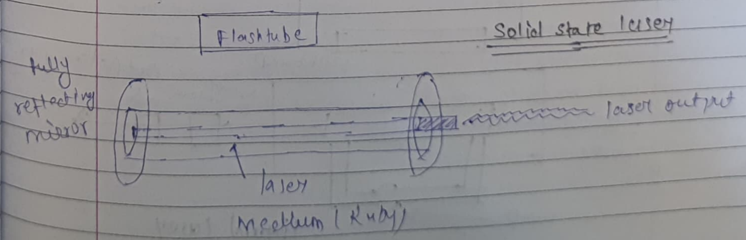
* **Types of laser**:- (1) Solid-state laser (2) Gas laser (3) liquid laser (4) semi-conductor laser

(1) **Solid-state laser**! A solid state laser that uses a gain medium that is solid, rather than liquid or gas. The inherent advantage of solid-states lasers are very high beam quality, nearly diffraction limit beam divergence, high beam pointing and amplitude stability, high peak power.

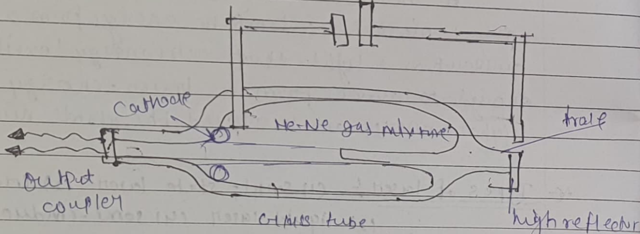
Due to efficiency which light can be coupled into the neodymium ~~ions~~ atoms.

Solid state laser are widly used in metal processing red-green-blue light source in laser printer and project

Solid state laser



(2) **Gas laser** :- A gas laser is a laser in which an electric current is discharged through a gas inside the laser medium to produce laser light. In gas laser the medium is in gaseous state.

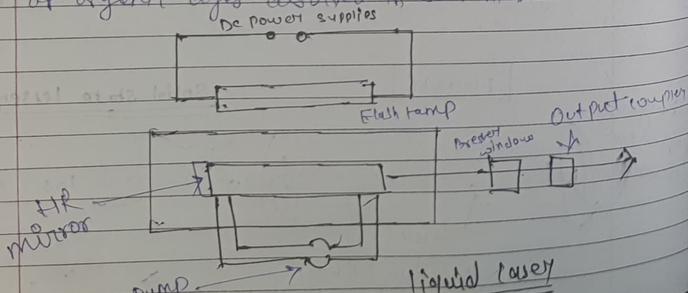


Gas laser

Gas laser are used in applications that requires laser light with very high beam quantity and long coherence length.

(3) **Liquid laser** :- liquid laser is laser that uses the liquid as laser medium in liquid laser, light supplies energy to the laser medium.

A dye laser is example of liquid laser, dye laser made up of an organic dye mixed with solvent, these laser generate laser light from excited energy states of organic dyes disolved in solvents.



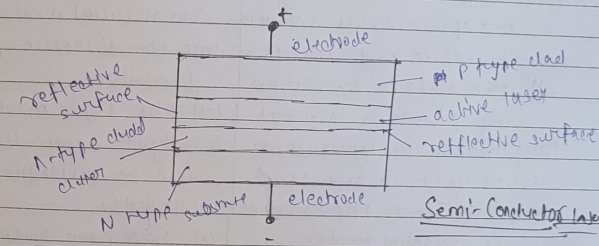
liquid laser

4) **Semi conductor laser** :- A semi conductor laser is a device that causes laser oscillation by flowing an electric current to semi conductor.

diode laser is example of semi conductor laser.

semi conductor laser used for optical data storage, meter spectroscopy material processing pumping of other laser.

This is small, volume, light weight, good reliability and low power consumption.



Semi-Conductor laser

Laser light and ordinary light :-

Laser light	Ordinary light
(1) The light emitted from a lamp, flame in chonerent light	(1) laser light is coherent light.
(2) laser beam is highly monocromatic	(2) Ordinary light source spread over a wavelength range 100 to 1000 Å.
(3) laser beam is extremly intense	(3) Intensity of ordinary light source decrease rapidly with distance
(4) laser source radiation only along one direction	(4) light source emit radiation in all direction.
(5) laser beam does'nt diverges	(5) ordinary light source are highly divergent light travel long distance with spread-ing.

Date :

Spontaneous emission	Stimulated emission
(1) Spontaneous emission is a random process,	(1) It is not random process.
(2) It can't be controlled from outside	(2) It can be controlled from outside.
(3) The photon emitted by the spontaneous emission travel in any direction	(3) The photon emitted by the stimulated emission travel with the direction of incident photons,
(4) The light is produce by process is incohrent	(4) The light produce coherent
(5) There is no application of light in process.	(5) Light application occure due to multiplication of photons,
(6) light from the source is unpolarized	(6) light from source polyrized

Properties of laser beam :-

(1) **Directionality :-** An ordinary light source emit light waves in all direction in a laser the photon of particular direction only allowed for multipule reflection thus laser is highly directio

(2) **Intensity :-** The intensity of ordinary light decreases as it travels in the space this is because of its spreading.

The laser light does not spread with distance at propogates in space in form of normal beam its intensity remain almost containt over long distance.

(3) **Coherence :-** The laser light is highly coherant A laser emits the light waves of same wavelength and in same phase. The ordinary light emits have of different wavelength without any phase relationship

(4) **Divergence :-** Divergence of light is a measure of its spread with distance. the angular spread in ordinary light is very high because of its propogation in the divergence in laser beam is negible A very small divergence is due to the diffraction laser light when it emerges out from silvered mirror.

* OPTICAL FIBER *

Optical fiber are used must often as a means to transmit light b/w the two ends of the fiber and wide usage in fiber optic communications.

Optical fiber are extremly thin strands of very high purity slica which transmit light from one end to other with minimal loss,

There are two types of fiber :-

(1) multimode fiber

(2) singlemode fiber,

In optical fiber light travel down a fiber optic cable by bouncing off the walls of the cable repedatly,

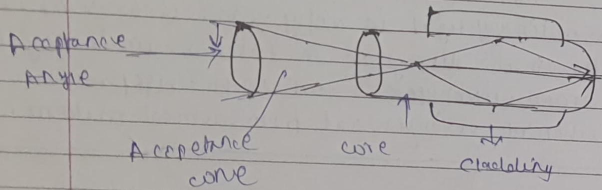
~~Acceptance angle = where optical fiber accept signal~~

Acceptance angle & cone :- Acceptance angle is the max angle at which incoming

Sunlight can be captured by solar concentrator

The acceptance angle of an optical fiber is defined based on purely geometrical consideration.

It is the maximum angle of a ray hitting the fiber cone which allows the incident light to be guided by the core.



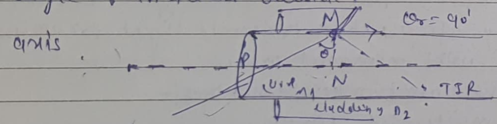
Acceptance angle & cone :

Acceptance angle of optical fiber:

Consider an optical fiber core R.I. is n_1

cladding refractive index is n_2

i = angle of incident outside.



$r \to$ angle of refraction at core

$\theta \to$ angle of incident at core cladding boundary.

$$\frac{\sin i}{\sin r} = \frac{n}{n_0} \quad \text{--- (1)}$$

In PNB

$$r + 90 + \theta = 180'$$

$$r = 90 - \theta i$$

Substituting r in eq (1)

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

$$\frac{\sin i}{\cos \theta i} = \frac{n_1}{n_1} \quad \text{--- (2)}$$

$i = i_{accp}$, $\theta = \theta_c$, $\theta_c > TIR$

$$\sin i_{accp} = \cos\theta \frac{n_1}{n_1}$$

$$\boxed{i_{accp} = \sin^{-1} \cos\theta_c \frac{n_1}{n}} \quad \text{--- (4)}$$

$\theta_i = \theta_c$, $\frac{\sin\theta i}{\sin\theta r} = \frac{n_2}{n_1}$

$\theta_r = 90'$ $\quad \frac{\sin\theta_c}{\sin 90} = \frac{n_2}{n_1}$ $\quad \sin\theta_c = \frac{n_2}{n_1}$ --- (5)

$$\cos\theta = 1 - \sin^2\theta$$

$$\cos\theta = \sqrt{\left(\frac{n_1}{n_2}\right)^2} \Rightarrow \cos\theta = \sqrt{\frac{n_1^2 - n_2^2}{n^2}}$$

$$\cos\theta = \frac{1}{n}\sqrt{n_1^2 - n_2^2} \quad \text{--- (6)}$$

$$\therefore i_{accp} = \frac{\sin^{-1}\sqrt{n_1^2 - n_2^2}}{2}$$

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

$$i_{accp} = \sin^{-1}\frac{\sqrt{n_1^2 - n_2^2}}{n_0}$$ this is acceptance of optical fiber

If medium is air $n_0 = 1$

$i_{accp} = \sin^{-1}\sqrt{n_1^2 - n_2^2}$

Acceptance cone θ = 2 × Acceptance

θ = 2 × I_{accp}

Acceptance cone = $2\sin^{-1}\sqrt{n_1^2 - n_2^2}$

Fractional index change:-

$$\Delta = \frac{n_1 - n_2}{n_1}$$

$$= 1 - \frac{n_2}{n_1}, \quad \boxed{\Delta = +ve}$$

TIR $n_1 > n_2$

* **Numerical Aperture (NA)** :- Light gathering capability of optical fibre and
also define as:-
Sine of the Acceptance angle

$$NA = \sin i_{acc}$$

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

$$NA = \sqrt{n_1^2 - n_2^2} \quad \text{also} \quad NA = n_1\sqrt{2\Delta}$$

$$NA = \sqrt{n_1^2 - n_2^2} = \sqrt{\frac{(n_1 - n_2)(n_1 + n_2)\, n_1}{n_1}}$$

$$\frac{n_1 + n_2}{2} \simeq n_1$$

$$\frac{n_1 - n_2}{2} = \Delta$$

$$NA = \sqrt{n_1 \Delta n_1 2} = \sqrt{n_1^2\, 2\Delta} = n_1\sqrt{2\Delta}$$

* **V- number** :- normalized frequency of fibre

$$V = \frac{2a\pi}{\lambda} NA$$

$2a \rightarrow$ diameter of cone
$\lambda \rightarrow$ wavelength

① If $V < 2.405$
[Single mode step index fiber]

If
② $V > 2.405$, (then the multimode graded index fiber)

③ If $V = 2.405$, cutoff frequency of fiber

$$\lambda_c = \frac{\lambda V}{2.405}$$

* **Attenuation** :- Signal loss, Power loss

* **different types of loss** :-
(1) Bending loss
(2) Scattering loss
(3) Dispersion loss