neutral state as in He-Ne laser.

Helium-Neon (He-Ne) Laser

Early in the development of laser technology it was found that a mixture of helium and neon gases would lase in the infrared. Soon afterward, the familiar red transition of the helium–neon laser was found and so began the life of the most dominant laser for the next 20 years until the spread of diode lasers. The first gas laser, the He-Ne laser, is an important source of coherent red light with uses ranging from bar-code scanning to alignment. The dominance of this laser in the market is decaying rapidly, due to inexpensive, reliable, and small semiconductor lasers operating in the same range of wavelengths and power levels as the He-Ne. Although these semiconductor lacks the beam quality of the He-Ne, but this is not important for many applications. He-Ne laser has three main Structures:

- Plasma Tube.
- Optical Cavity.
- Power Supply.

The active medium is a mixture of helium and neon in the ratio of about ten parts of helium to one part of neon. The mixture is contained in a narrow bore tube a few millimeters in diameter and from 0.1 to 1m long at a pressure of about 10 torr (being dependent primarily on the diameter of the plasma tube).A discharge is induced as outlined above but a point to note is that because the tube resistance falls to low values once a discharge has started a resistor must be placed in series with the power supply to limit the current.

Although He-Ne lasers with mirrors external to the discharge tube are sometimes made (Fig 2.1), for example when it is desired to place additional optical components within the optical cavity. It is more usual to have the mirrors sealed directly to the ends of the tube. A typical design of He-Ne laser is shown in Fig. 2.2. Here a thick outer cylindrical glass tube with diameter of about 2.5 cm and is sealed from the outside. The purposes of this outer tube are :

- To make a stable structure which protects the inner tube and the laser mirrors from movements.

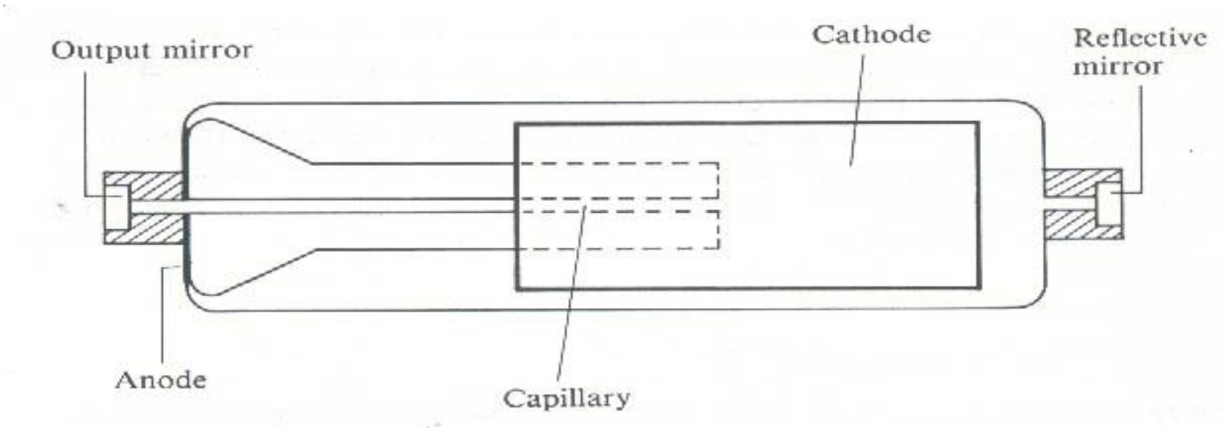

Figure2.2:Typical structure of a sealed mirror He-Ne laser.

- To act as a large gas reservoir which refreshes the Neon gas that has been absorbed by the cathode.

The active volume in the discharge is defined by a hard glass capillary tube (inner tube) which has a diameter of about 2 mm and length of tens of centimeters and extending from the anode most of the way towards the cathode end. The cathode itself is an quite large and high purity aluminum alloy tube which is contained inside a large gas ballast volume; electron emission taking place from its interior. It is obviously important that the mirrors are sufficiently robust to resist degradation during the time they are exposed to the discharge. They are usually made of multilayer stacks of alternating quarter wavelengths of titanium dioxide and silicon dioxide. If a polarized output is required, then a window orientated at the Brewster angle may be incorporated.

Although the He-Ne laser gives a low power output, typically ranging from 0.5 to 50 mW (In laboratory prototypes an output power of the order of 100 mW was achieved), it has other compensating virtues such as an exceptionally narrow lasing linewidth combined with excellent beam quality(excellent spectral and coherence characteristics). It is also small and light enough to be readily portable.

The He-Ne laser is a 4 level laser with favorable dynamics, so He-Ne lasers have low thresholds and operate in CW mode. The energy level diagram is described in figure 2.3. The lasing transitions take place between the energy levels of Ne. Two meta-stable energy levels act as upper laser levels. The He-Ne laser have two lower laser levels, so quite a few wavelengths can come out of the transitions between these levels.

The important wavelengths are:

λ_1=0.6328 μm (632.8 nm), λ_2=1.152 μm, λ_3=3.3913 μm, λ_4=0.5435 μm

The energy transfer processes in the active medium is as follows:

a. Electron impact excites the helium atoms into the long-lived 2^3S and 2^1S states

b. Collision between He and Ne atoms excites the Neon into the 2s and 3s states.

c. Population inversion created between the 3s/3p and2s/2p states in neon. Stimulated emission gives gain.

d. The lifetime of the 2p and 3p states is short and they rapidly decay to the 1s state.

e. Collisions between the neon atoms and the tube walls returns the neon atom to the ground state.

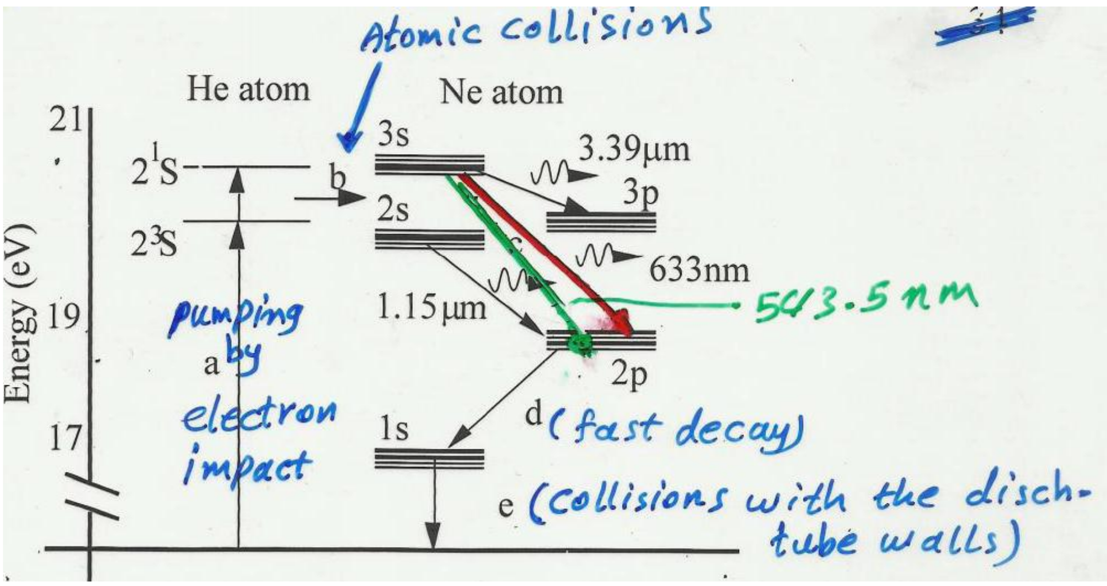

Figure 2.3: Energy Level Diagram of He-Ne Laser.

We can state in brief that the entire process includes : excitation of the helium atoms, transfer to the ULL in neon, lasing transitions, and decay from the LLL.

Each of the four main laser transitions (at 3.39 μm, 1.15 μm,632.8 nm and 543.5 nm) shares with one of the others either a common starting or terminating level. Thus the transitions are always competing with each other and precautions must be taken to prevent the two unwanted wavelengths from lasing. Usually all that is required is for the mirrors forming the laser cavity to be highly reflective at only the wanted wavelength.

Since the He-Ne laser is an example of a four–level system, it is required that the population of the lasing transition terminal level be kept as low as possible. This implies that electrons in the terminal level should decay as rapidly as possible back to the ground state. In neon this is a two-step process; the first, 2p to 1s, is a rapid transition, but the second, 1s to the ground state, is not so rapid. The latter transition rate is, however, enhanced by collisions with the walls of the discharge tube, and indeed the gain of the laser is found to be inversely proportional to the tube radius. For this reason the discharge tube diameter should be kept as narrow as possible.

The transition 2p to 1s is also of interest since it gives rise to the familiar color of 'neon lights'. Thus the 2p level itself must be populated by the discharge. This is unfortunate since an increase in population of the 2p level implies a decrease in population inversion (at least as far as the 1.15 µm, 632.8 nm and 543.5 nm wavelengths are concerned), and in fact this effect is to a large extent responsible for lasing ceasing at high tube currents. We cannot therefore increase the output simply by increasing the current indefinitely. Thus the HeNe laser is destined to remain a relatively low-power device.

The role of the Helium gas in He-Ne laser

Helium gas only serves as a buffer gas that enhances lasing by causing the pumping efficiency to be increased. Two effects make Helium particularly valuable:

1. The direct excitation of Neon gas is inefficient, but the direct excitation of He gas atoms is very efficient.
2. An excited state of the He atom (2^3S and 2^1S) has an energy level which is very similar to the energy of an excited state of the Neon atom (3s and 2s).

The excitation process of the Neon atoms is a two stages process:

- The high voltage causes electrons to accelerate from the cathode toward the anode. These electrons collide with the He atoms and transfer kinetic energy to them.