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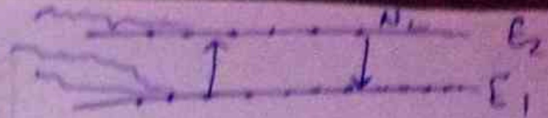
Lasers.

* Laser (Light Amplification by stimulated emission of Radiation)
* Chars of Laser.
1) Directionality is very high. laser is unidirectional light which emits radiation in one particular direction Used in LASIK to cure ratina of eye.
2) Extremely high intensity. Eg:- Nuclear exp. and welding
3) Laser lights are monochromatic
4) Highly Coherence having both temporal & spatial coherence
* Coherency :- Two waves are coherent, they have a phase diff which is constant over a time
1) Temporal or Longitudinal :- beam is said to be temp. if phase diff. of wave crossing 2 points say P & Q at any instant is constant
2) Spatial / Lateral / Transverse :- If the phase diff. of waves of 2 diff. points in a plane ⊥ to the direction of propagation is constant.

→ Applications of Laser.
Medical purp. Communication Material processing Militiary Purposes Nuclear rxns.

* Absorption :- It occurs when an atom / molecule absorbs a photon of light and gains energy. This causes e^- in the atom or molecule to Jum to a higher energy Level

Spontaneous	Stimulated.
1) Here atom deexcite to lower energy state naturally after ending its lifetime	Photon is required to induce a transition from higher energy level to lower energy level
2) In this process, higher energy level has smaller lifetime	2) Transition occurs b/w metastable higher energy level & lower energy level



3) Emitted photons are incoherent	3) Emitted photons are coherent
4) Prob. of sp emission doesn't depend on energy density of incident radiation.	4) Prob of ... depends on energy density of incident radiation
$\left(\frac{dN_2}{dt}\right)_{sp} = -A_{21}N_2$	$\left(\frac{dN_2}{dt}\right)_{st} = -W_{21}N_2$
Transition Probability $= A_{21}$	Trans. Prob $= B_{21}E(\nu)$

Abs: $\frac{dN_1}{dt} = -W_{12}N_1$ $\quad [W_{12} = \underset{\text{Einstein coefficient}}{B_{12}}F \rightarrow \text{flux.}]$

$$\frac{dN_1}{dt} = B_{12}E(\nu)$$

$$\rightarrow \underbrace{N_2[A_{21}+B_{21}E(\nu)]}_{\text{Emission}} = \underbrace{N_1[B_{12}E(\nu)]}_{\text{Abs}}$$

$$N_2A_{21} + N_2B_{21}E(\nu) = N_1B_{12}E(\nu)$$

$$N_2A_{21} = E(\nu)[N_1B_{12} - N_2B_{21}]$$

$$E(\nu) = \frac{N_2A_{21}}{N_1B_{12} - N_2B_{21}}$$

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

Acc. to Boltzmann eqn

$$N_1 = N_0e^{-\frac{E_1}{kT}}, \quad N_2 = N_0e^{-\frac{E_2}{kT}}$$

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

On comparin

$$E(\nu) = \frac{A_{21}}{B_{21}}\left(\frac{1}{e^{\frac{h\nu}{kT}}\left(\frac{B_{12}}{B_{21}}\right) - 1}\right)$$

On comparing Plank law of radiation

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

$$\boxed{\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}}, \quad \frac{B_{12}}{B_{21}} = 1, \quad \boxed{B_{12} = B_{21}}$$

* Population inversion
No. of atom per unit volume that occupy a given energy level is called its population.

$N_1 >> N_2$:- Abs > Emission.

$N_1 << N_2$:- Stimulated Emission > Absorption

$$\frac{N_1}{N_2} = e^{\frac{E_2 - E_1}{KT}}$$

$$\frac{N_2}{N_1} = e^{-\frac{(E_2 - E_1)}{KT}}$$

Temp:- (-ve) (-ve temp. state)

Pop. Inversion:- Condition in which there are more no. of particles in higher energy level as compared to lower energy level.

* Metastable state - There exist such excited states where atom can stay more than its life-time. These states are called meta-stable state.

$(10^{-3}$ sec to 10^{-6} sec$)$

For achieving lasing action, a metastable state is required. It is readily available when there is a impurity atom in a crystal.

* Active medium:- Medium where pop. inversion can be achieved. Eg:- Ruby, CO_2, Ne.

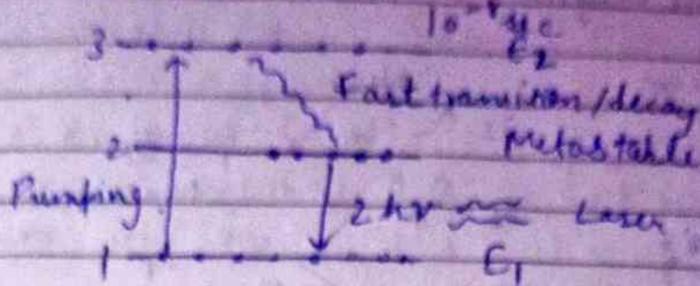
- Pumping:- Process of supplying energy to laser medium in order to achieve population inversion state in it

  Optical:- Flash Lamp, Laser diode

  Electrical pumping:- Electrical discharge.

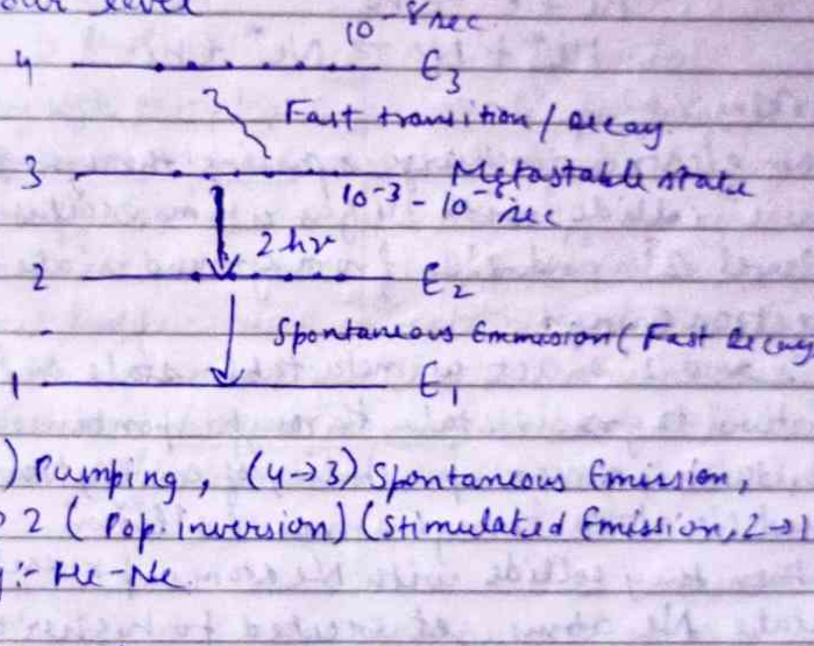
- Optical cavity:- It consists of 2 mirrors facing each other. One of mirror is fully reflective and other one is partially reflective. Used to stimulate more no. of atoms in active medium

* 3 level laser



$1 \to 3$ (Pumping), $(3 \to 2)$ Spontaneous,
Pop. inversion b/w 2 & 1, stimulated emission
Eg:- Ruby laser.
Laser is emitted b/w 2 & 1 by

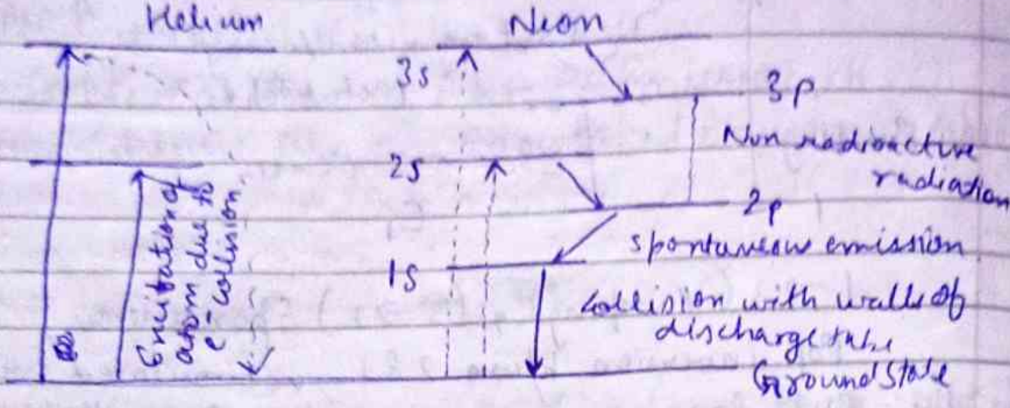
* Four level



(1-4) Pumping, $(4 \to 3)$ Spontaneous Emission,
$3 \to 2$ (Pop. inversion) (Stimulated Emission, $2 \to 1$ (Spontaneous emission
Eg:- He-Ne

* He-Ne laser
He-Ne gas used as active medium.
4 level laser
λ of radiation = 632.8 nm.
He : Ne = 10 : 1
Electric Discharge used for Pumping
He at 1 mm of Hg Ne at 0.1 mm of Hg

Energy level diagram.



$3s \to 3p = 3.39\,\mu m$, $3s \to 2p = 6328\,\mathring{A}$, $2s \to 2p = 1.15\,\mu m$

$$He + e^- \to He^*$$

$$He^* + Ne \to Ne^* + He$$

Working.

When electric discharge is passing through gas mixture, the e^- collide with He gas atoms excites into higher level 2^3s and 2^1s from ground state by absorbing electron energy

2^3s and 2^1s act as metastable state so He atom can't return to ground state through spontaneous emission. So, there is a max. possibility of energy transfer b/w He and Ne atoms through atomic collision.

When they collide with Ne atoms present at ground state Ne atoms get excited to higher energy level

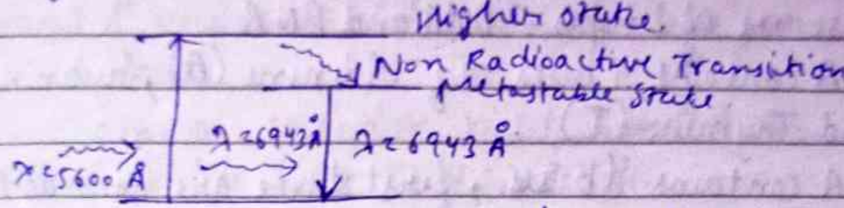
He atoms are used to pump ground state Ne atoms as He atoms are lighter in mass. Hence it is much more readily excited by e^- discharge than Ne-atoms

In e^- impact ex

* Ruby Laser

Solid-state laser, 3 level, Optical pumping, Works in Pulse mode.

Ruby crystal (Rod) ē $Al_2O_3 + Cr_2O_3$ mixed in such a way that 0.05 % Al^{3+} ions are separated by Cr^{3+} ions



Cr ions get excitation by absorbing 5600 Å of λ radiation

3 level	4 level
Very high pumping power is required	Small pumping power is required.
Low efficiency	high efficiency.
Operates in pulse mode. and happens as population inversion condition is required to achieve after some time.	Operates in continuous mode as atoms come back to ground state from intermediate state. go back to highly excite state for pumping & cycle goes on