PUMPING METHODS

The process by which we can realise and maintain the state of population inversion is known as pumping. In this process, it is necessary that atoms must be continuously promoted from the lower level to the excited state. The pumping energy is to be supplied somehow to the atoms to raise them from the lower level to the excited level and to ensure that population at the excited level is more than that at the lower energy level. Thus in simple words we can say that the processes by which atoms are raised from the lower energy level to the upper energy level are called pumping. The commonly used pumping methods are

- **Optical Pumping:** In optical pumping, a light source is used to supply luminous energy. Most often this energy is given in the form of short flashes of light. This technique was first used by Maiman in the Ruby laser and is also widely used in solid-state-lasers.
- **Electrical Discharge:** The pumping by electric discharge is preferred in lasing materials whose higher energy levels have a narrow bandwidth e.g. Argon-ion laser. When a potential difference is applied between cathode and anode in a discharge tube, the electrons emitted from cathode are accelerated towards anode. Some of these electrons collide with atoms of the active medium, ionise the medium and raise it to higher level. This produces the required population inversion. This is also called direct-electron excitation. This procedure is mainly used in gas lasers.
- **Inelastic atom-atom collision:** This procedure is suitable when we have two types of atoms in the active medium. An electric discharge raises one type of atom to their excited states. These excited atoms collide inelastically with the second type of atom, energy exchange takes place and the required population inversion is created in the later atoms. An example of this type is He-Ne laser.
- **Direct conversion:** A direct conversion of electrical energy into radiant energy occurs in light emitting diodes (LEDs). This method is used in semi conductor lasers.
- **Chemical pumping:** In chemical pumping, the energy for pumping is obtained from a chemical reaction. For example when hydrogen combines with fluorine to form hydrogen fluoride, enough heat is generated.

  $$\mathbf{H_2 + F_2 \longrightarrow 2HF}$$

  This energy is enough to pump a CO_2 laser. Chemical pumping usually applies to materials in the gas phase and it generally requires highly reactive and often explosive gas mixture.

MAIN COMPONENTS OF A LASER:

The three main components of any laser device are:

- **The Active Medium:** A material which, on being excited, sustains population inversion. Such a material is called an active medium. The medium may be a solid, liquid or gas. A large number of materials have been identified which can be used as a suitable medium and therefore there are various types of laser materials.

- **The Pumping Source:** The pump is an external source that supplies energy and helps in obtaining the population inversion. The pumps can be optical, electrical or thermal.

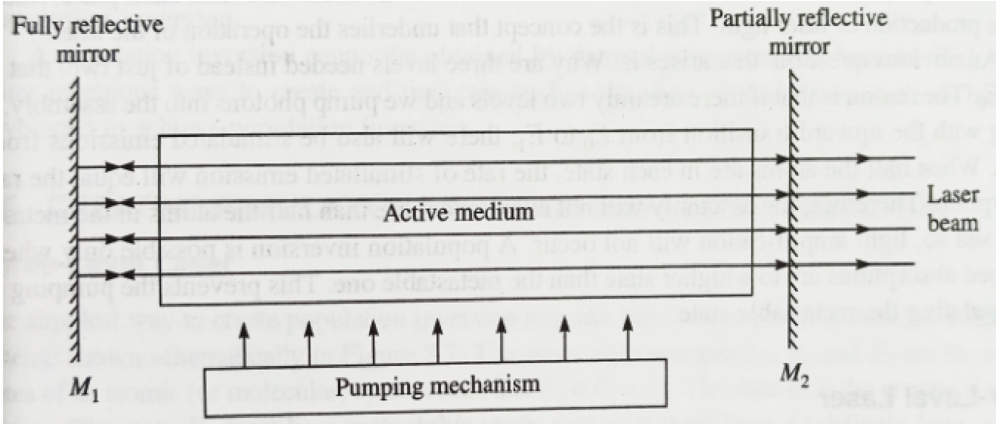

Fig.9 Basic components of a laser system

- **The Optical Resonator:** The active medium is enclosed in an optical cavity which is usually in the form of a cylinder with plane or concave mirrors at the ends. The photons produced due to stimulated emission are sent back and forth through the medium many times by the mirrors M_1 and M_2 so as to stimulate further emission from as many excited atoms as possible. The mirror M_1 is fully reflective while M_2 is partially transparent. Therefore a small fraction of the intense laser beam emerges from M_2.

THE HELIUM-NEON LASER:

The helium-neon laser is the most commonly used gas laser. It was first developed by Ali Javan and his collaborators in 1961. It is a *four-level laser* and *provides a continuous supply of laser beam*. The schematic diagram of the essential components of a He-Ne laser is shown in fig.10. A mixture of helium and neon in the ratio 4:1 is filled in a glass discharge tube at a very low pressure (of the order of 1mm of Hg). Helium acts as the pumping medium and neon as the lasing medium. The tube has parallel mirrors M_1 and M_2 at the two ends, M_1 being fully reflective and M_2 partially transparent.

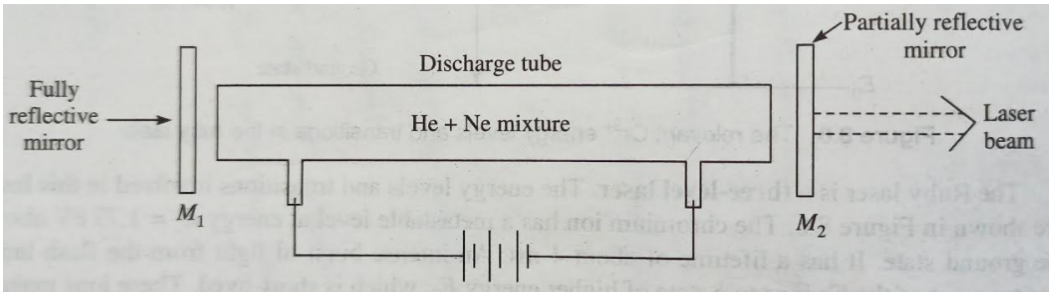

Fig.10 Schematic diagram of a He-Ne laser

When a sufficiently high voltage is applied between the electrodes, a continuous electric discharge is produced. Fig.11 shows the four levels involved in the pumping- lasing process. E_0 is the common ground state. E_1 is a short-lived state in neon. E_2 and E_3 are metastable states in neon and helium respectively. The energetic electrons in the discharge strongly excite the state E_3 in helium. When these excited He atoms collide with the unexcited Ne atoms, their excitation energy can be easily transferred to the Ne atoms to raise them to the level E_2. As a result of this energy transfer, the neon level E_2 can become more heavily populated than the neon level E_1. This population inversion is easy to maintain because- (a) initially there are very few neon atoms in the state E_1, (b) the metastability of the helium state E_3 ensures a good supply of neon atoms in state E_2 and (c) atoms in state E_1 decay rapidly to the ground state E_0.

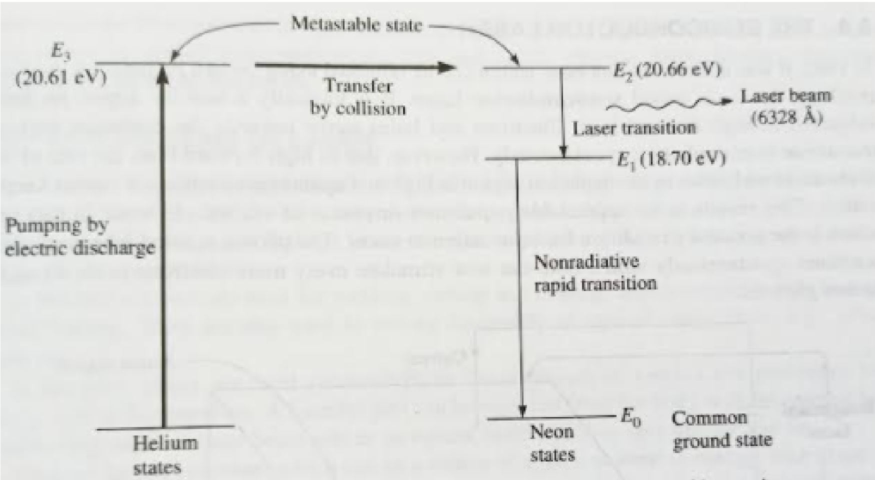

Fig.11 He-Ne energy levels and the laser transitions

Now let us suppose that a photon is spontaneously emitted as a neon atom makes a transition from the state E_2 to the state E_1. Such a photon can stimulate the emission of another photon and these two photons can trigger other stimulated emissions. Those photons which are moving parallel to the tube axis are sent back and forth through the tube many times due to successive reflections from mirrors M_1 and M_2, causing further emissions. A chain reaction thus builds up rapidly and a red coloured laser beam of wavelength 6328A^0 passes out through the partially transparent mirror M2. The distance between the mirrors is made exactly equal to an integral multiple of half the wavelength of the laser light, which ensures constructive interference between multiple reflected waves.

The He-Ne laser system provides a continuous beam of laser light. Typical small models generate a laser beam of power 1mW and consume electric power of a few watts.