Unit V

LASERS

B.Sc. Sem 6

Introduction

- LASER is a acronym for Light Amplification by Stimulated Emission of Radiation.
- Theoretical development by the prediction of stimulated emission of radiation by Albert Einstein in 1917.
- C.H.Townes discovered MASER using the concept of Einstein in 1954.
- In 1955 Prokhorov and Basov suggested an optical pumping of multilevel system as a method for obtaining the population inversion, which later became one of the main methods of laser pumping.
- First LASER device called Ruby LASER developed by T.H.Maiman in 1960.
- Emits red light of wavelenth 64.3 nm.
- Soon, A,Javen and co-workers He-Ne Gas LASER.

Townes, Basov, and Prokhorov shared the Nobel Prize in Physics in 1964.
Development of LASER has provided stimulus to make optics one of the most rapidly growing fields in Science & Technology.
Following the birth of the Ruby and Helium neon laser other devices followed in Rapid succession each with the different laser medium and a different wavelength emission. For the greater part of the 1960 the laser was viewed by world of industry and Technology as scientific curiosity.

Characteristics of LASER

- The following characteristics distinguish a laser beam from an ordinary light:
- Coherence: the wave train which are identical in phase in direction are called coherent waves.
- High intensity due to the coherent nature of laser it has ability to focus our small area of 10^{-6} cm^2.
- High directionality: An ordinary light source emits light in all possible directions but laser beam can travel our long distance without spreading.
- Monochromaticity: the light from a normal monochromic source spreads overr range of wavelength of order 100 nm but the spread is of 1 nm for laser.

Principle of LASER

- It is based on the principle of stimulated emission of radiation with light amplification. For stimulated emission of radiation to take place, the population of atoms in higher energy level should be greater than the lower energy level that is N2>N1
-

Thermal Equilibrium

Consider two level energy system having energy E1 and E2 having population N_1 and N_2 resp.

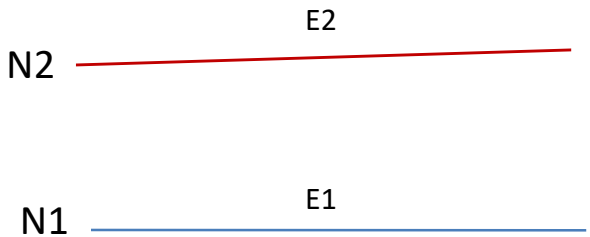
According to Boltzmann statistics:

$$N_1 = Ae^{-E_1/kT}$$

$$N_2 = Ae^{-E_2/kT}$$

$$\Rightarrow \quad N_1/N_2 = e^{-E_2/kT}/e^{-E_1/kT}$$

$$\Rightarrow \quad N_1/N_2 = e^{-(E2-E1)/kT}$$



1. At room temp. For H-atom

   $E_2-E_1=-3.4-(-13.6)=10.2eV$, T=300K, kT=0.025 eV

   $\Rightarrow \quad N_1/N_2 = e^{-(10..2)/0.025} = e^{-408.4} \approx 0$

2. At high temp. (6000k)

   $N_1/N_2 = 4x10^{-10}$

3. If T is infinite then $N_1=N_2$

   This shows that the population of higher energy level can never be more than that of ground state.

Interaction of light with mater: Einstein's quantum theory of radiation

Einestein in 1916 predicted that when a matter is exposed to a stream of photons, three types of processes took place

- Stimulated Absorption: Electrons jump from ground state to excited state on absorption of incident photon of definite frequency.
- Spontaneous Emission: The electron came back to ground state without any external stimulas giving out a photon.
- Stimulated Emission: An external resonant frequency photon stimulates the emission at a particular time.

Spontaneous Emission

- It is the process in which there is an emission of a photon whenever an atom comes from higher energy state to a lower energy state without the aid of any external agency.
- For this process to take place the atom has to be in the excited state since the higher energy level is an unstable one. The excited atom in higher energy level E_2 spontaneously return to the lower energy level E_1 with the emission of a photon of energy h new equal to $E_2 - E_1$
- The rate of spontaneous emission of radiation R_{21}(spon) is proportional to the population N_2 at the higher energy level E_2.

Stimulated Emission

- It is the process in which there is an emission of a photon whenever an atom transits from higher energy state to a lower energy state with the aid of any external agency i.e.inducing photon.
- For this process also the atom should be already in the excited state. Let a photon having energy equal to E_2-E_1 interact within atom in the excited state.
- Under such interactions the incident photons stimulate the excited atom in the level E_2 to transit to lower energy level even resulting in the emission of photon of energy $hv = E_2 - E_1$
- The rate of stimulated emission of radiation is proportional to population N_2 at higher energy level E_2 and to the density of incident photon.

Population Inversion

- Population inversion is a state of achieving more number of atoms in excited state compared to the ground state.

$$N_2 > N_1$$

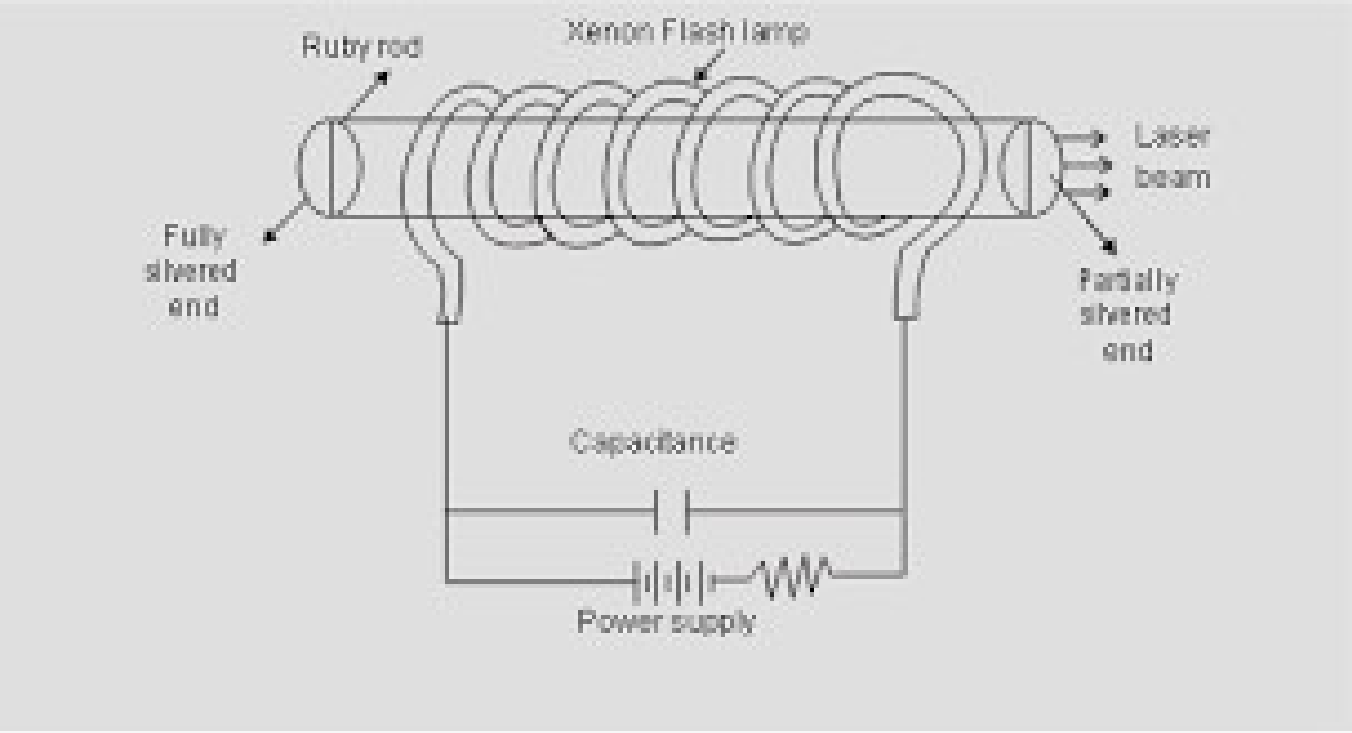
- If the condition is satisfied then there is more chance of stimulated emission to take place hence population inversion is an essential condition for producing laser.
- Population inversion can be achieved by a process called pumping.

Types of LASER

- Among the various kinds of laser some important type of laser are listed below:

1. solid state laser: ruby laser
2. gas laser: CO2 laser, Helium neon laser
3. liquid laser: Europium chelate laser
4. Dye lazer:
5. semiconductor laser: Inp laser

Ruby Laser


Ruby rod
Xenon Flash lamp
Laser beam
Fully silvered end
Partially silvered end
Capacitance
Power supply

Construction and working

- In Ruby laser, a cylindrical Ruby rod made up of Aluminium oxide which is dropped with 0.05% weight of chromium oxide.
- one end of rod is fully silver and the other one partially silvered so it act as optical resonator.
- When the flash lamp light will be flashed on ruby rod the chromium ion excites to higher energy states.
- After staying for up to 10^{-8} seconds, ions get transmitted to the metastable state.
- the laser radiation of a wavelength of 6943 angstrom is emitted and Laser emission is pulse one.