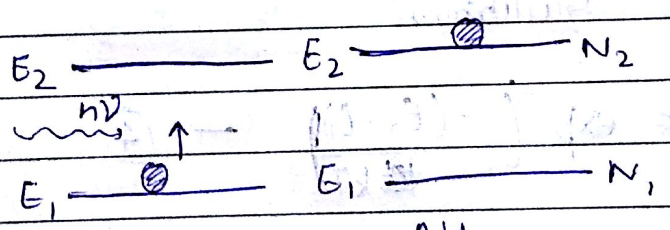
(*) LASER → light amplification stimulated emmision of Radiation

LASER

Interaction of Radiation with matter

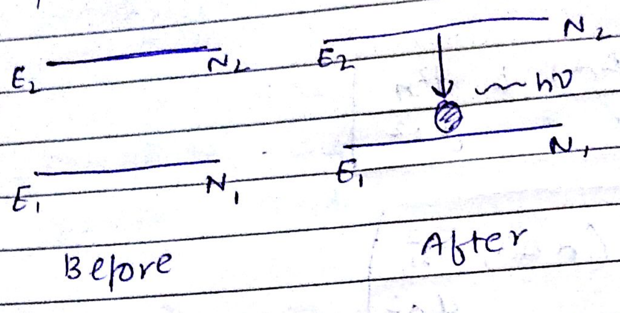
1) Absorption



Before After

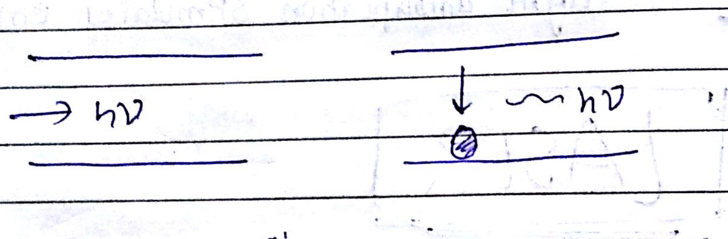
$$R_{12} = B_{12} N_1 \rho(\nu) \quad \text{—} (1)$$

(2) Spontaneous Emission



$$R_{21}^{spon} = A_{21} N_2 \quad — ②$$

(3) Stimulated Emission



$$R_{21}^{stim} = B_{21}\, \rho(\nu) N_2 \quad — ③$$

Relation between Einstein's coeff.

In thermal equilibrium

$$\frac{N_2}{N_1} = \exp\left(\frac{-(E_2 - E_1)}{kT}\right) \quad — ④$$

where $T > 0$.

$E_2 > E_1$

$N_2 < N_1$

Now Absorption rate = Emission rate

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

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

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

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

$$e(\nu) = \frac{A_{21}/B_{12}}{\frac{N_1}{N_2} - \frac{B_{21}}{B_{12}}} \quad -(5)$$

By eq. (4)

$$e(\nu) = \frac{A_{21}/B_{12}}{\left(e^{h\nu/kt} - \frac{B_{21}}{B_{12}}\right)} \quad -(6)$$

Acc to Plank's Number

$$\rho(\nu) = \frac{8\pi h \nu^3}{c^3} \left[\frac{1}{e^{h\nu/kT} - 1} \right] \quad -(7)$$

Comparing eq (6) and (7)

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

$$\boxed{\frac{A_{21}}{B_{12}} = \frac{8\pi h \nu^3}{c^3}}$$

→ Condition to achieve lasering action

(1) Population inversion → rate of emmission > rate of absorption

(2) Spontaneous emission should be negligible.

(3) Coherent beam of light must be sufficiently amplified.

Mean component of LASER

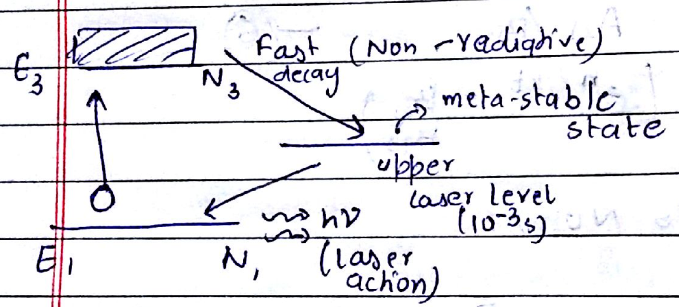
1. Pumping source
   - → Optical pumping
   - → Electrical pumping
   - → chemical pumping

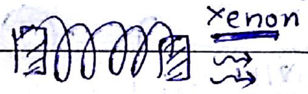
2. Active Medium
3. Resonance cavity

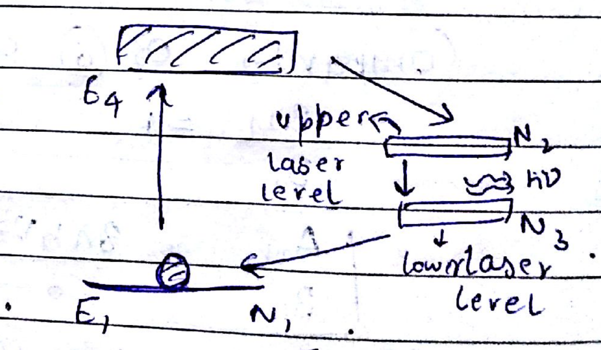
→ Types of laser

- Three level Laser system (Ruby Laser
- low level laser system (He-Ne laser)

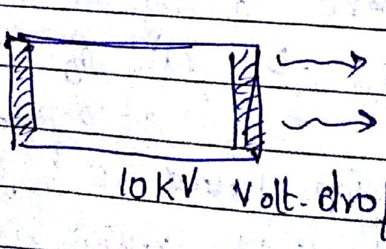
$$\eta = \frac{E_2 - E_1}{E_3 - E_1}$$







$$\eta = \frac{E_2 - E_1}{E_4 - E_1}$$



10kV Volt-drop

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$$\frac{d^2x}{dt^2} + \underbrace{\frac{b}{m}}_{2\gamma}\frac{dx}{dt} + \underbrace{\frac{k}{m}}_{\omega_0^2}x = 0$$

$$\boxed{\frac{d^2x}{dt^2} + 2\gamma\frac{dx}{dt} + \omega_0^2 x = 0}$$

Try solution

$$\boxed{x = Ae^{\alpha t}}$$

Put $\frac{dx}{dt}$, $\frac{d^2x}{dt^2}$

$$\Downarrow$$

$$\boxed{\alpha = -\gamma \pm \sqrt{\gamma^2-\omega_0^2}}$$

$$\alpha = -\gamma + \sqrt{\gamma^2 - \omega_0^2}$$

$$\alpha = -\gamma - \sqrt{\gamma^2-\omega_0^2}$$

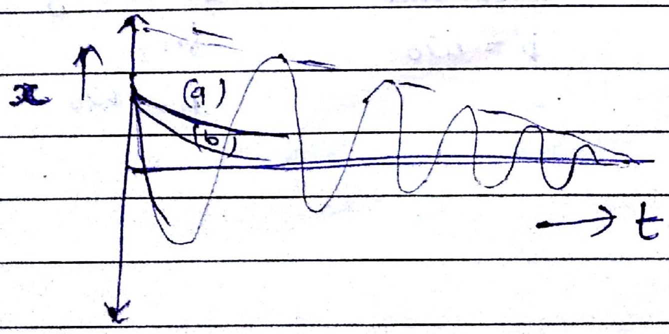
General solⁿ

$$\boxed{x = A_1 e^{(-\gamma+\sqrt{\gamma^2-\omega_0^2})t} + A_2 e^{(-\gamma+\sqrt{\gamma^2-\omega_0^2})t}}$$

(a) Heavy damping ($\gamma^2 > \omega_0^2$)

(b) Critical Daming ($\gamma^2 = \omega_0^2$)

(c) Low Damping ($\gamma^2 < \omega_0^2$)



$$\boxed{x = ae^{-\gamma t}\sin(\omega t + \phi)} \leftarrow \text{(low damping)}$$

⟹ Quality factor: $Q = 2\pi \dfrac{(\text{energy stored in system})}{(\text{energy loss per second})}$

$$= 2\pi\left(\frac{E}{PT}\right) = 2\pi \frac{(E)}{\left(\frac{E}{\tau} T\right)} = \frac{2\pi\tau}{T}$$

$$\boxed{Q = \omega\tau}$$

⟹ $\boxed{\text{Forced H.O}}$

$$\boxed{\frac{d^2x}{dt^2} + 2r\frac{dx}{dt} + \omega_0^2 x = f_0 \sin pt}$$

If RHS = 0
complementry
function

Same as Damped
H.O

steady
State function

$$\boxed{x = \frac{f_0}{\sqrt{(\omega_0^2 - p^2) + 4r^2p^2}} \sin(pt - \phi)}$$

low driving
freq.

$p \ll \omega_0$

Resonance

$p = \omega_0$

High driving
freq.

$p \gg \omega_0$