(U4) Lecture 35: Amplification of light by Population Inversion

Population inversion: The number of atoms per unit volume occupying a certain energy state is called population. In any atomic system ordinarily the number of electrons in the lower energy state (N_1) is more in comparison to the population of excited state (N_2). For achieving the light amplification an artificial situation is created in which the number of electrons at the excited state is more than the number of electrons in lower energy state. This situation is called as population inversion.

In any atomic system number of photons absorbed may be written as:

$$N_a = B_{12} N_1 u(\nu)$$

It means absorption is proportional to the N_1, whereas number of photons emitted by stimulated emission may be written as:

$$N_{st} = B_{21} N_2 u(\nu)$$

Equation above indicates that stimulated emission is directly proportional to the N_2 i.e. the population of excited state. It clearly establishes that if the number of electrons at excited state N_2 is more than the number of electrons at ground state N_1, then probability of stimulated emission will be more in comparison to the absorption and the light amplification will take place.

Components of Laser

Active Medium: The active medium is a collection of atoms or molecules, which can be excited to achieve population inversion situation for amplification of light by stimulated emission. The active medium can be in any state of matter: solid, liquid, gas or plasma. The active medium determines the emitted wavelengths possible by lasing transition.

Pumping: Pumping is an energy source working on an active medium for achieving population inversion. Various pumping mechanisms are:

i. Optical Pumping
ii. Electric Discharge
iii. Inelastic Atomic Collisions
iv. Direct Conversion
v. Chemical reaction

Optical Resonator: Optical resonator is a pair of mirror facing each other. The active medium is enclosed in this cavity. In optical resonator one of the mirrors is partially polished while other mirror is completely polished. Optical cavity ensures the availability of photons for stimulated emission and contributes for light amplification by optical feedback. A schematic diagram of optical resonator is given in the figure below.

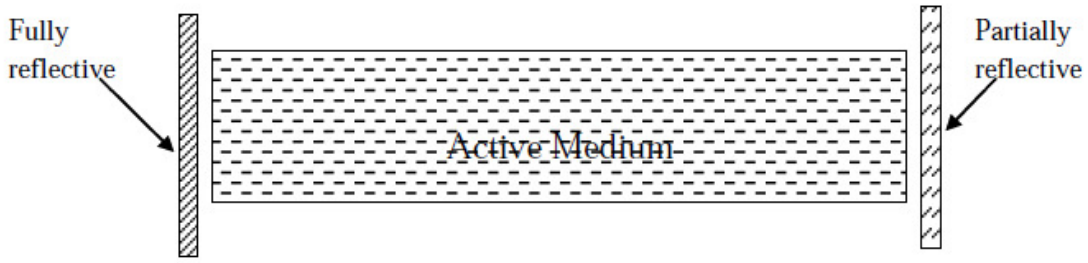
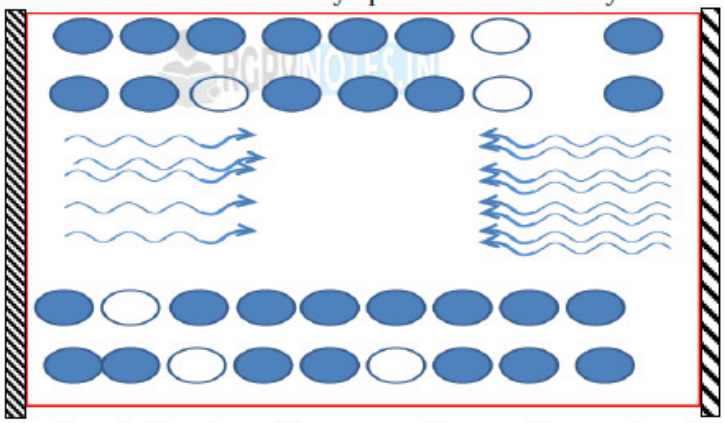


Figure : Active medium enclosed by optical resonator cavity



Action of Optical resonator: In the above figure an active medium enclosed between two parallel mirrors is shown. In the active medium hollow spheres present electrons in the ground state while filled sphere presents electrons in the excited state.

Step1: Some of the electrons from the excited makes down ward transition spontaneously resulting in the emission of photons.

Step2: Out of the emitted photons, The photons traveling in the axial direction is reflected back into active medium.

Step3: These reflected photons initiates the process of stimulated emission into active medium and more photons are obtained.

Step4: After multiple reflections a strong laser beam emerges out from partially reflective end of the optical resonator.