The emission absorption mechanism of LASER

The three different mechanisms are shown below (Figure)

1. **Absorption:**

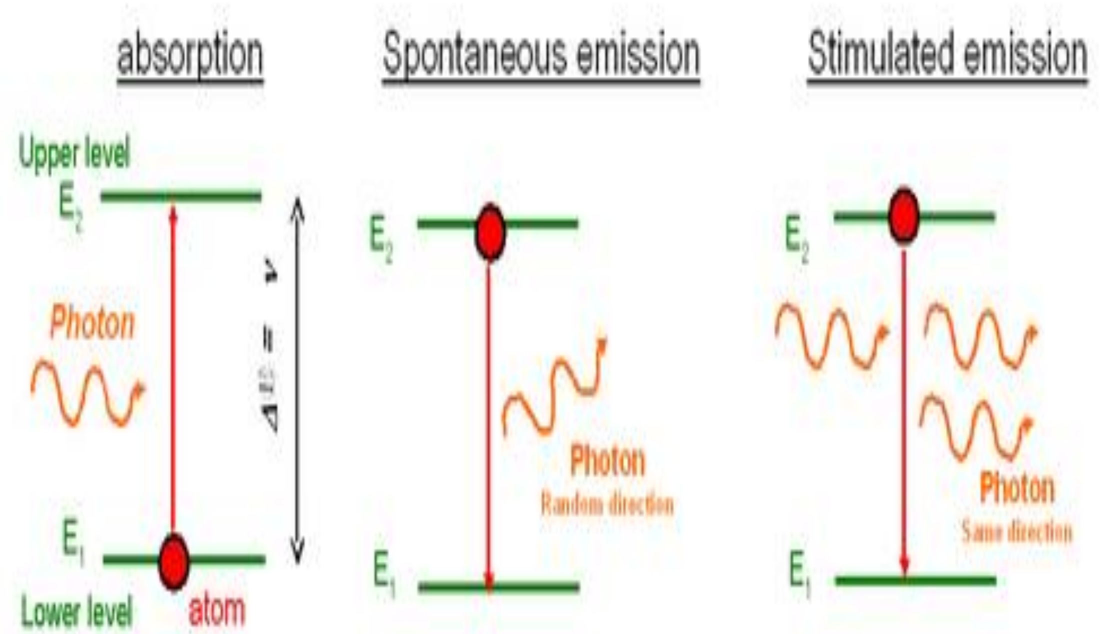
   An atom in a lower level absorbs a photon of frequency hν and moves to an upper level.

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.

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.



Competition between three mechanism

For a radiative transition, these three mechanisms are always present at the same time. To make a laser medium, conditions have to be found that favour stimulated emission over absorption and spontaneous emission. Thus, both the right medium and the right conditions must be chosen to produce the laser effect.

- An incident photon of energy $h\nu$ has an equal chance of being absorbed by a ground-state atom as being duplicated (or amplified!) by interacting with an excited-state atom. Absorption and stimulated emission are really two reciprocal processes subject to the same probability. To favour stimulated emission over absorption, there need to be more excited-state atoms than ground-state atoms.
- Spontaneous emission naturally tends to empty the upper level so this level has to be emptied faster by stimulated emission. It has been proved that stimulated emission is much more likely to happen if the medium

used is flooded with light (i.e. with a large number of photons). A good way to do this is to confine the photons in an optical cavity.

Population Inversion and Pumping

If there are more atoms in the upper level (N_2) than in the lower level (N_1), the system is not at equilibrium. In fact, at thermodynamic equilibrium, the distribution of the atoms between the levels is given by Boltzmann's Law:

In this case, N_2 is always less than N_1. A situation not at equilibrium must be created by adding energy via a process known as “pumping” in order to raise enough atoms to the upper level.

This is known as **population inversion** and is given by $\Delta = N_2 - N_1$. Light is amplified when the population inversion is positive. Pumping may be electrical, optical or chemical.

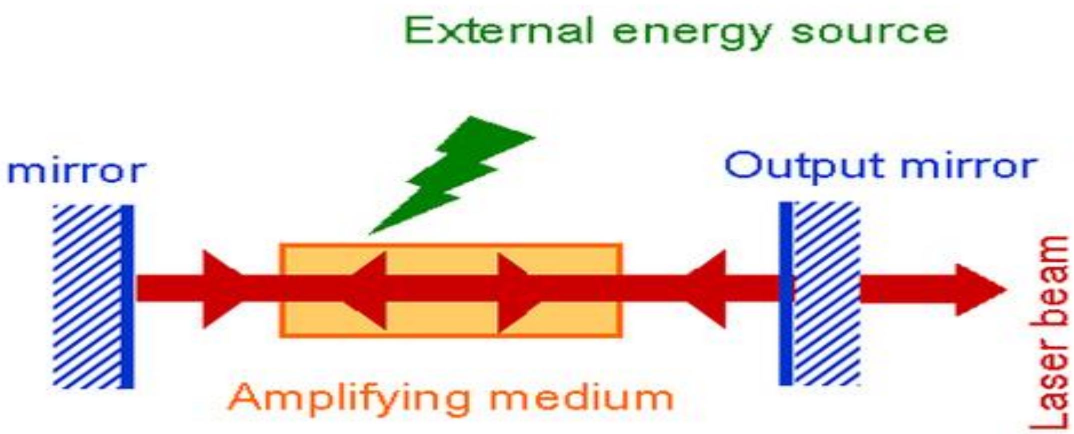
Stimulated emission is fundamental to light amplification and thus to the operation of the laser. To understand it, it must be placed in the context of interactions between light and matter. Here, the matter is composed of optically active elements in “solution” in a gas, plasma, solid or liquid medium. These elements can be atoms, ions, molecules, free radicals or electrons (for simplicity, we consider “atoms” in the following). Their energy levels are quantified and are such that light of a certain frequency can interact with the population found in these levels. More precisely, let us consider two energy levels E_1 and E_2 (E_1 is less than E_2) whose atoms can interact with light of frequency $h\nu = E_2 - E_1$. The group E_1-E_2 is called radiative transition if atoms can only pass from E_1 to E_2 (or from E_2 to E_1) by interacting with light. E_1 is called the lower energy level and E_2 the upper energy level.

A laser consists of two fundamental elements:

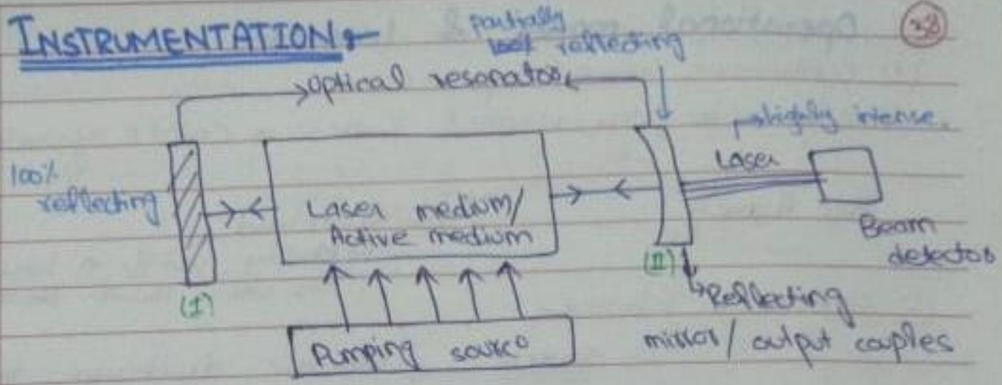
- an amplifying or gain medium (this can be a solid, a liquid or a gas). This medium is composed of atoms, molecules, ions or electrons whose energy levels are used to increase the power of a light wave during its propagation. The physical principle involved is called stimulated emission.
- a system to excite the amplifying medium (also called a pumping system). This creates the conditions for light amplification by supplying the necessary energy. There are different kinds of pumping system: optical (the sun, flash lamps, continuous arc lamps or tungsten-filament lamps, diode or other lasers), electrical (gas discharge tubes, electric current in semi-conductors) or even chemical.

These two components are sufficient to amplify an existing light source. This is known as a laser amplifier. However, most lasers also incorporate an optical resonator (or cavity) in order to produce a very special radiation. Technically, the whole device is known as a laser oscillator, but this term is often shortened to simply “laser”. The laser oscillator uses reflecting mirrors to amplify the light source considerably by bouncing it back and forth within the cavity. It also has an output beam mirror that enables part of the light wave in the cavity to be removed and its radiation used.

The different components that make up a basic laser are illustrated in the diagram below



INSTRUMENTATION :-



Source → Tungsten lump, chemical reax as source, Explosive material, Flash lamp, Electric discharge, Electric current

⇒ Light in the form of photons strike on surface of active media. Spontaneous emission occurs. Then strike optical resonator and reflect the light at laser medium. This is a source of stimulated emission.

⇒ At room temp, no atom move from G.S to E.S unless some external force apply.

⇒ (II) optical resonator can change. It depends upon the behaviour either ~~broo~~ obtain broad or narrow beam.
It can be concave or convex.

⇒ Optical resonator is used for reflecting and population inversion phenomena operate.
The double headed arrow shows that light is goes to reflector and then reflect back to media.

⇒ Laser beam in the form of continous waves or in the form of pulses
- continous waves ↳ if we require intense & highly energetic beam.
- pulses ↳ if we require short beam.