LASER

The word LASER stands for Light Amplification by Stimulated Emission of Radiation. It is a process by which we can get an intense beam of light which is monochromatic, coharent and almost perfectly parallel.

(i) Induced Absorption:

If an atom is in a lower state (or ground state), it can be raised to higher energy state (or excited state) by absorbing a photon of suitable energy. This process is called induced absorption.

(ii) Spontaneous Emission:

Spontaneous emission is the process of emission of radiation by an excited atom during its return to ground state from an excited state without any external aid.

(iii) Stimulated Emission:

Stimulated emission is the process of emission of radiation by an excited atom during its return to ground state from an excited state when a photon of suitable frequency (energy) is incident upon it. In stimulated emission the incident photon and emitted photon are coharent.

(iv) Life Time:

The time during which an atom remains in any excited state is called its life time. It is of about $10^{-8}s$.

(v) Metastable State:

Metastable state is an excited state for which life time is about $10^{-3}s$ (i.e., 10^{5} times longer than any excited state).

(vi) Pumping:

The process of obtaining state of population inversion is called pumping. Generally pumping is of two types:

(a) Optical pumping.

(b) Electrical Pumping.

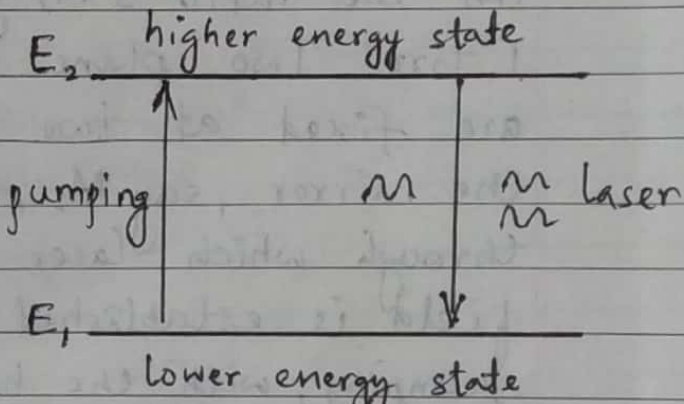
(vii) Population Inversion:

Population inversion is a condition at which number of atoms in higher energy state is greater than that in the lower energy state.

(vii) Active Medium:

For the absorption of light by stimulated emission process a medium is required called active medium. An active medium may be a solid, liquid or gas.

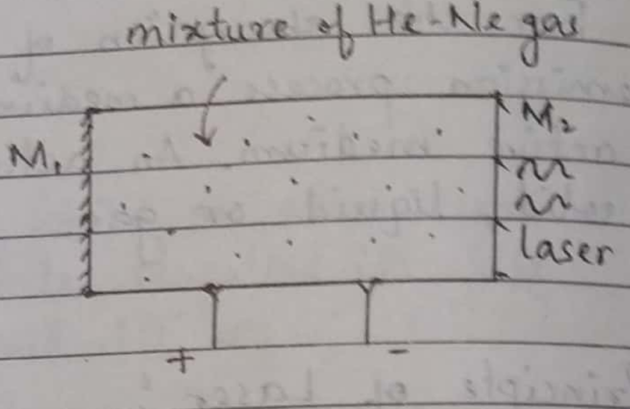
Principle of Laser:



Consider a metastable state of an atom having higher state energy E_2 and ground state energy E_1. By any process population inversion is achieved between ground state and metastable state (or higher energy state).

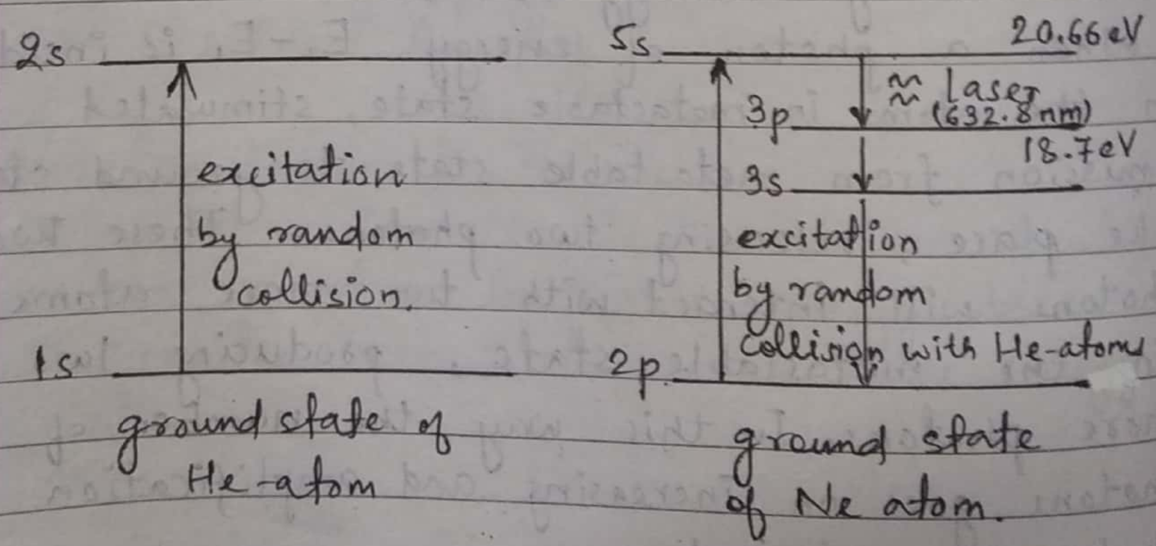
When a photon of energy $E_2 - E_1$ is incident on the atoms in metastable state, stimulated emission from metastable state to ground state take place, releasing two photons. These two photons will interact with two more atoms in the metastable state, producing two more photons. In this way the number of photons goes on increasing and amplification of photon is obtained.

He-Ne Laser



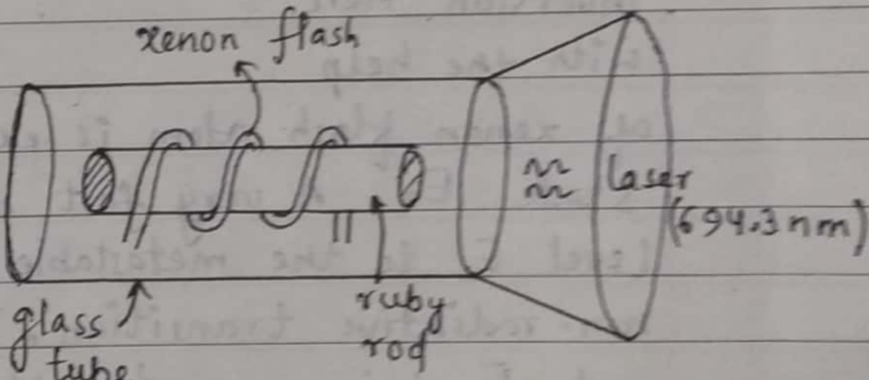
It is a gas laser. It consists of a cylindrical tube containing a mixture of He and Ne (in the ratio 5:1) gas at pressure of about 1 torr. Two plane mirrors M_1 and M_2 are fixed at two ends of the tube, one of the mirror, say M_2, is partially transmitting, through which laser will come out. A electric field is established inside the tube, for pumping, with the help of two electrodes.

Working:



When electric field is applied across the tube, some of the atoms get ionized. These ions collide with the He atoms in ground state and rise it to metastable state (2S). The He atom in metastable state collides with Ne atom in ground state and rise it to excited state (5s) but itself returns to ground state. This process continues state of population inversion is obtained between energy levels 5s and 3p of Ne atom. Therefore, stimulated emission will take place in Ne atom when light is incident upon it and laser of wavelength 832.8 nm is obtained.

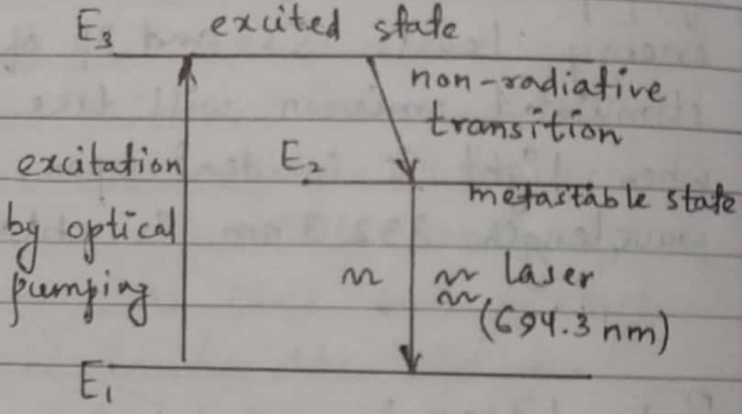
Ruby Laser:



Ruby is a crystal of Al_2O_3 (corandum) in which some of the Al^{3+} ions are replaced by Cr^{3+} ions. Ruby rod are normally made of pink ruby, which contains 0.05% chromium. The aluminium and oxygen atoms of ruby crystal are inert. The chromium ions are active centers.

Ruby Laser consists of cylindrical rod of ruby in a cylinderical glass tube. One end of ruby rod is fully reflecting and other end is partially transmitting from where the laser will come out. A xenon flash (550nm) surrounding ruby rod is used for optical pumping, as shown in fig.

Working:

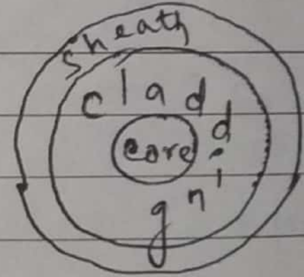


Ruby laser use the three level scheme of population inversion. Here with the help of xenon flash atom is excited to one of excited state E_3. A very fast decay follows from level E_3 to the metastable state E_2. This is non-radiative transition. This process continues and E_2 being a metastable state soon a state of population inversion is attained between metastable state E_2 and energy level E_1. When a photon of energy $E_2 - E_1$ is incident stimulated emission takes place and laser is produced.

Optical Fiber

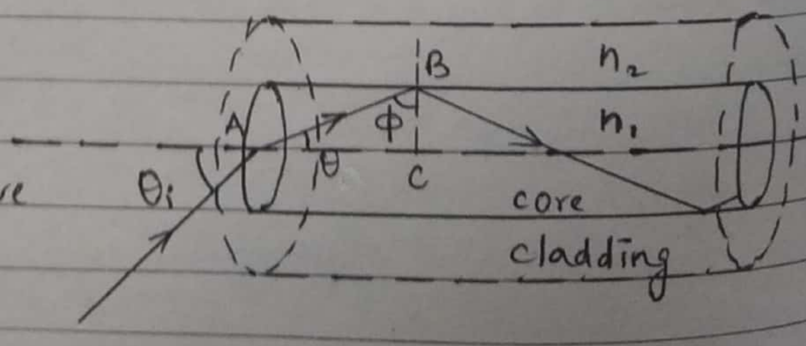
An optical fiber is a very thin (diameter of about 125 μm) transparent fiber, made of glass or plastic, used to guide light wave along its length. The core is typically made of silica doped with impurities to increase its refractive index. The cladding is made by pure silica and has lower refractive index than core. The transmission of light in the optical fiber is based on the principle of total internal reflection.

An optical fiber consists of three co-axial regions:
(i) core
(ii) cladding
(iii) sheath.



Critical Angle of propogation:

Consider an optical fiber having refractive indices of core and



cladding as n_1 and n_2 respectively such that $n_1 > n_2$. Let us incident a ray of light at one end of the optical fiber making an angle θ_1 with the axis. This end at which the light enters the fiber is called launching end. If the refracted ray when incident on the core cladding interface makes an angle (angle of incidence) equal to the critical angle then the ray is called critical ray.

If ϕ_c is the critical angle for the core-cladding interface then

$$\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) \text{ ——— } (1)$$

A ray incident with an angle larger than ϕ_c will be confined to the fiber and propogate in the fiber. The critical ray makes an angle θ_c with the axis of the fiber. This angle θ_c is called critical angle of propogation.

In ΔABC,

$$\frac{AC}{AB} = \cos\theta_c \text{ ——— } (2)$$

and $\frac{AC}{AB} = \sin\phi_c \Rightarrow \frac{AC}{AB} = \frac{n_2}{n_1}$ ——— (3)

$\therefore$ from eq^n (2) and (3),

$$\cos\theta_c = \frac{n_2}{n_1}$$

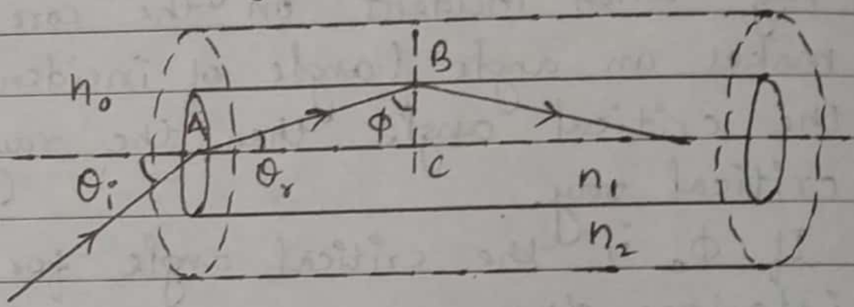
$$\Rightarrow \quad \theta_c = \cos^{-1}\left(\frac{n_2}{n_1}\right) \text{ ——— } (4)$$

Scanned with CamScanner

Acceptance Angle

The minimum angle of incidence that a light ray can have relative to the axis of the fiber so that it propogate down the fiber.

Let n_1 and n_2 be the refractive index of core and cladding respectively such that $n_1 > n_2$. Let n_0 be the refractive index of the medium from which light is launched into the fiber. Consider that light ray enters the fiber at an angle θ_i and gets refracted θ_r. Let this refracted ray strikes the core-cladding interface making an angle ϕ. As long as the angle ϕ is greater than ϕ_c, the light will stay within the fiber.



Applying Snell's law at the launching face,

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_1}{n_0} \quad \text{——— (1)}$$

From ΔABC,

$$\sin\theta_r = \sin(90^\circ - \phi)$$

$$\Rightarrow \sin\theta_r = \cos\phi \quad \text{——— (2)}$$

from eq. (1) and (2), we get,

$$\frac{\sin\theta_i}{\cos\phi} = \frac{n_1}{n_0}$$

$$\Rightarrow \sin\theta_i = \frac{n_1}{n_0}\cos\phi$$

If θ_i is increased beyond a limit, ϕ will drop below the critical value ϕ_c and ray escapes from side wall of the fiber. The largest value of θ_i occurs when $\phi = \phi_c$.

When $\phi = \phi_c$, $\theta_i = \theta_0$ (acceptance angle)

$$\therefore \sin(\theta_0) = \frac{n_1}{n_0}\cos\phi_c \quad \text{--- (3)}$$

We have,

$$\sin\phi_c = \frac{n_2}{n_1}$$

$$\Rightarrow \cos\phi_c = \frac{\sqrt{n_1^2 - n_2^2}}{n_1} \quad \text{--- (4)}$$

from eq. (3) and (4), we get,

$$\sin(\theta_0) = \frac{n_1}{n_0} \cdot \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$$

$$\Rightarrow \sin(\theta_0) = \frac{\sqrt{n_1^2 - n_2^2}}{n_0} \quad \text{--- (5)}$$

Generally, the incident ray is launched from the air, for which $n_0 = 1$.

$$\therefore \sin\theta_0 = \sqrt{n_1^2 - n_2^2}$$

$$\Rightarrow \theta_0 = \sin^{-1}\sqrt{n_1^2 - n_2^2} \quad \text{--- (6)}$$