Laser Module - 1

L - light
A - amplification
S - stimulation
E - emission
R - radiation

* Laser is a acronym of light amplification by stimulated emission of radiation.

* Laser is an "opto electronic" device.

* Laser light has special characteristic differ from those of light from conventional sources

→ Laser's are characterised by,

1). Highly "mono chromatic" very short single frequency. Monochromatic refers to a single wavelength

2). Highly directional [means it should be a in a straight directional] i.e. Laser light is of very small divergence

3). specially and temporally coherent [i.e. has same frequency(ν) & wavelength(λ)]

4). Laser light causes high power density & brightness.

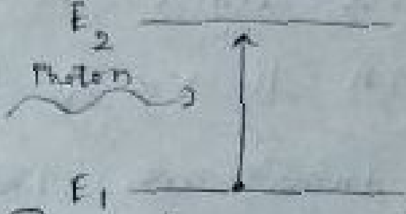
5). The laser beam spreads in order of a few millions - radians.

6). The production of Laser light is a particular consequence of "Interaction of radiation with Matter"

7). Any matter, irrespective of its state of existence is reffered as "A quantized" system

* **Interaction of Radiation with Matter:**

1. Absorption of light
2. Emission of light



Rate of absorption $\propto N_1 U_f$

** Rate of absorption $= B_{12} N_1 U_f \rightarrow (1)$

$B \rightarrow$ with radiation

Emission :

The lifetime of an electron in excited state is very small i.e, $10^{-8} - 10^{-9}$ (nano sec)

There are 2 Types of emission :

1. Spontaneous emission :

Spontaneous emission $\propto N_2 = A_{21} N_2$ $\rightarrow (2)$ [where A is without / no radiation]

rate of

2. Stimulated emission :

rate of stimulated emission $\propto N_2 = B_{21} N_2 U_f$ $\rightarrow (3)$

Under thermal equilibrium rate of absorption = rate of emission

$$B_{12} N_1 U_f = A_{21} N_2 + B_{21} N_2 U_f$$

$$B_{12} N_1 U_f - B_{21} N_2 U_f = A_{21} N_2$$

$$U_f [B_{12} N_1 - B_{21} N_2] = A_{21} N_2$$

$$U_f = \frac{A_{21} N_2}{[B_{12} N_1 - B_{21} N_2]} \longrightarrow (4)$$

dividing B_{21} in both Numerator & denominator

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

$$U_f = \left(\frac{A_{21}}{B_{21}}\right) \left[\frac{N_2}{\left(\frac{B_{12}}{B_{21}}\right) N_1 - N_2} \right] \longrightarrow (5)$$

According to Max planck's quantum Theory of radiation

$$U_f = \frac{8 \pi h \nu^3}{c^3} \left[\frac{1}{e^{h\nu / K_B T} - 1} \right] \longrightarrow (6)$$

WKT, $\frac{A_{21}}{B_{21}} = \frac{A}{B}$

Suppose rate of absorption process = rate of stimulated emission process

i.e, $B_{12} = B_{21}$

$$\therefore U_\nu = \left(\frac{A_{21}}{B_{21}}\right)\left[\frac{N_2}{N_1 - N_2}\right] \longrightarrow (7)$$

divide N_2 both in numerator & denominator

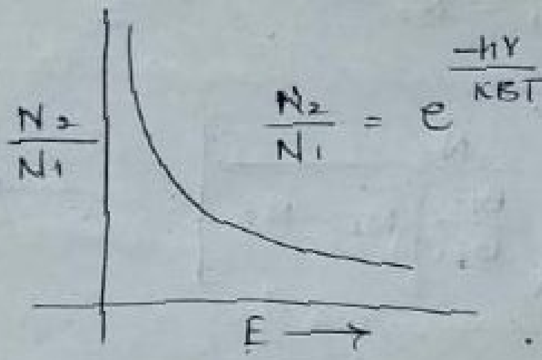
$$U_\nu = \frac{A_{21}}{B_{21}} \times \frac{\cancel{N_2}}{\cancel{N_2}\left(\frac{N_1}{N_2} - 1\right)}$$

$$U_\nu = \left(\frac{A}{B}\right) \times \frac{1}{\frac{N_1}{N_2} - 1} \longrightarrow (8)$$

according to Boltzman equation,

$$\frac{N_2}{N_1} = e^{\frac{-h\nu}{K_BT}} \rightarrow \frac{N_1}{N_2} = e^{\frac{h\nu}{K_BT}}$$

which is shown by the below graph



[Note: If
$E\uparrow$ $\frac{N_2}{N_1}\downarrow$
If $E\downarrow$ $\frac{N_2}{N_1}\uparrow$]

$$\therefore U_\nu = \frac{A}{B} \times \frac{1}{\left(e^{\frac{h\nu}{K_BT}} - 1\right)} \longrightarrow (9)$$

by Substituting eqⁿ 9 in 8.

$$\therefore \text{we get, } U_\nu = \left(\frac{A}{B}\right) \times \frac{1}{\left(e^{\frac{h\nu}{K_BT}} - 1\right)}$$

where h = plank constant
ν = frequency radiation
c = speed of light
K_B = Boltzman constant

$\therefore \frac{A}{B} = \frac{8\pi h\nu^3}{c^3}$

Eq^n number (6) is the expression for einstein A & B Co-efficient

* Stimulated emission

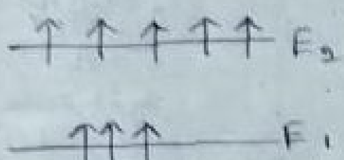
Same phase
$\therefore$ amplification takes place
$A = A_1 + A_2$

Spontaneous

different Phase
no amplificatio

Conditions for laser actions :-

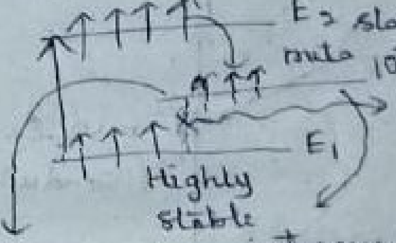
1. Always the population of ~~lower~~ higher energy level is more occupied than that of lower energy level which is called "population inversion" which leads to emission



2. Increase the life-time of upper level

E_2 (10^{-7} to 10^{-8}s) very small

E_1 (10^{-3} to 10^{-3}s)



life time is more than E_2 level

* $\therefore$ The difference in energy b/w intermediate level & E_1 level leads to laser light or produces Laser.

$\therefore$ population of inter-mediate level is more than E_1

Requirements for building Laser :-

1. pumping of electrons from stable state to unstable state

   1). optical pumping : shining the light → Energy Source

   2). Electrical pumping : (DC) are used.

2. Active medium :- region of the Laser device which is able to increase population inversion

3. Laser cavity :-

Semiconductor diode Laser

* GaAs (Galium arsanide) Laser :-

Construction and instruction

Semiconductor
↓
- Elemental : Si, Ge

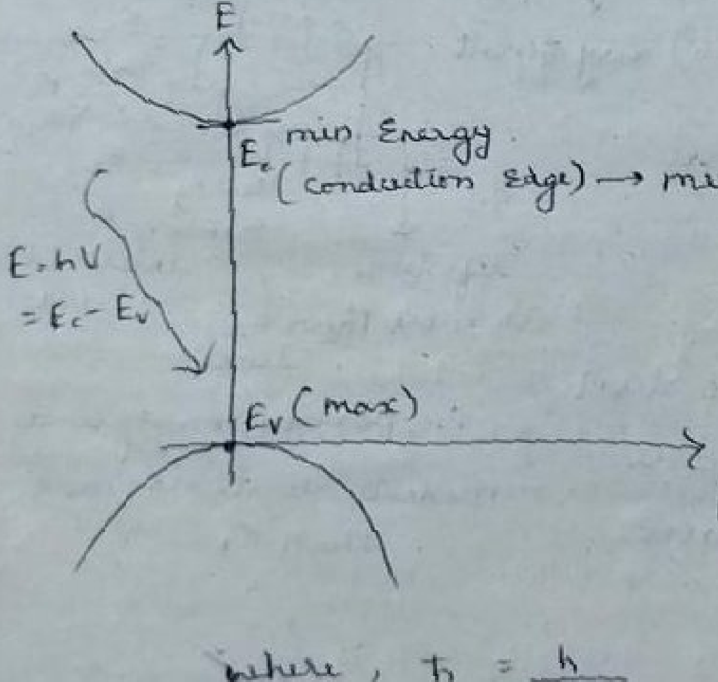
Compound

III - V
Eg : GaAs

II - VI
Eg : ZnTe, CdTe, HgTe — Binary

HgCdTe, CdZnTe — Tertiary

Band structure :



(conduction Edge) → minima of conduction band.

where, $\hbar = \frac{h}{2\pi}$

Reduced planck's constant

k - wave number

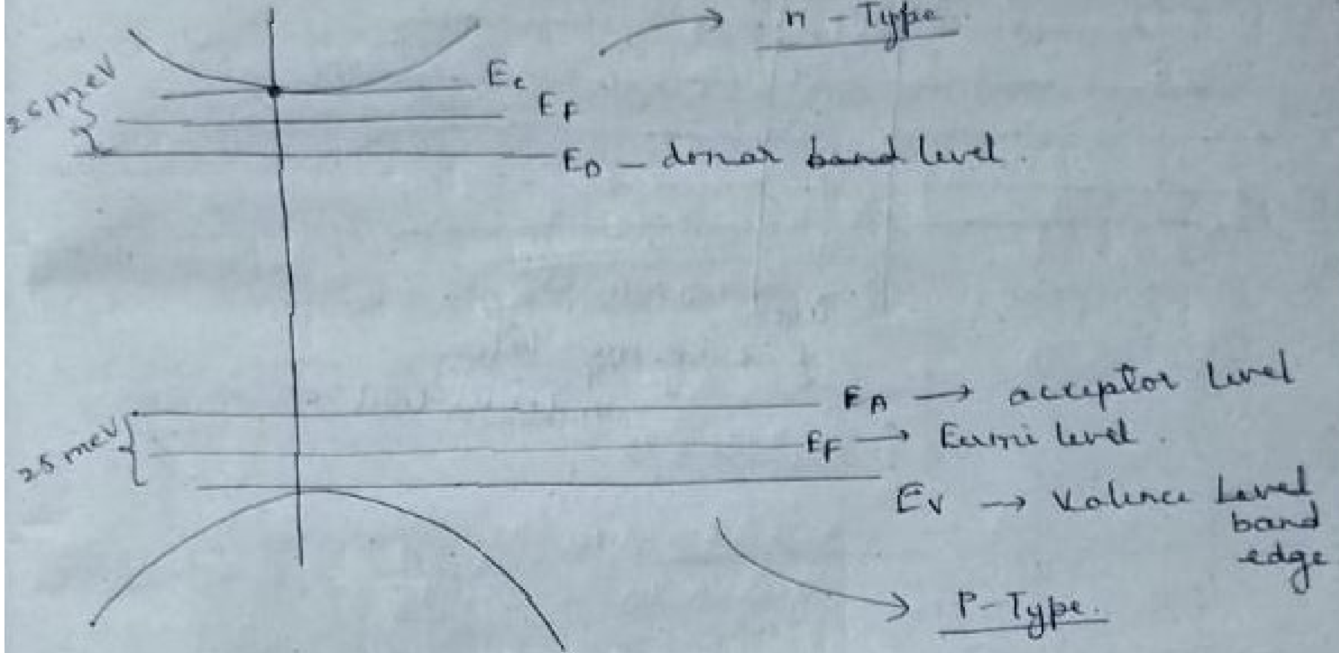
$k = \frac{2\pi}{\lambda}$

$p = \frac{h}{2\pi} \times \frac{2\pi}{\lambda} \Rightarrow p = \frac{h}{\lambda}$

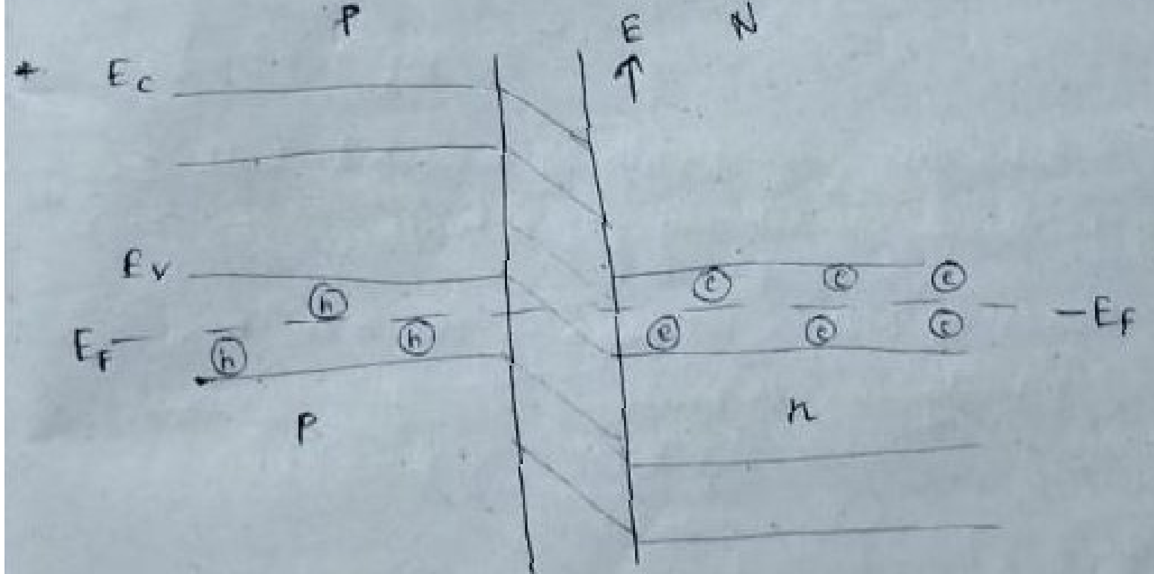
$p = \frac{h}{\lambda} \longrightarrow$ de-broglie

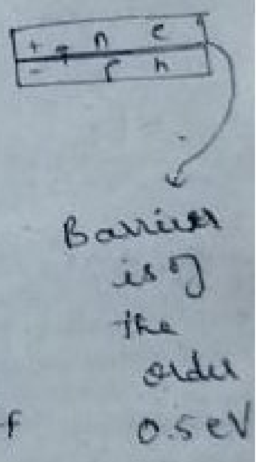
$\lambda = \frac{h}{p}$

Direct band gap Semiconductor → It is a Semi Conductor at which conduction band edge and Valence band edge have same momentum Value



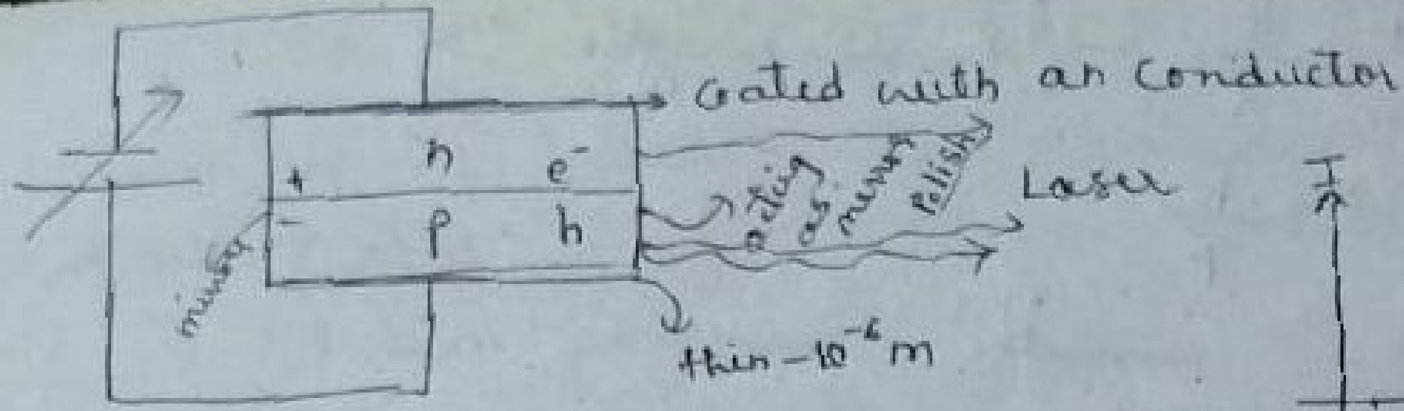
Electrons moves from n to p type

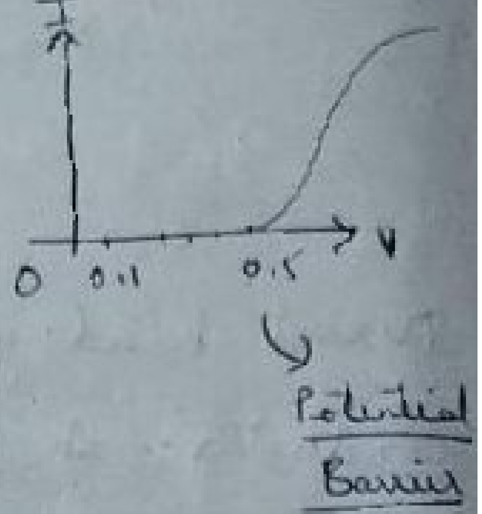


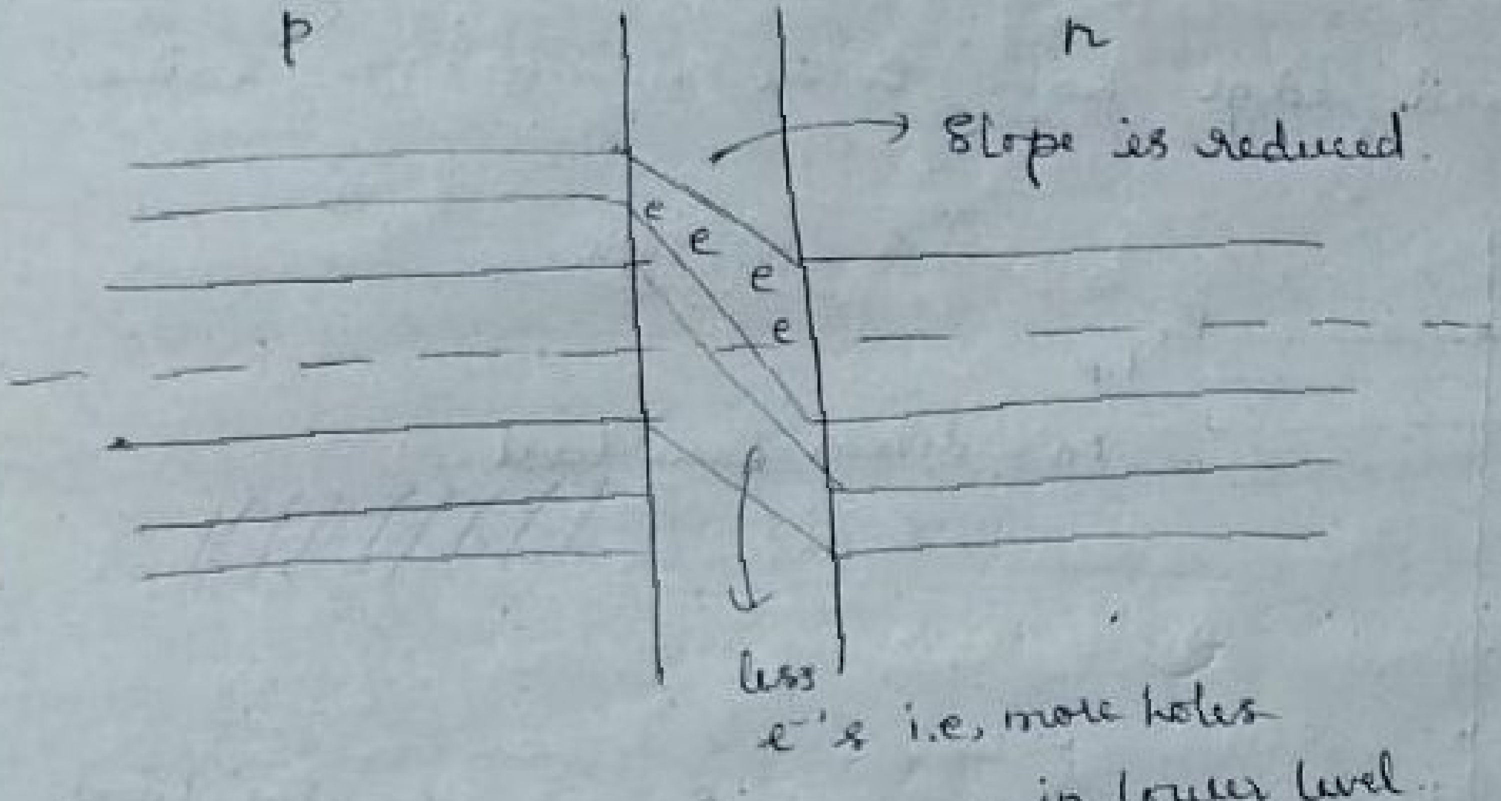


Indirect band gap S.C — Ge, Si

direct band gap S.C — GaAs, GaP, GaAsP, CdTe CdZnTe etc


Coated with an conductor
n e⁻
p h
acting as mirror polish
Laser
mirror
thin - 10^{-6} m


I
V
0
0.1
0.5
Potential Barrier


p
n
Slope is reduced
e
e
e
e
less e's i.e, more holes is lower level