2.4.2 Metal Vapor Lasers

As the name implies, the active medium in these lasers is a vapor consisting of metal atoms. There is a distinction between two types:

a. Neutral metal vapor lasers, which include:
   1. Copper vapor laser (CVL).
   2. Gold Vapor Laser (GVL).
b. Ionized metal vapor lasers, which include Helium-Cadmium (He-Cd) Laser(will be discussed under ionized gas lasers group).

All metal vapor lasers emit : visible electromagnetic radiation in a form of rapid pulses and with high efficiency.

We shall concentrate on Copper Vapor Laser as an example for neutral vapor lasers.

2.4.2.1 Copper vapor laser (CVL)

The copper vapor laser has been known for some time(lasing action in copper vapor was first demonstrated in 1966), but it has become important (the first commercial copper vapor lasers appeared around 1980) only when various improvements in the associated technology have enabled high powers and reasonable lifetimes to be achieved.

This laser was attractive because it combines the following advantages over other visible gas lasers:

- High peak power, over 400 kW
- Over 1% efficiency
- Average power of tens of watts

Copper Vapor Laser Structure

Copper vapor laser is a gas laser; build as a tube of diameter 10-80 mm, with windows at both ends. A solid bulk of pure Copper metal is inserted in a reservoir in the middle of the tube before the tube is filled by neon gas at a 25-50 Torr pressure. As the name implies the active medium is copper vapor and to maintain a high enough concentration of copper, the tube has to be kept at fairly high temperatures, so the tube is build from Alumina or Zirkonia (which are high temperature resistant materials).

The Neon gas is a buffer gas. The buffer gas is essential in a laser in which the electrodes and windows are cold since it provides the discharge

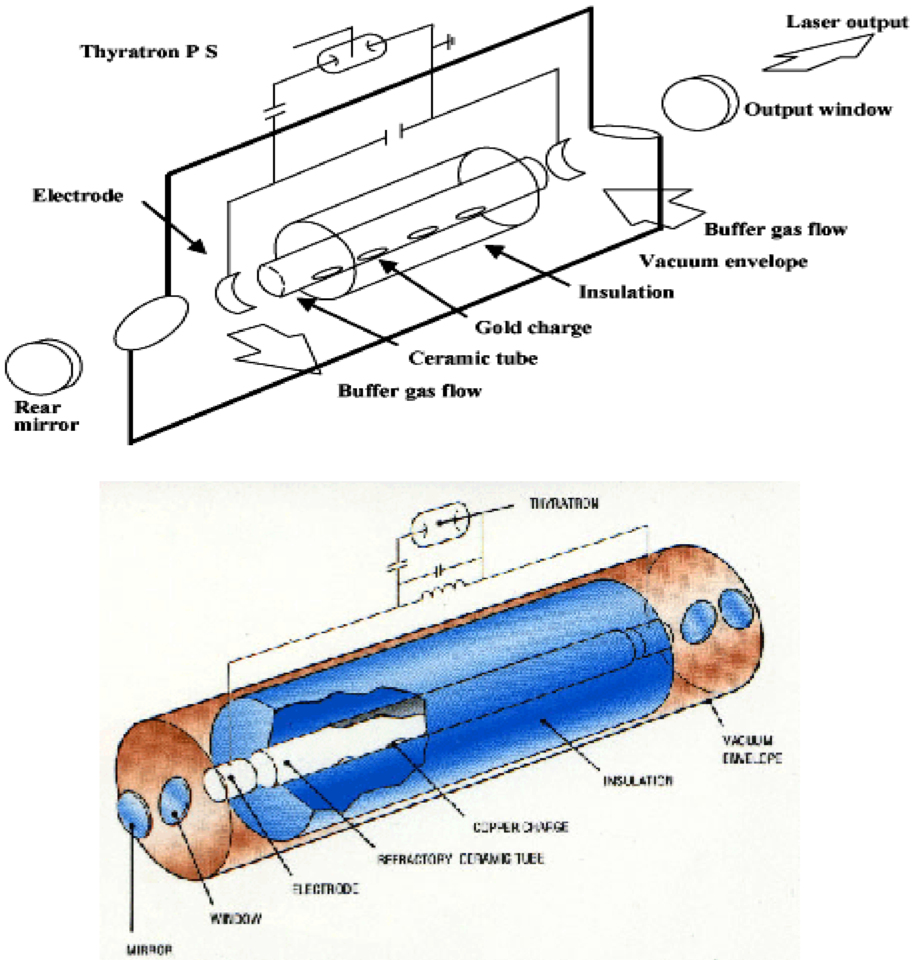

Figure 2.5:Structure of an CVL.

medium in the cold part of the tube and also prevents Cu vapor from reaching and condensing on the windows. The buffer gas is the majority of species in the hot region as well.

Copper Vapor Laser operation

To attain high temperatures, which are higher than the melting point of Copper (the melting temperature of Copper is 1083^0C),an electric discharge is initiated by high voltage to the electrodes at the ends of the tube. The waste heat from the discharge raises the temperature of the tube to between 1400°C and 1500°C when the copper has a vapor pressure of about 0.1 torr at which a sufficient copper concentration for lasing is achieved.

During the laser operation copper vapor tends to diffuse toward the ends of the tube (where the temperature is lowest) and deposit itself there, so the amount of Copper vapor in the tube is reduced. After a few hundred hours of operation, new Copper must be inserted into the tube.

The high voltage pulses applied to the electrodes at the ends of the tube cause the accelerated electrons to collide with the Copper vapor molecules, exciting them into one of the two available high laser energy levels, as seen in figure 2.6.

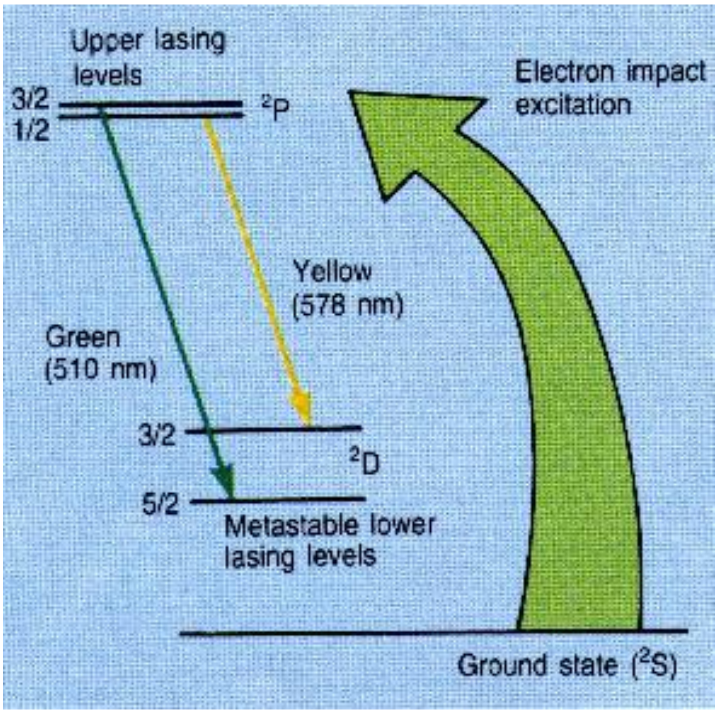

Figure 2.6: Energy Level Diagram of Copper Vapor Laser.

The wavelengths emitted by Copper vapor lasers are: **510.6 nm (Green),** and **578.2 nm (Yellow)**

Why copper vapor laser is restricted to pulsed operation?

CVL has a large gain so the population in the upper levels decays very rapidly by stimulated emission. Unfortunately, both of the laser transitions end at lower laser energy levels which are meta-stable (with long lifetimes of hundreds of micro-seconds). As a result the population of these energy levels increases rapidly, and lasing can only take place for a short time before population inversion is destroyed where laser action stops. After the lasing stops, the lower energy levels decay to the ground state by collisions of the excited molecules with the tube walls. Then, another laser pulse can form. The time of each laser pulse is less than 100 n sec (0.1 μsec). The copper vapor laser is a three level laser:

- Ground state of the Copper atom.
- Upper laser energy level.
- Lower laser energy level

Summary of Copper laser properties

- Copper vapor pressure is about 0.1 Torr.
- Optimal operating temperatures: $1450^0C \pm 50^0C$.
- The laser is very sensitive to the purity of the active gas.
- The laser operates simultaneously on two spectral lines (Green and Yellow) with no competition between them (separate levels). The optimal ratio of powers in green and yellow lines is reached at a certain optimal temperature of the wall in the discharge cavity.
- The energy per pulse of the green line (510.6 nm) depends on the frequency of the applied electric pulse (experimental fact).
- The energy per pulse of the yellow line (578.2 nm) is almost independent of the frequency of the applied electric pulse (experimental fact).
- Copper vapor lasers have very high gain (some 1% per mm) , and can operate even without an optical cavity. In practice, one mirror reflects 100%, and the other about 10% (uncoated plane window) can be used.
- The high temperature required for the lasing process, is achieved by heating as a result of the electric breakdown in the gas.
- It is possible to achieve lasing at lower temperatures (400^0C), by using Copper salts like CuCl, but there are still problems with these lasers, and they are in experimental stages.
- Pulse repetition frequencies of 2-100 KHz (5 kHz are typical) which are higher than other high power visible lasers.
- Pulse width of 5-60 ns.
- High pulse powers: peak powers of 50- 5000 KW and average powers of 10–50 W.
- Overall efficiencies are reasonably high up to 2%(the highest for visible gas lasers) so that when only a few watts of average power are required air cooling is often sufficient .

- Since there is an optimum laser temperature, the output power can be increased by: increasing tube volume (either by lengthening the discharge tube or mostly by increasing the tube diameter) ; using additives such as Hydrogen in optimized proportion to the buffer gas Neon.

Applications of Copper Vapor Lasers

1. Pump Sources for Dye lasers, for short pulses.
2. Illuminating objects in high speed photography.
3. In Forensics: to analyze fingerprints.
4. Photo-Dynamic-Therapy (PDT): is therapy used on cancer patients.
5. Enrichment of Uranium (U^{235}).
6. Micromachining (down to 1 m) and material processing.
7. Flow visualization.
8. Pulsed holography.

2.4.2.2 Copper Halides vapor laser

It is possible to achieve lasing at lower temperatures by using Copper salts like CuCl, but there are still problems with these lasers, and they are in experimental stages.

Mainly the copper halides (CuCl, CuBr, CuI) have considerably higher vapor pressures than metallic copper. It is possible to achieve a sufficient copper concentration for lasing in the 300 to 600°C range (depending on the copper halide). There is a definite optimum temperature; for all three halides the optimum temperature corresponds to the same vapor pressure. The optimum temperature is independent of other laser parameters and is 370°C for CuCl, 420°C for CuBr, and 500°C for CuI. Argon, neon, and helium are suitable buffer gases . Typical dependence of laser output on halide temperature is shown in Fig. 2.7.

2.4.2.3 Gold Vapor Lasers

The Gold Vapor laser is very similar to The Copper Vapor laser both in structure, and principles of operation. Sometimes, the same system(laser tube and power supply) is used for both lasers. The only change is to replace the solid Copper by a wire of pure Gold. The wavelength of Gold lasers is Red: 628 nm.