12. Describe the difference between single line output and multiline output. How does each output be achieved?
13. How could output wavelengths be selected in Ar^+ laser?
14. Why does the highest power Ar^+ laser operate at a multiline output?
15. List and explain four critical factors that must be considered in ion laser tube design.
16. Explain reasons for the following design features of argon laser tubes:
a. Gas fill reservoir. b. Annular metal disks.
c. Solenoid (magnet). d. Gas bypass channels(gas return paths).
17. Explain the dependence of the output power of an argon laser on each of the following parameters:
a. Tube current. b. Magnetic field strength. c. Tube diameter.
18. How could we increase the output power in Cu vapor laser and in Ar ion laser? Why does the power increased in such a way?
19. Why is it desirable to operate argon lasers with a narrow bore and a high electrical current?

Ans:

It is desirable to operate Ar lasers with a narrow bore and a high electrical current because of the following reasons:

a- Very high gain.
b- The output power scales nonlinearly with the current density.
20. What are the main applications of Ar lasers?

2.5.3 Helium-Cadmium Laser

Helium-Cadmium lasers can be categorized among either:
--Metal vapor lasers - The properties of Helium-Cadmium laser are similar to those of He-Ne laser which is a neutral atom gas laser. Metal vapor ion lasers are typically low-current, high-voltage devices similar in many ways to He-Ne lasers,
--Ion gas lasers - Cadmium is a metal, the lasing action in Helium Cadmium laser occurs between energy levels of singly ionized Cadmium atoms (Cd^+), so the lasing medium is ionized metal vapor.

The Helium-Cadmium (He-Cd) laser is one of a class of gas lasers using helium in conjunction with a metal which vaporizes at a relatively low temperature (250^0C). He-Cd laser is the only relatively economical, continuous-wave sources for violet-blue(442 nm) and ultraviolet(325 nm) output. At room temperature, cadmium is a metal. For lasing to occur, the metal must be evaporated from a reservoir, and then the vapor must be distributed uniformly down the laser bore. The excitation to the upper laser level of the Cadmium atoms in the gas is similar to the excitation process of the Neon gas in a He-Ne laser: Helium atoms are excited by collisions with accelerated electrons, and then they pass their energies to Cadmium atoms by collisions.

Lasing action in a Helium-Cadmium Laser

The lasing action in a He-Cd laser takes place as follows (see Fig. 2.12):

-Cd metal is heated in a gas discharge to a temperature of 250^0C to create the appropriate vapor pressure (few millitorrs).

-The cadmium vapor atoms must be both ionized and excited, which is achieved in a single step by energy exchange with excited helium atoms. The process is called Penning ionization and may be expressed as follows:

$$\mathbf{He^* + Cd \rightarrow (Cd^+) + He + e}$$

The electron released in this reaction carries away any energy difference between the two excited states [He is a noble gas, its excitation energy is very high (24.46 eV) compared to the Cd which is a metal with low excitation energy (8.96 eV)].

-Lasing can then take place between the initial Cd^+ excited states and some states nearer the Cd^+ ground state ($^2S_{1/2}$). About twelve lines in blue-violet and UV are available, but the two main lines are: 325 nm(UV), and 442 nm(blue).

-These states in turn return to the Cd ground state with an ion–electron recombination at the tube walls.

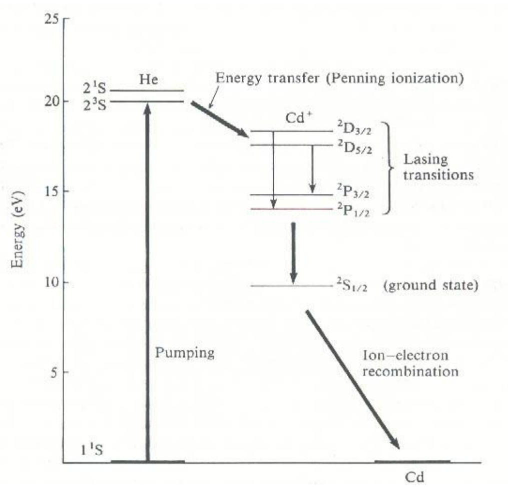

Fig.2.12 Energy level diagram of the He-Cd laser.

The He-Cd Laser Structure

A typical He-Cd laser structure is shown in Fig. 2.13. Although the He-Cd is still a gas laser, its construction is quite complex compared to, say, a common He-Ne laser tube. Cadmium is contained in a reservoir near the anode end of the plasma tube and heated in a gas discharge a temperature of 250^0C to obtain the appropriate vapor pressure (about 0.1 Torr). The helium gas at a pressure of few Torr (3–7 Torr) fills the cavity of the tube, while the positive Cd ions are moving toward the negative cathode. The practical problem in Helium-Cadmium laser is to maintain homogeneous distribution of the metal vapor inside the electrical discharge tube. The ions are attracted to the cooler cathode end of the tube, so the most of the effort in the design of the tube of He-Cd laser is to reduce to a minimum the amount of Cd ions on the cathode. The best He-Cd lasers lose about 1 gm Cd metal for 1000 hours of operation of the laser. Hence, Cd metal may have to be replenished from time to time. For this reason the cathode needs protecting from cadmium contamination and this is usually done by incorporating some form of cold trap just before it. Cold traps may also be needed to

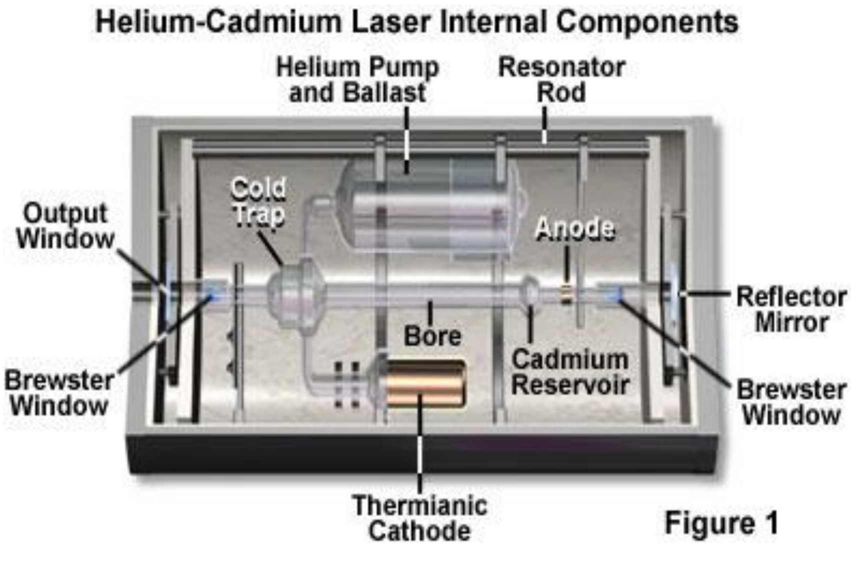

Fig. 2.13.Structure of an He-Cd laser.

prevent coating of the Brewster windows or end mirrors with cadmium. Additionally the helium itself can be lost by a number of processes including burial under condensing cadmium and cathode sputtering, and again some means of replenishment is necessary.

The output power of the He-Cd lasers is strongly affected by: plasma tube current, helium pressure and cadmium pressure. Regulation circuits are provided in the power supply to ensure that three parameters remain constant during the lifetime of the laser.

High reliability and long lifetime are obtained by: optimum choice of construction materials, careful design of the mechanical structure and of the cadmium vapor and helium pressure control circuits, and precise control of the manufacturing process.

Characteristics of He-Cd lasers

- Output wavelengths: Blue light 441.6 nm and Ultra-Violet (UV) light 325nm. The output wavelengths may be selected by changing dielectric coated mirror.
- Maximum output power: Higher output at 442 nm(150 mW in the blue line, and 50 mW at UV).
- Maximum total efficiency: 0.02% in the blue line, and 0.01% in the UV.
- Spectral width: 0.003 nm (about 5 GHz), and coherence length: about 10 cm of coherence length.
- Distance between two longitudinal modes: about 200 MHz.

The helium–cadmium laser combines features of three of the lasers considered so far, namely the He-Ne, the copper vapor and the argon ion:-Tube voltages and currents(about 100 mA) are very similar to the He-Ne laser, although the He pressure is somewhat higher (at around 6 torr). -The excitation to the upper laser level of the Cadmium atoms in the gas is similar to the excitation process of the Neon gas in a He-Ne laser. Helium atoms are excited by collisions with accelerated electrons, and then they pass their energies to Cadmium atoms by collisions but, here, the cadmium vapor atoms are both ionized and excited in a single step called Penning ionization while in He-Ne laser the Ne atoms are only excited by collisions with excited he atoms in a process called resonance energy transfer.

-The lasing wavelengths are in the shorter wavelength region(UV and blue-violet) than that of He-Ne laser(Red).

-The gain and the power output of the main two lines of He-cd laser(50-150 mW) are higher than that for He-Ne laser(0.5 to 50 mW) but less than that of Ar^+ laser(tens of Watts). Thus Cd^+ lasers are used for many applications where a blue or UV beam of moderate power is required.
-The efficiency of Cd^+ laser is much higher than that of the Ar^+ laser with which it is a competitor in certain applications. Hence, air cooling of the laser tube is sufficient.
- As in CVL, cadmium metal is heated in a gas discharge to obtain appropriate vapor pressure of about 0.1 Torr. The Cd metal is heated to 250^0C while the Cu in CVL is heated to a temperature between 1400^0C and 1500^0C to create the appropriate vapor pressure of about 0.1 Torr.

QUESTIONS

1. how could He-Cd laser be categorized?
2. How could you categorize He-Cd laser according to:
a. the emitted spectrum.
b. the mode of operation.
3. Discuss the lasing action in a He-Cd laser.
4. What are the lasing wavelengths of He-Cd laser?
5. What is the practical problem in He-Cd laser? How could we overcome this problem?
6. What is the function of the reservoir in He-Cd laser?
7. What is the function of the cold trap? Where it should be placed?
8. Is it necessary to replenish the He gas?
9. How could output wavelengths be selected?
10. Discuss how He-Cd laser combines features of He-Ne, copper vapor, and Ar^+ lasers?
11. What are the most important characteristics of He-Cd lasers?
12. Discuss how the output power of He-Cd laser is strongly affected by certain parameters?