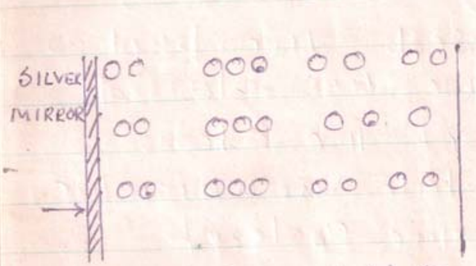
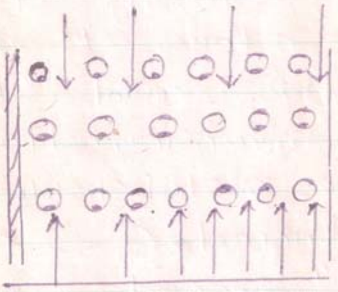
Exciting a Laser material by optical pumping and cavity resonance :- - - -

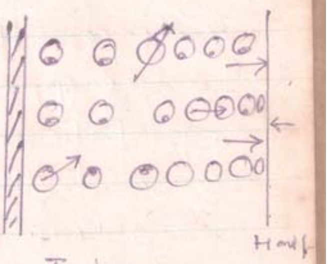
Operation of a Laser :



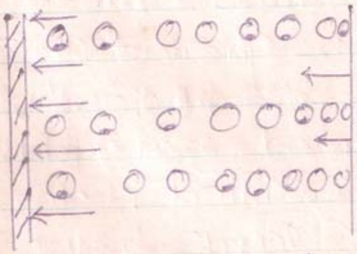
Normal ground state



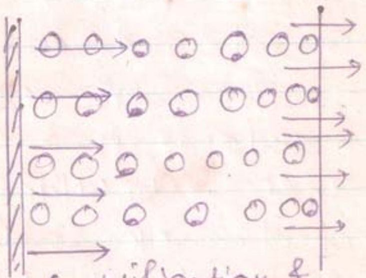
Excited to Population Inversion by Optical Pumping.



Trigger actions by Spontaneous emission.



Stimulated emission by photons reflected back and forth.

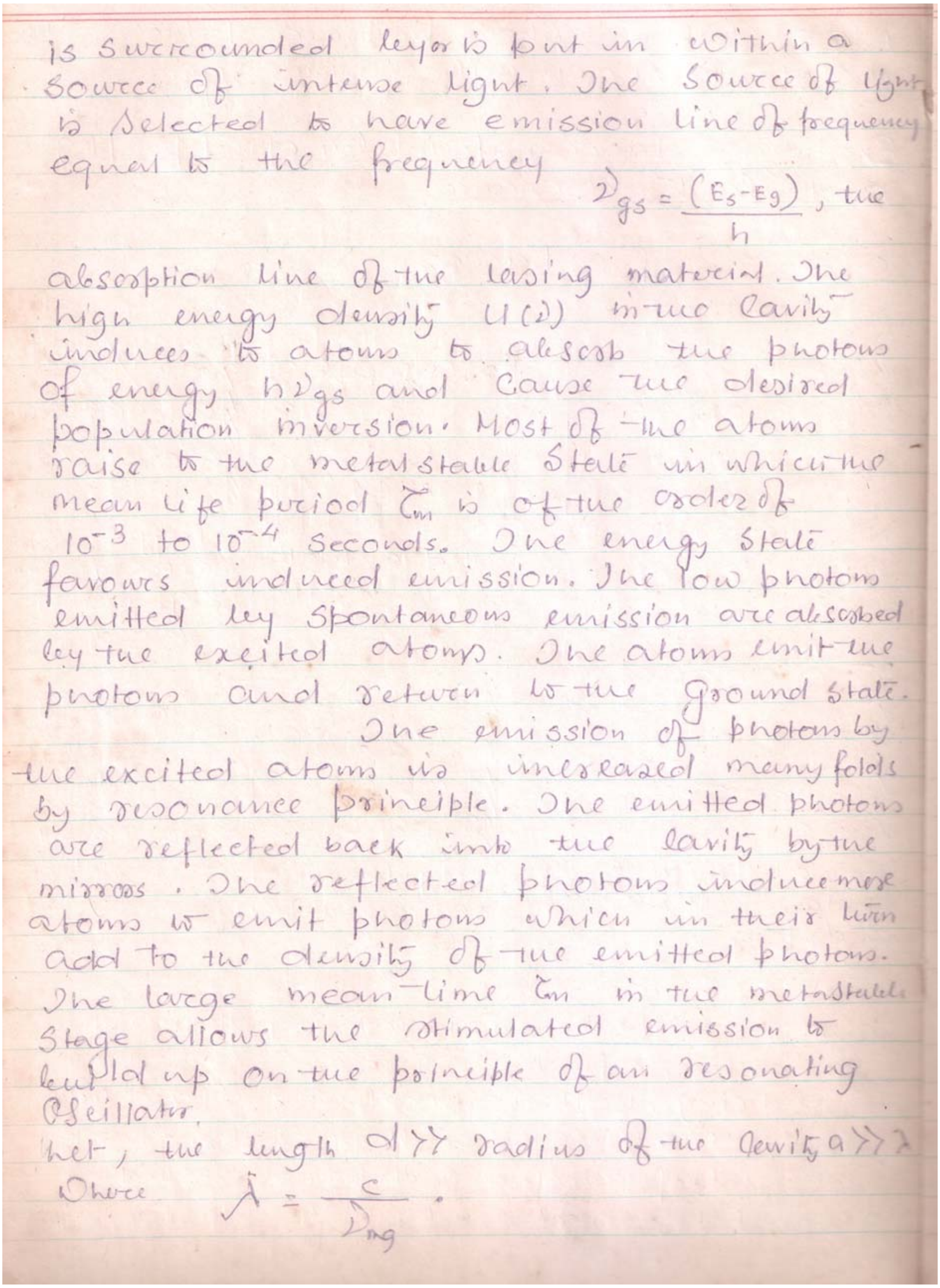


Amplification & emission of Laser beam.

○ ground State of atom

● excited State of atom.

Cavity: The lasing material is put in between two reflecting mirrors. One of them being half silvered. The Space between the mirrors resembles a Febry-Perot Interferometer and hence is called Febry-Perot Cavity. The lasing material



is surrounded layer is put in within a source of intense light. The source of light is selected to have emission line of frequency equal to the frequency

$$\nu_{gs} = \frac{(E_s - E_g)}{h}, \text{ the}$$

absorption line of the lasing material. The high energy density $u(\nu)$ in the cavity induces to atoms to absorb the photons of energy $h\nu_{gs}$ and cause the desired population inversion. Most of the atoms raise to the metal stable state in which the mean life period τ_m is of the order of 10^{-3} to 10^{-4} seconds. The energy state favours induced emission. The low photons emitted by spontaneous emission are absorbed by the excited atoms. The atoms emit the photons and return to the ground state.

The emission of photons by the excited atoms is increased many folds by resonance principle. The emitted photons are reflected back into the cavity by the mirrors. The reflected photons induce more atoms to emit photons which in their turn add to the density of the emitted photons. The large mean time τ_m in the metastable stage allows the stimulated emission to build up on the principle of an resonating oscillator.

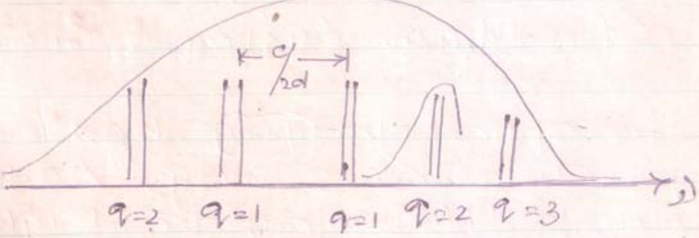
Let, the length $d \gg$ radius of the cavity $a \gg \lambda$

Where $\lambda = \frac{c}{\nu_{mg}}$.

The radiation travel to and fro between the mirrors many thousand times. They interfere constructively if

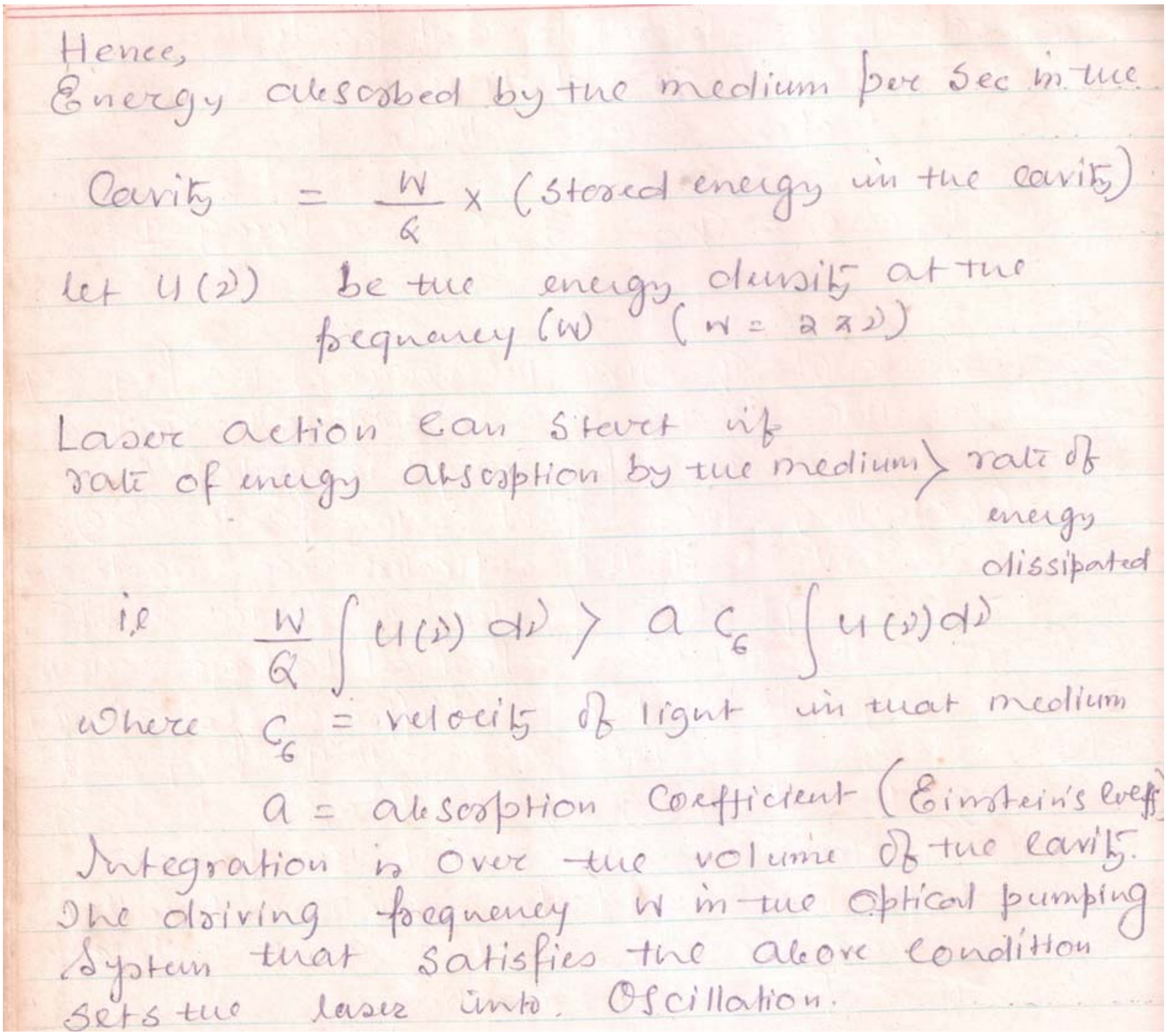
$$2d\cos\theta = q\lambda = q\frac{c}{\nu_{mg}} \quad \text{where } q = 1, 2, 3 \ldots$$

Each value of q gives the value of the frequency for which the cavity can resonate. The gap between successive frequency (resonating) is $\frac{c}{2d}$. (neglecting the effect of the factor $\cos\theta$). The cavity and the reflectors are so designed that the quality factor Q of the cavity is large only at the desired laser emission. The energy loss due to diffraction, scattering etc. is large at other resonating frequencies making the damping quite large. The large quality factor Q ensures that the power gained from stimulated emission induced by the energy density in the cavity is larger than the power dissipation.



In a resonant cavity oscillating with an angular frequency w, the quality factor Q is given by

$$Q = \frac{\text{Energy stored in the frequency mode}}{\text{Energy absorbed by the medium per second, in the frequency mode.}}$$



Hence,
Energy absorbed by the medium per sec in the

Cavity = $\frac{w}{Q}$ × (stored energy in the cavity)

let $u(\nu)$ be the energy density at the frequency (w) ($w = 2\pi\nu$)

Laser action can start if
rate of energy absorption by the medium > rate of energy dissipated

i.e $$\frac{w}{Q}\int u(\nu)\,d\nu > a\,c_6 \int u(\nu)\,d\nu$$

where c_6 = velocity of light in that medium

a = absorption coefficient (Einstein's coeff)

Integration is over the volume of the cavity.
The driving frequency w in the optical pumping system that satisfies the above condition sets the laser into oscillation.