Laser

LASER stands for Light amplification by stimulated emission of radiation. Laser is a device which emits a powerful, monochromatic collimated beam of light. The emitted light waves are coherent in nature.

Characteristics of Laser

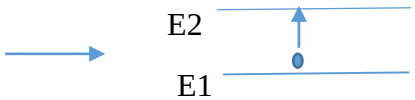
1. **Directionality**: Lasers emit light that is highly directional. Laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as coming from the sun, a light bulb, or a candle, is emitted in many directions away from the source.
2. **Monochromatic**: The light emitted from a laser is monochromatic, that is, it is of one wavelength (color). In contrast, ordinary white light is a combination of many different wavelengths (colors).
3. **Coherent:** The light from a laser is said to be coherent, which means the wavelengths of the laser light are in phase in space and time.
4. **Intensity:** Since an ordinary light spreads in all directions, the intensity reaching the target is very less. But in the case of laser, due to high directionality, the intensity of laser beam reaching the target is of high intense beam. For example, 1 mill watt power of He-Ne laser appears to be brighter than the sunlight.

These properties of laser light are what make it more of a hazard than ordinary light. Laser light can deposit a great deal of energy within a very small area.

Important term related to Laser

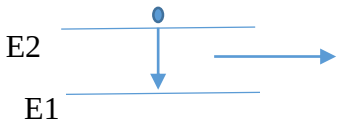
1.Absorption: An atom in a lower level absorbs a photon of frequency hν and moves to an upper level. Molecule absorbs a quantum of radiation (a photon) and is excited from 1 to 2.

$M + h\nu \rightarrow M^*$ (state 1) to.(state 2)



2.Spontaneous Emission: An atom in an upper level can decay spontaneously to the lower level and emit a photon of frequency hν if the transition between E2 and E1 is radiative. This photon has a random direction and phase. Spontaneous emission M* (in state 2) spontaneously emits a photon of radiation. Photons emitted in all directions and on a random time scale. So the emitted photons are INCOHERENT

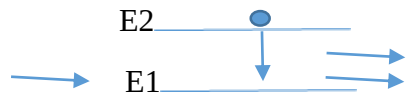
$M^* \rightarrow M + h\nu$



3.Stimulated Emission: An incident photon causes an upper level atom to decay, emitting a "stimulated" photon whose properties are identical to those of the incident photon. The term "stimulated" underlines the fact that this kind of radiation only occurs if an incident photon is present. The amplification arises due to the similarities between the incident and emitted photons. A quantum of radiation is required to stimulate M* to go from 2 to 1. Emitted and

stimulating photons have the same Frequency, Direction, and Phase. So the emitted and incident photons are COHERENT

$M^* + h\nu \rightarrow M + 2h\nu$



Rates of absorption and emission processes

Rates are determined by the Einstein coefficients for each process

$dN_1/dt=N_1 B_{12}D(\upsilon)$ absorption

$dN_2/dt=N_2 B_{21}D(\upsilon)$ Spontaneous emission

$dN_2/dt=N_2 A_{21}$ Stimulated emission

B_{12}, B_{21}, and A_{21} is known as Einstein coefficients. $D(\upsilon)$ is the energy density of the incident radiation and N1 and N2 are the populations of states 1 and2 respectively. Under thermal conditions the population of two states 1 and 2, is determined by the Boltzman distribution

$N_2/N_1=\exp(-\Delta E/KT)$

First condition for laser action:

If N1 > N2

If most molecules in state 1, then incoming radiation is mainly absorbed then Incident radiation is attenuated (reduced)

If N2 > N1

If most molecules are in state 2, absorption of incoming radiation is slowed down so the result is stimulated emission. Therefore, Incident radiation is amplified. Thus for laser action require a population inversion, N2 > N1

Link for Laser 1. https://youtu.be/BKVMw4jpDZw
2. https://youtu.be/QlVDFZDL2Ho

3 https://youtu.be/iWaAPwsrJhg

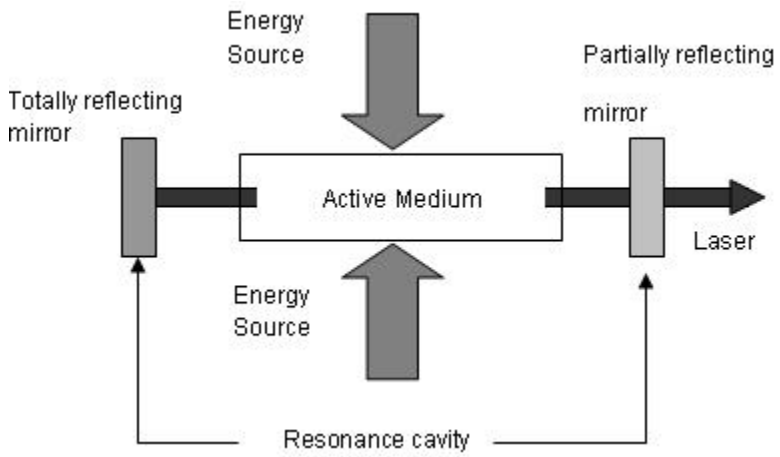
4.https://youtu.be/1LmcUaWuYao

Components of Lasers

1. Active Medium: It is the material in which the laser action takes place. The active medium may be solid crystals such as ruby or Nd:YAG, liquid dyes, gases like CO2 or Helium / Neon, or semiconductors such as GaAs. This medium decides the wavelength of laser radiation. Active mediums contain atoms which can produce more stimulated emission than spontaneous emission and cause amplification they are called “Active Centers”.

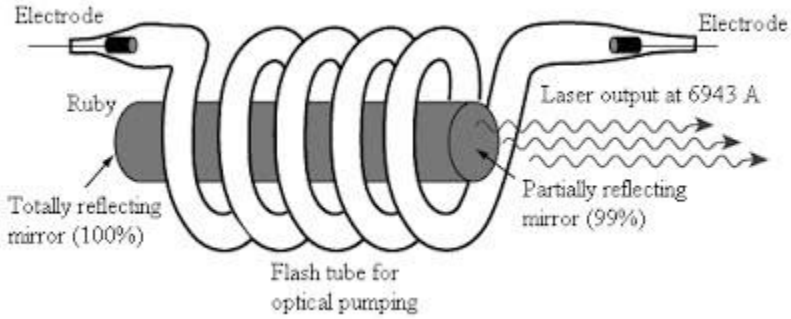
2. Energy Source (Excitation Mechanism): Energy Source (Excitation mechanisms) pumps the active centers from ground state to excited state to achieve population inversion. The pumping by energy source can be optical, electrical or chemical depending on the active medium.

3. Resonance Cavity: Resonance cavity consists of active medium enclosed between two mirrors one is highly reflective mirror (100% reflective) and the other is partially transmissive mirror (99% reflective).



Ruby Laser

The ruby laser is the first type of laser actually constructed, first demonstrated in 1960 by T. H. Maiman. The ruby mineral (corundum) is aluminum oxide (Al2O3) with a small amount (about 0.05%) of chromium ions (Cr3+) which gives it its characteristic pink or red color by absorbing green and blue light. The ruby laser is used as a pulsed laser, producing red light at 6943Å. After receiving a pumping flash from the flash tube, the laser light emerges for as long as the excited atoms persist in the ruby rod, which is typically about a millisecond. The ruby laser has following main parts:

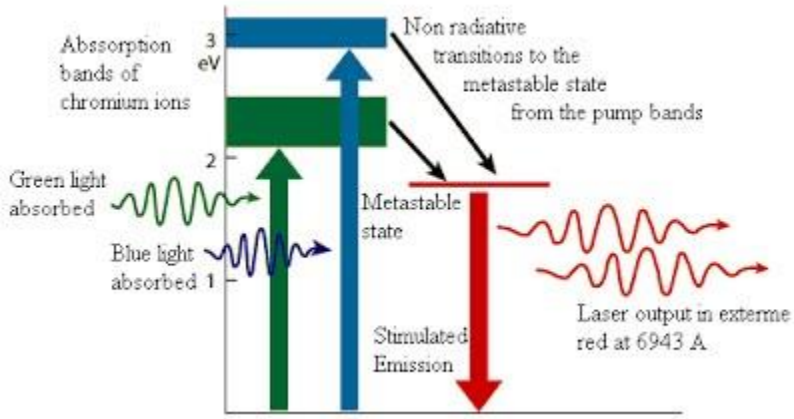


1. The working substance (active medium)- is in the form of a rod of ruby crystal (10 cm in length, 0.8 cm in diameter) in which Cr3+ are active centers while Al and O2 are inert.

2. The resonance cavity- is made by silvering and polishing the ends of ruby rod. Fully reflecting plates at the left and a partially reflecting plate at the right, both optically plane and accurately parallel.

3. The optical pumping system -consists of a helical xenon discharge tube. It produces flash of few milliseconds.

Ruby laser uses a three level pumping scheme. The xenon discharge generates a flash of white light for few milliseconds. The Cr+3 ions are excited to the E3 level by absorbing green and blue component of white light. From there the Cr+3 ions undergo non-radiative transitions and quickly drop to the metastable level E2. The metastable state has greater life time than E3. Therefore Cr+3 ions accumulate at E2. When more than half ions are accumulated at E2 the population inversion is established between E2 and E1. A chance spontaneous emission leads to chain stimulated emission. Red light (of wavelength 6943 Å) emerges from the front face.



Link for ruby laser:1. https://youtu.be/yQ0lMSNuj_o

2. https://youtu.be/7wcGWK52wjA

2.