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Unit : 03

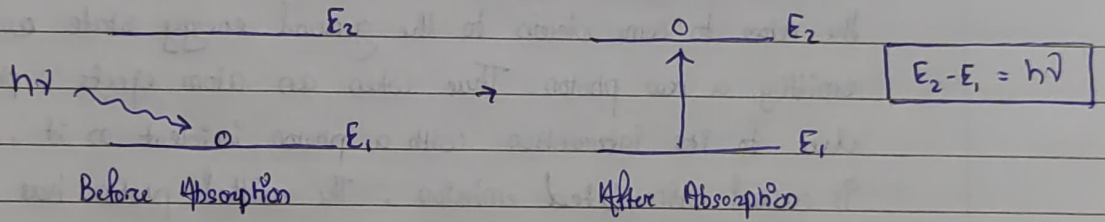
LASER

Basic Principle : Light Amplification by Stimulated Emission of Radiation

Three basic processes for LASER action :-

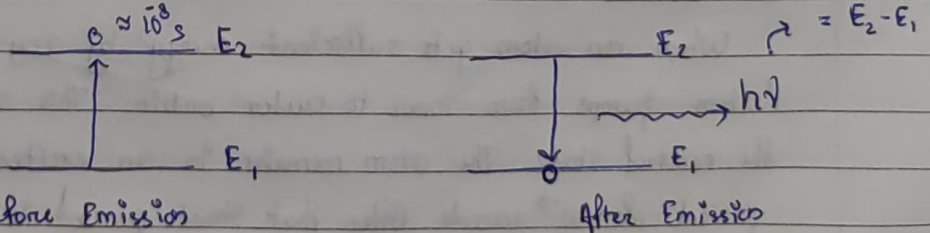
→ Absorption & Radiation
→ Spontaneous Emmission
→ Stimulated Emission

- Absorption of Radiation :-



When the photon of light having energy $h\nu (= E_2 - E_1)$ is incident on the atom in the lower energy state, the atom in the ground state ever may absorb the photon and jump to the higher energy state E_2. This process is called absorption of photon or stimulated absorption of radiation

- Spontaneous Emission :-



The atom in excited state automatically decays to the ground state by emitting a photon of energy $h\nu = E_2 - E_1$. This process is known as spontaneous emi of radiation. The spontaneous

emission has following characteristics :

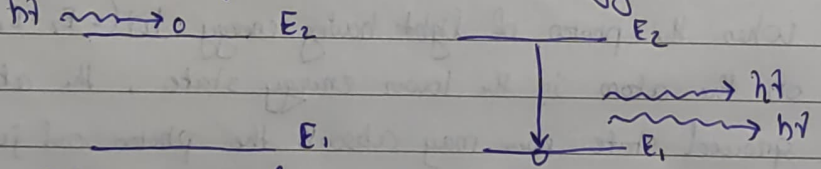
① The emitted photon of energy ($h\nu$) can move in any random direction

② There is no phase relationship b/w the photons emitted from various atoms and systems.

③ The radiation coming out in spontaneous emission are incoherent.

- **Stimulated Emission :**

Suppose the atom is in excited energy state (E_2) and a photon of energy exactly equal to $E_2 - E_1$ is incident on it. The incident atom interacts with the atom then it ~~induces~~ induces the atom to come down to the ground energy state even by emitting a new photon. Thus when an atom ejects a photon due to its interaction with a photon incident on it, the process is called stimulated emission. The emitted photon has exactly the same phase direction and energy as the incident photon.



- **Meta Stable State :-**

When an atom gets sufficient energy by any means its electron / atom jumps from inner to outer orbit. This state of atom is called the excited state. The atom remains in an excited state for a period of 10^{-8} seconds. After that short period it comes back to the ground state by releasing excess energy spontaneously. For stimulated emission the atom should remain for a longer time. As the atoms are continously going to excited state by pumping process they should in the higher energy state until the population

in the higher energy state (N_2) becomes greater than that in lower state (N_1) i.e. ($N_2 > N_1$). Long lived energy state (10^{-3} s) from which the excited atom do not return to the level spontaneously is called meta stable state.

- **Population Inversion :-**

  According to Maxwell - Boltzman distribution law, the no. of atom in energy states E_1 and E_2 are gives by $N_1 = N_0 e^{-E_1/kt}$ and $N_2 = N_0 e^{-E_2/kt}$ where N_0 is the no. of atoms at temp T in thermal eq^n. For population inversion $N_2 > N_1$

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

→ population ratio formula

* $E_2 - E_1$ ki value give hoga

* K is boltz constant

Pumping :-

(i) optical pumping → light energy
(ii) Electric pumping →
(iii) Chemical pumping →

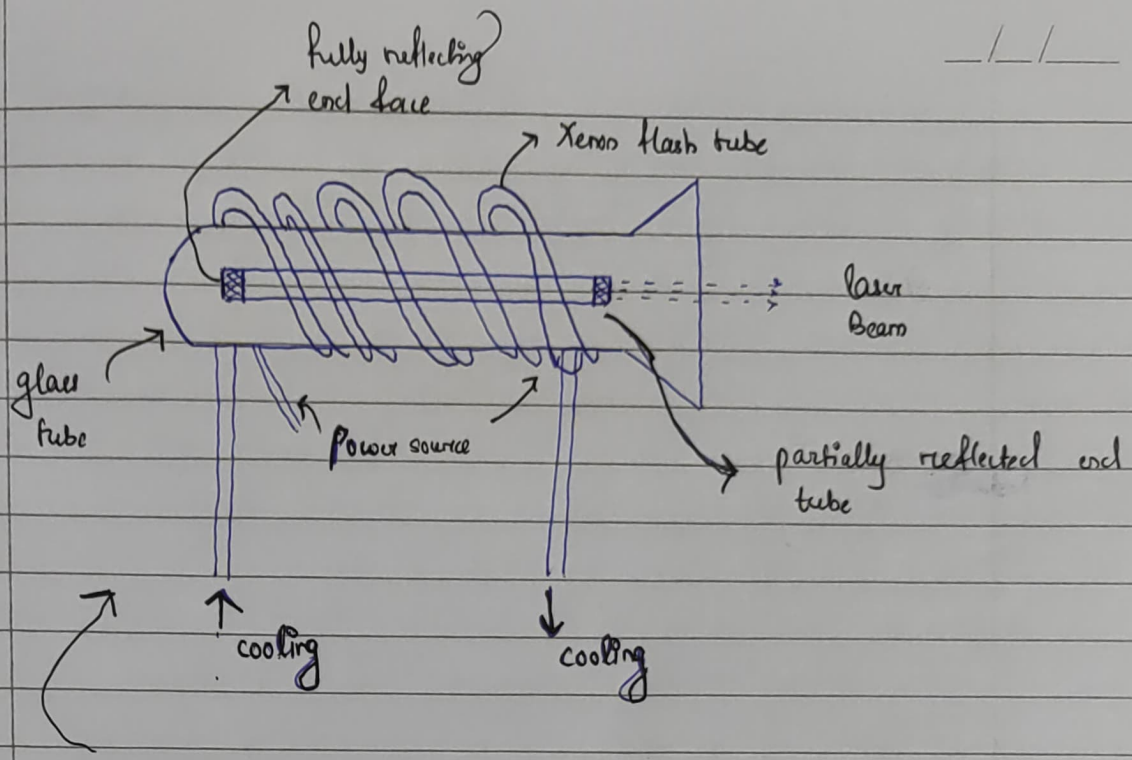
- Components for laser action :

(i) Active medium →
(ii) Population inversion
(iii) Pumping

A system in which population inversion is to be achieved is called an active medium/system

The method of raising the molecules or atoms from lower energy state to higher energy state is called pumping.

A state in which the no. of atoms in higher energy state is greater than that in lower energy state is called population inversion



Ruby Laser (Solid state laser) :-

A solid laser can be made by introducing impurity atoms into a crystal. Ruby was the first solid material which was used in the production of laser. The Ruby laser was first developed in 1960. It consists of a single crystal of a pink ruby (Al_2O_3) doped with 0.05 % Chromium ions (Cr^{+3}). The crystal is in the form of a cylindrical rod with opposite ends flat and parallel. [One end is fully silvered and the other is partially silvered] so as to reflect part of the light incident normally on them and transmit rest part of it. The ruby rod is surrounded by a helical Xenon flash tube which provides the pumping light to raise the chromium ions to upper energy level. In the xenon flash tube each flash lasts several milliseconds and in each flash a few thousand Joules of energy consumed. Only a small part of this energy is used in pumping chromium ions while the rest is wasted by heating up the apparatus / ~~sys~~ system

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Construction & working principal :

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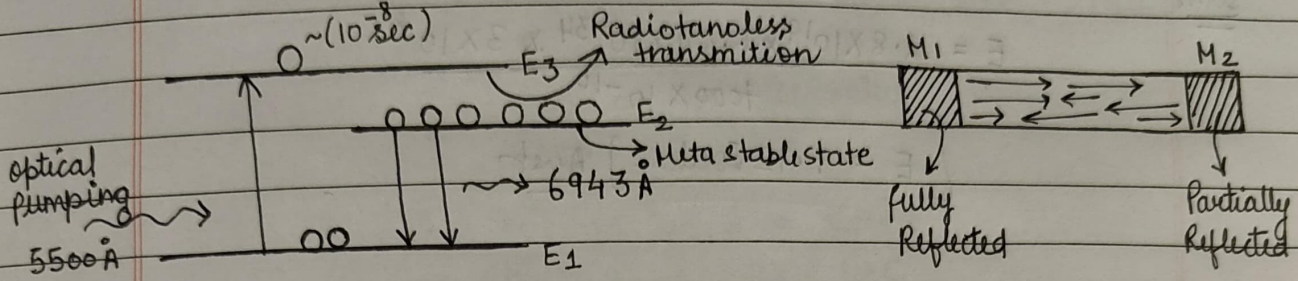
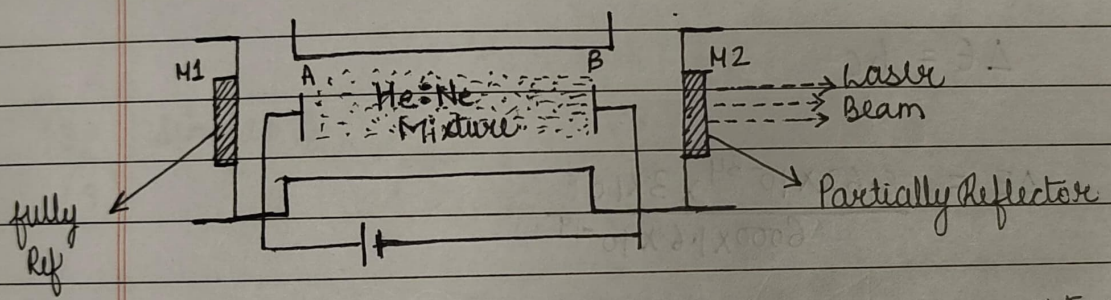
In Ruby laser 'Cr' atoms are the active atoms which absorbs energy in broadbands in In green and yellow. The solid state ruby laser is also called pulse laser or 3-level laser. In normal state most of the chromium atom are in ground state E_1 when the Ruby rod is flashed with Xenon lamp a 550 Å radiation photon are absorbed by the chromium ion which are pumped to the excited state E_3. Since the state E_2 is the meta stable state. The number of ions in this state goes on increasing while due to optical pumping the number of chromium ion in the ground state are decreasing. Thus the population inversion is achieved between E_2 and E_1. When an excited ion from the meta stable state drop down from state E_2 to E_1 it emits a photon of 6.93 Å. This photon travels throught the ruby rod and is reflected back and forth by the silver ends until a stimulates other

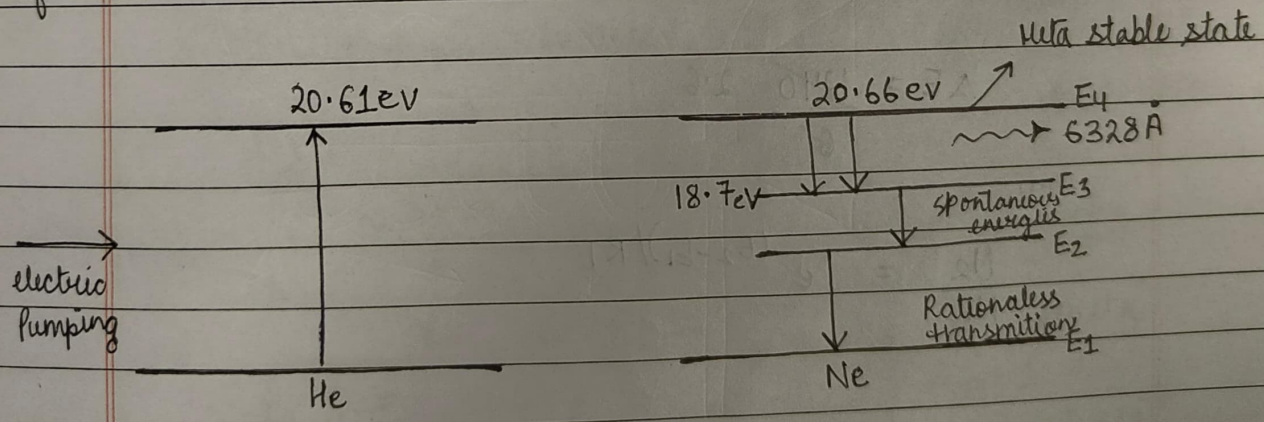
excited ions and causes it to emit a fresh photon in say with the stimulated photons.

▸ Energy Level Daigram :-



He-Ne laser : He : Ne = 7 : 1





There is no cailing required. It is contenious laser.

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Q1. In a Ruby laser Total numbers of chromium ions is 2.08×10^{19}, if the laser emitted the radiation of an wave length 7000 Å. Calculate the energy of the laser pulse?

Soln:

$$E = nh\nu$$

$$E = \frac{2.8 \times 10^{19} \times 6.62 \times 10^{-34} \times 3 \times 10^{8}}{7000 \times 10^{-10}}$$

$[E = 7.92 \text{ Joules.}]$ Ans

Q2. Calculate the population ratio of two states in helium - neon laser that produces light of wavelength 6000 Å at 300 K?

Soln:

$$\Delta E = \frac{hc}{\lambda}$$

$$\Delta E = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 1.6 \times 10^{-19}}$$

$$\Delta E = \frac{1240}{6} \; 2.6$$

now,

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

$\frac{314}{2.2}$
1.28