Module III - Lasers & Fiber optics

Laser stands for Light Amplification by Stimulated Emission of Radiation.

A Laser is a device that can produce a very narrow intense beam of monochromatic coherent light.

characteristics :

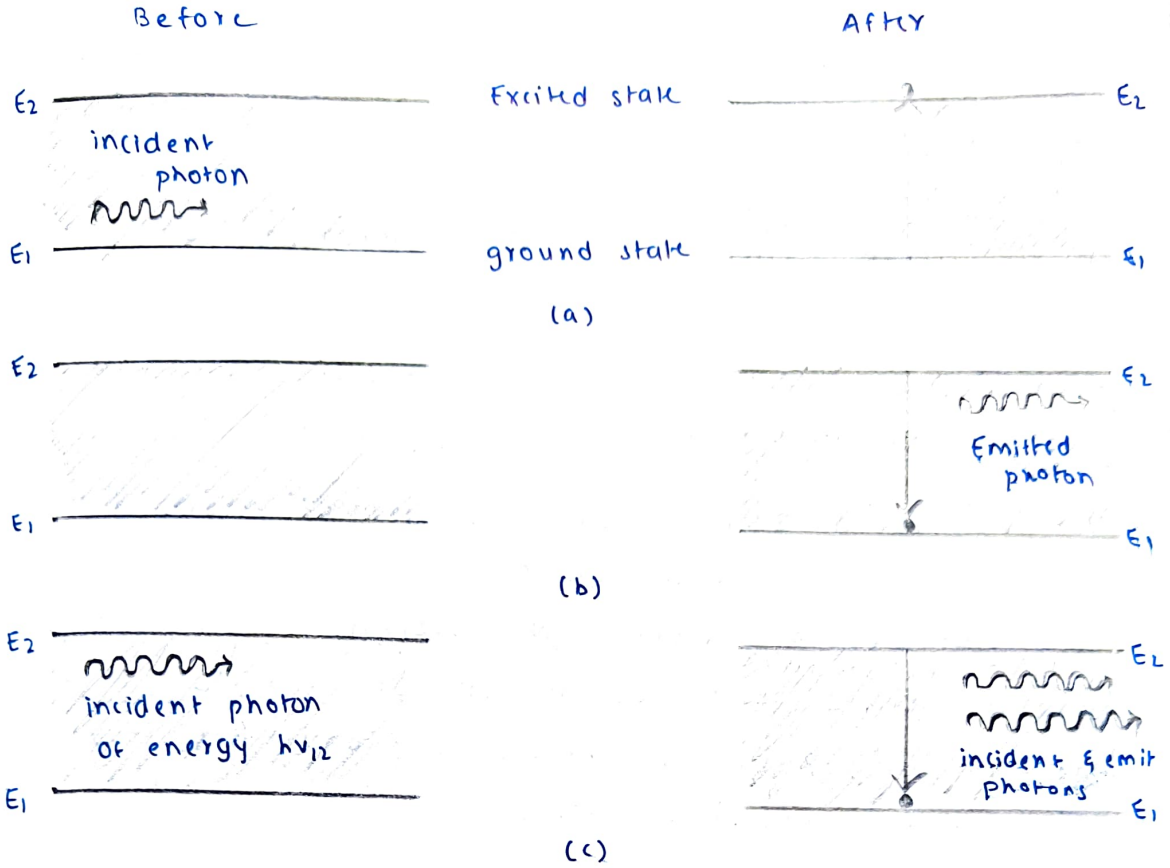
- High monochromaticity
- High Directional
- High intensity
- Highly coherent

Spatial coherence : If two lights fields at different points in space maintain constant phase difference over any time t, then they are said to have spatial coherence. The distance up to which same phase or constant phase difference is maintained is coherence length.

Temporal coherence : refers to the correlation of phase between the light fields, at a point over a period of time.

Transitions :

- Absorption
- Spontaneous emission
- Stimulative emission



	Spontaneous Emission	Stimulated Emission
1.	Spontaneous emission takes place when excited atoms make a transition to lower energy level voluntarily without any external stimulation.	Stimulate emission takes place when a photon of energy equal to $h\nu_{12} = (E_2 - E_1)$ stimulates an excited atom transition to lower energy.
2.	Polychromatic radiation.	Monochromatic radiation.
3.	Less Intensity	High intensity
4.	Less directionality, more angular spread during propagation.	High directionality, so less angular spread during propagation
5.	Spatially and temporarily incoherent radiation.	Spatially and temporarily coherent radiation.
6.	Eg: Light from ordinary source	Eg: Light from a Laser.

Meta stable state : The excited states which have a relatively long lifetime due to solwo radioactive and non-radioactive decay are called meta stable states. The life time of such a state is 10^{-6} to 10^{-3} seconds.

* Population Inversion :

Usually in a system, the number of atoms (N_1) present in ground state (E_1) is larger than the number of atoms (N_2) present in the higher energy state (E_2). The process of making $N_2 > N_1$ is called population inversion. Conditions for population inversion are :

- The system should posels atleast a pair of energy levels ($E_2 > E_1$) sperated by an energy equal to the energy of a photon ($h\nu$).
- There should be a continuous supply of energy to the system ~~act~~ such that the atoms must be raised continuously to the excited state.

There could be no population inversion and hence no laser action, if metastable states didn't exist.

* Pumping :

For maintaining a state of population inversion atoms have to be raised continuously to excited state. It requires energy to be supplied to the system. The process of supplying energy to the medium with a view to transfer it into the state of population inversion is known as pumping. Simply, the process of attaining population inversion is called pumping.

Commonly used pumping types are:

- optical pumping - Exposure to EM radiation.
- Electric discharge
- Atom collision
- Direct conversion
- Chemical reactions
- Injection current.

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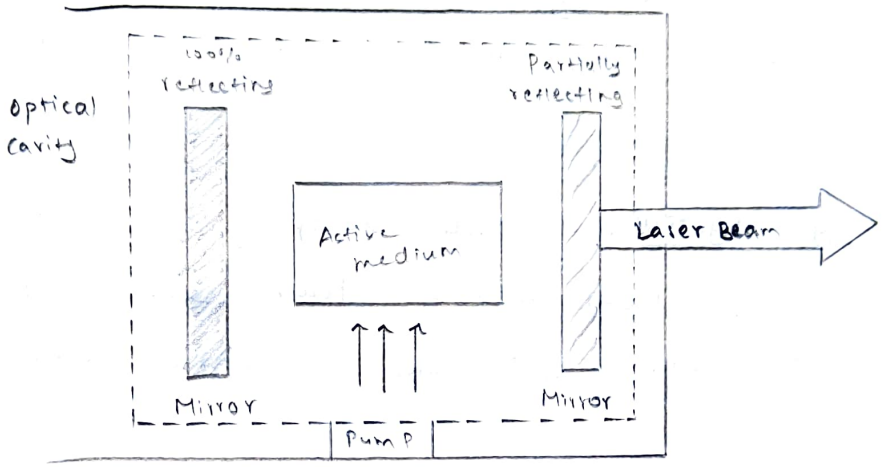
* Components of LASER:



* Different types of LASERs :

- solid LASER - Ruby Laser, Nd:YAG laser.
- Gas LASER - He-Ne, CO_2, laser, Arg-ion laser.
- Liquid LASER - Europium chelate laser, $SeOCl_2$ laser
- Dye LASER - Rhodamine 6G Dye laser, Courmarin Dye Laser.
- Semiconductor laser - InP laser, GaAs laser.

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* Ruby Laser

Active material: Ruby crystal in the form of a rod $[Al_2O_3] + [Cr_2O_3]$

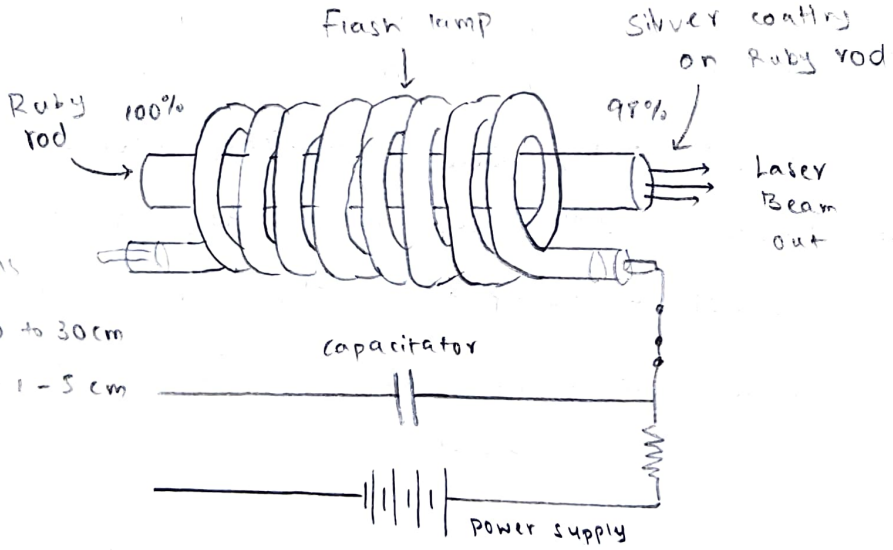
- **Resonating cavity**: A fully reflecting surface at the left end of the ruby crystal and partially reflecting end at the right side of the ruby crystal are to be arranged.

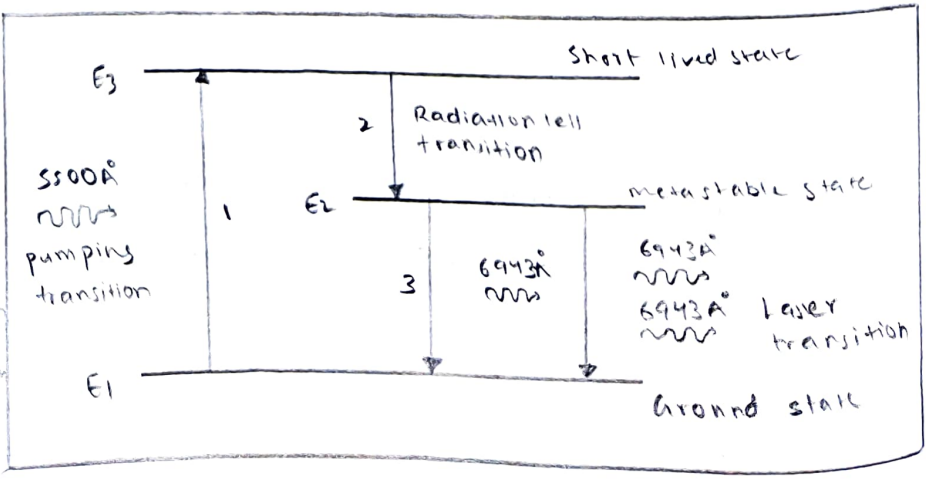
For this, both the ends of the ruby rod are highly polished and painted with silver such that one end is fully reflecting and the other end is partially reflecting. Both the reflecting surfaces are optically flat and are exactly parallel to each other.

- **pumping system**: Optical pumping.

For this, a helical xenon flash lamp with a power supply to pump Cr^{+3} ions to higher levels is used.

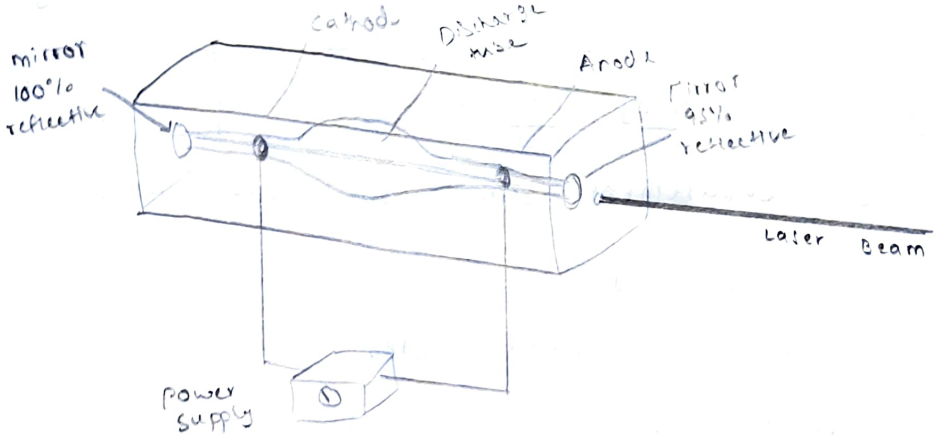
$Al_2O_3 + Cr_2O_3$



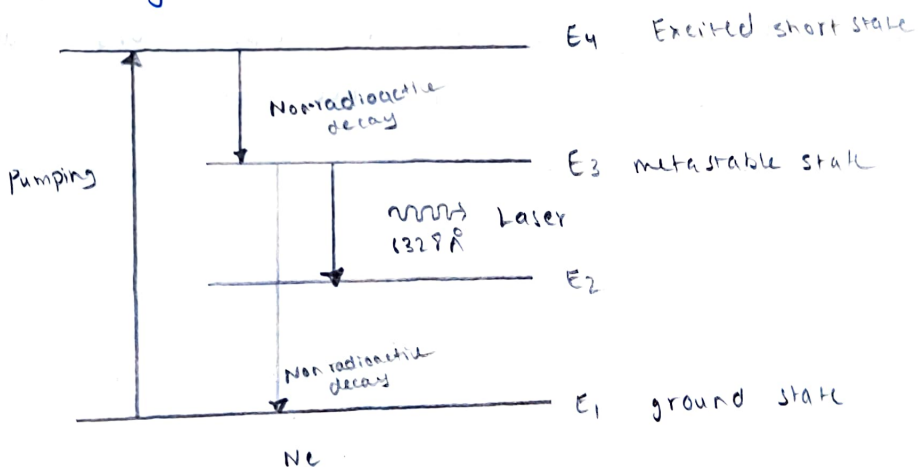


* He-Ne Laser

- Active material - He, Ne in the ration {He- 1 mm of Hg, Ne- 0.1 mm of Hg}.
- Resonating cavity: One will have two mirrors at ends of discharge tube which are at Brewster's angle ($R\bar{I} = \tan\theta$).
- pumping system: Electrical discharge.



Energy level diagram of He-Ne Laser.



Ruby Laser is a pulse laser whereas He-Ne laser is a continuous wave laser.

Laser action involves five steps:-

- pumping
- Population inversion
- Spontaneous emission
- Amplification
- Oscillations

Applications of He-Ne laser:

- very widely used laboratories for all interferometric experiments.
- Used in metrology in surveying, measuring etc.
- He-Ne scanners have also been used for optical character recognition
- Used in 3D recording of objects, called holography.

Applications of Ruby Laser:

- Distance measurement using pulse echo technique
- Pulsed holography.
- For drilling high quality holes.
- In military, used as target designators and range finders.
- Used in general research applications such as plasma production and fluorescence spectroscopy