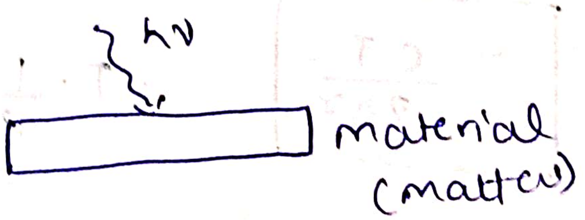
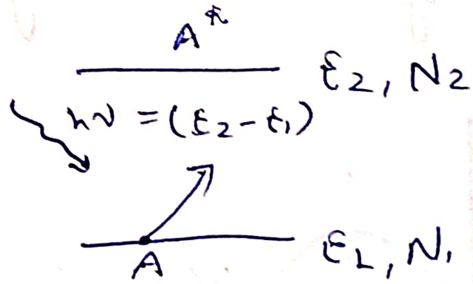
Laser :- [Light amplification by stimulated emission of radiation]

* monochromatic source of light
* Directional , coherent.

→ Energy matter interaction :-





1. Stimulated Absorption $E_1 \rightarrow E_2$
2. spontaneous emission $E_2 \rightarrow E_1$
3. Stimulated Emission.

1) Stimulated Absorption :-

1916 - Einstein
1958 - ~~MAFt~~ MASER
1958 - LASER

$(P_{12})_{\text{Sti. Ab.}} \propto \cancel{\rho(\nu)}\ \rho(\nu)$

Probability of occurance of that particle (stimulated absorption)

$12 \Rightarrow 1$ to 2

$$\boxed{= B_{12}\,\rho(\nu)}$$

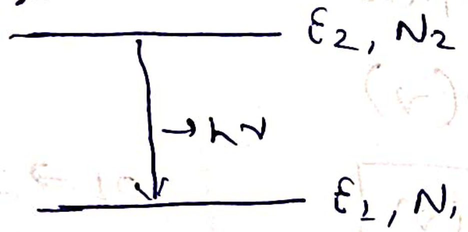
where,

B_{12} = Einstein coefficient for stimulated absorption

No. of atoms goes to excited state = $\boxed{B_{12}\,\rho(\nu)\,N_1\,\Delta t}$

2). Spontaneous emission :-

$\tau = 10^{-8}$ sec



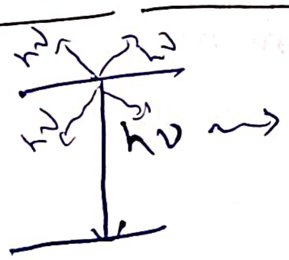
$A^* \rightarrow A + h\nu$

Probability of occurance of this process, $\boxed{(P_{21})_{\text{spon. emi.}} = A_{21}}$

where, A_{21} is einstein coefficient for spontaneous emission.

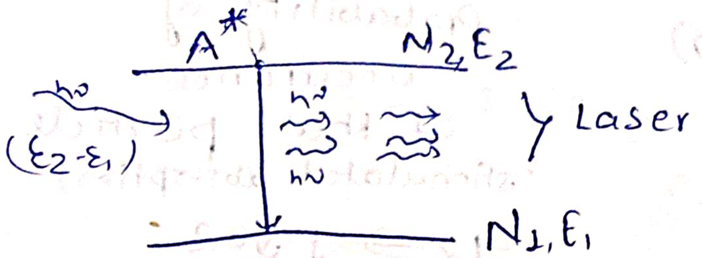
No. of atoms comeback to ground state through spontaneous process through spontaneous emission = $\boxed{N_2\,A_{21}\,\Delta t}$

3). Stimulated Emission :-



Random directional ~~spont~~ spontaneous emission can occur in any direction

3) Stimulated emission:-



$$A^* + h\nu \longrightarrow A + 2h\nu$$

* Emitted radiation have same phase frequency, direction and plane of polarisation.

* Probability of occurance of this reaction,

$$(P_{21})_{stim.\ emiss} \propto \rho(\nu)$$

$$\boxed{= B_{21}\, \rho(\nu)}$$

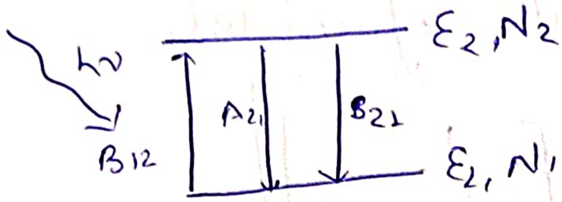
21 ⇒ 2 to 1

* No. of atoms comes to ground state through stimulated emission process =

$$\boxed{N_2 B_{21}\, \rho(\nu)\, \Delta t}$$

- Einstein's A and B coefficient:-

→ Assumption ⇒ * Radiation and matter are in thermal equillibrium.



$$\Rightarrow \; E_2 - E_1 = h\nu$$

* Distribution of particles among various states follow MB statistics. (maxwell & Boltzman)
* Radiation is consisted with Black Body Radiation.

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

$$\Rightarrow \; \rho(\nu)\,[B_{12} N_1 - B_{21} N_2] = A_{21} N_2$$

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

$$\boxed{\rho(\nu) = \frac{A_{21}/B_{12}}{\left[\frac{N_1}{N_2} - \frac{B_{21}}{B_{12}}\right]}}$$

$$\Rightarrow \; \boxed{\frac{N_2}{N_1} = e^{-(E_2 - E_1)/kT}}$$

$$\Rightarrow \; \boxed{\rho(\nu) \; \frac{A_{21}/B_{12}}{\left[e^{h\nu/kT} - \frac{B_{21}}{B_{21}}\right]}} \quad \text{— (1).}$$

As per Black body radiation formulae,

$$\boxed{\rho(\nu) = \frac{8\pi h\nu^3}{c^3}\left[\frac{1}{e^{h\nu/kT}-1}\right]} \quad \text{—(2)}$$

$$\Rightarrow \frac{A_{21}}{B_{12}} = \left(\frac{8\pi h\nu^3}{c^3}\right) \quad \text{—(I)}$$

$$B_{12} = B_{21} \quad \text{—(II)}.$$

* ~~Pora~~ Probability of exitation & dexitation is same.

$\Rightarrow A_{21} = \frac{1}{\tau}$ [τ = Relaxation of time of exited state]

$$\boxed{\frac{\text{Stimulated transition /emission}}{\text{Spontaneous transition /emission}} = \frac{B_{21}\cancel{N_2}\rho(\nu)}{\cancel{N_2}A_{21}}}$$

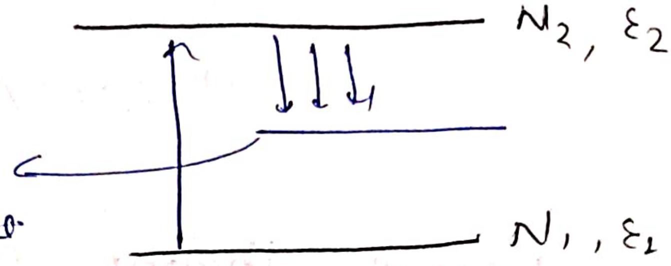
$$A_{21} = \frac{1}{\tau}$$

$$\Rightarrow \boxed{= B_{21}\,\rho(\nu)\,\tau}$$

$$\frac{\text{Stimulated emission}}{\text{Stimulated absorption}} = \frac{B_{21}N_2\,\rho(\nu)}{B_{12}N_1\,\rho(\nu)}$$

$$\Rightarrow \boxed{= \frac{N_2}{N_1}}$$

$$\frac{N_2}{N_1} = e^{-(\varepsilon_2 - \varepsilon_1)/kT}$$



meta stable energy state

⇒ N_2 must be greater than N_1 always.

⇒ Population inversion process.

$\Rightarrow N_2 >> N_1$

* photon density must be Φ.

* Relaxation time of energy is comparatively large.

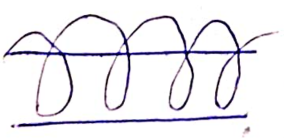
$\Rightarrow \tau \approx 10^{-4}$ sec

⇒ Meta stable energy state.

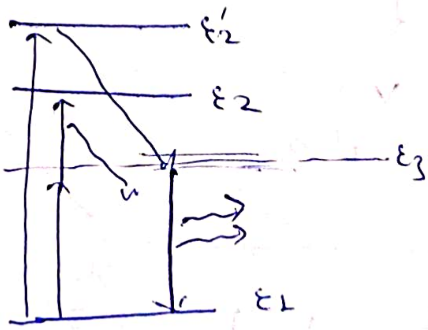
① . RUBY LASER :- (solid state laser)

$Al_2O_3 + 0.05\% \, Cr$ (blue & green range)

② He-Ne LASER :- (Gaseous state laser)



xenon



⇒ He-Ne Laser light :- GAS LASER

$\boxed{\text{He-Ne}}$

⇒ 10 : 01 (mix) ≈ kV

⇒ 6328 Å