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Unit-5

LASER

1. Characteristics of Laser light
2. Stimulated and spontaneous emmision.
3. Einstein's Coefficients.
4. Relative Contribution of stimulated and spontaneous Emmision.
5. Population inversion.
6. Laser emission.
7. Ruby Laser
8. He-Ne Laser.

LASER :- Light Amplification by Stimulated Emission of Radiation.

It is a process by which we get a highly intense, monochromatic, unidirectional and highly coherent beam of light.

Population :- The number of atoms per unit volume that occupy a given energy level is called population.

let E_1 = Ground level
E_2 = exicted level.
population at E_1 = N_1
population at E_2 = N_2

by boltzmann law -

$$N_1 = e^{-E_1/kT}$$
$$N_2 = e^{-E_2/kT}$$

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

For Hydrogen atom :- monoatomic,

(i) at $T = 300K$, $N_2 \approx 0$
(ii) at $T = 6000K$, $N_2 = 4$ & $N_1 = 10^{10}$ atoms

☆ $N_1 >> N_2 \Rightarrow$ Normal distribution

(iii) at $T = \infty \Rightarrow \boxed{N_2 = N_1}$

Spontaneous Emission :- In this process, the atom in excited state emits radiation even in absence of any incident radiation.

$$A^* \longrightarrow A + \underbrace{h\nu}_{\text{energy of radiation}}$$

Rate of spontaneous transition -

$$R_{sp} = A_{21} N_2$$

where A_{21} = Einstein Coefficient for spontaneous emission.

Properties of spontaneous Emission :-

(1) The photons emitted from various atom have no phase relationship between spontaneous emission them.

(2) The emitted radiation is incoherent.

(3) Emitted photons can move in any direction.

(4) It doesnot produce laser action.

Stimulated Emission :- In this process, an incident signal of appropriate frequency triggers atom in excited state to emit radiation.

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

Rate of stimulated emission of photon is given by -

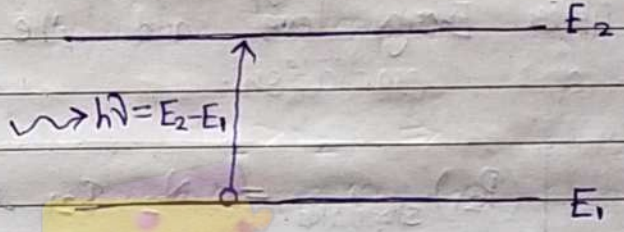
$$\boxed{R_{st} = B_{21} e(\nu) N_2}$$

B_{21} = Einstein Coefficient for stimulated emission

Properties of stimulated emission :-

1. The emitted photons have same frequency and are in same phase.
2. Emitted radiations are Coherent
3. The incident photons and outgoing photons travel in same direction.
4. It produce Laser action.

Absorption :- when a photon of light having energy $h\nu = (E_2 - E_1)$ is incident on an atom into lower energy state, the atom in ground state E_1 may absorb the photon and jump to higher energy state. This process is called stimulated absorption.



Einstein's Coefficient of spontaneous emission :-

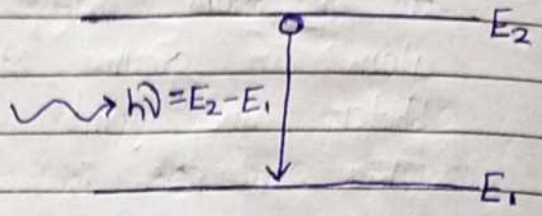
(1) Probability of spontaneous emission ② → ① is independent of energy density of radiation field and depend only the properties of states involved in the transition,

$$P_{21} = N_2 A_{21}$$

A_{21} = einstein coefficient of spontaneous emission.

Einstein's Coefficient of stimulated emission :-

The probability of stimulated emission transition is directly proportional to the number of atoms, upper Energy level and the energy density of radiation.



$$(P_{21})_{stimulated} = N_2 B_{21} e(\nu)$$

B_{21} = einstein's Coefficient of SE.
N_2 = no. of atom in excited state.
$e(\nu)$ = energy density of incident radiation.

Relation between A_{21} and B_{21} :-

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

At thermal equilibrium, the probability of spontaneous emission is more than stimulated emission and increase rapidly with the energy difference between the two states.

Population Inversion :-

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

The situation in which no. of atom in higher energy state is greater than lower energy state is called population inversion.

At this condition, $(N_2 > N_1) \Rightarrow$ stimulated emission is dominated over the spontaneous emission and Laser started lasing.

☆ Thus Laser action takes place only if system have more than 2 energy levels.

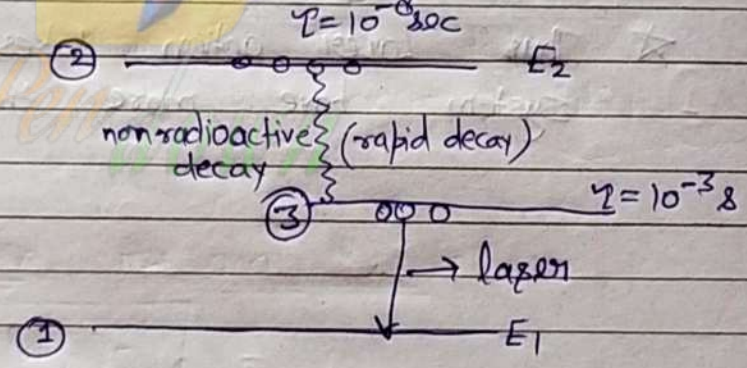
Conditions for achieving laser action -

(1) Rate of emission > rate of absorption.

(2) Probability of spontaneous emission must be negligible in comparision to the probability of stimulated emission.

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

(4) Population inversion cannot be achieved in two levels laser.



★ (3) is metastable energy state.