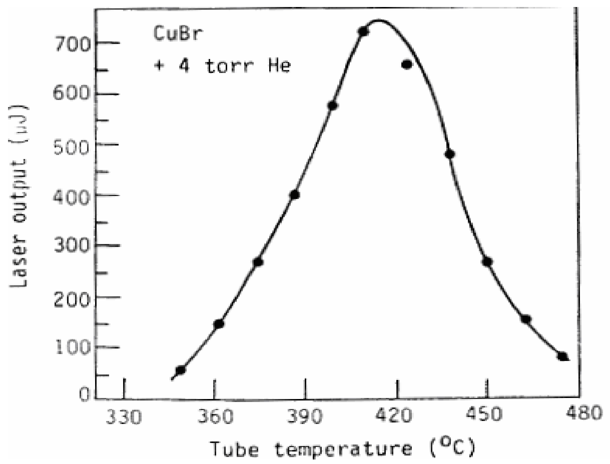


Fig.2.7:Dependence of laser output on tube temperature.

The main applications of Gold vapor laser are in the experimental cancer treatment of Photo-Dynamic Therapy (PDT).

QUESTIONS

1. What are the emission characteristics of the neutral metal vapor lasers?
2. Why does CVL become important at mid eighteens?
3. What are the CVL advantages over other visible gas lasers? Or, Why CVL is attractive?

Ans:

a- Exhibits very high gain → operate even without optical cavity.
(≈ 1% per mm)
→ Uncoated plane windows on the discharge tube serve as adequate "mirrors".

b- Prf : 2 - 100 kHz → higher than that of other high power visible laser.
: 5 kHz (typical)

c- high pulse power : P_{av} : 10 – 50 W
Peak power : 50 – 5000 kW

d- Its relative high efficiency : 1 – 2 % in the visible spectrum.
When P_{av} = few Watts → air cooling is sufficient

e- Pulse width : 5 – 60 ns.

4. Why high temperature is needed for CVL?
5. Why the CVL tube is made of high temperature resistant materials? What are these materials?
6. What is the function of the reservoir in CVL?
7. Why Ne gas at low pressure(25-50 Torr) is added in the tube of CVL?

Ans:
Neon gas acts as a buffer gas. The buffer gas is essential in a laser in which the electrodes and windows are cold.
The role of Ne gas in CVL are:
a- Prevents copper vapor from reaching and condensating on the tube windows.
b- Provides the discharge medium in the cold part of the tube.
The buffer gas (i.e., Ne) is the majority (Cu vapor pressure ≈ 0.1 Torr) of species in the hot region as well.
8. How could the output power be increased in CVL? Why?
9. What are the lasing wavelengths that could be obtained from CVL? Are these wavelengths compete with each other? Why?
10. How could the optimal ratio of powers in the two lasing lines be reached?
11. What are the most important properties of CVL?
12. What are the most important applications of CVL?
13. Is it possible to achieve lasing at lower temperatures than 1450^0C?
14. Why CVL is restricted to pulsed operation?

2.5 Ionized Gas Lasers

Here we turn to a gas laser where the transitions are between the electronic energy levels of an ion. The most common ionized gas lasers are from the noble gases Argon (Ar^+) and Krypton (Kr^+)[almost all commercial ion lasers manufactured today are CW Argon and Krypton lasers].We shall concentrate on the Argon Ion laser since it is more common. Also, many metals in addition to gases operate as an ion lasers when vaporized (41 elements like mercury, selenium, gold, cadmium, etc..) but only He-Cd laser is a commercially available laser.
Ion lasers produce : a large number of high power lasing wavelengths ranging from the ultraviolet, through the visible, into the near infrared portion of the spectrum. Ion lasers are compact for the amount of laser power they generate relative to other types of visible lasers.

2.5.1 Argon Ion (Ar^+) Gas Laser

The Argon laser was invented in 1964 by William Bridges at Hughes. Argon ion laser contains a tube filled with Argon gas which transforms into plasma in an excited state (Plasma is a state of matter in which the electrons are separated from the atoms and molecules, which means that it contains free electrons and ions). A schematic diagram of the energy levels of the Argon laser is shown in figure 2.8. As usual the excitation takes place within a gas discharge. Firstly the neutral argon atom is ionized, which requires energy of 15.75 eV(this is a large amount of energy that must be supplied to the laser but is not used for creating laser radiation, i.e., this is a wasted energy). Then the ion is further excited to a group of levels 19.68 eV above its ground state.

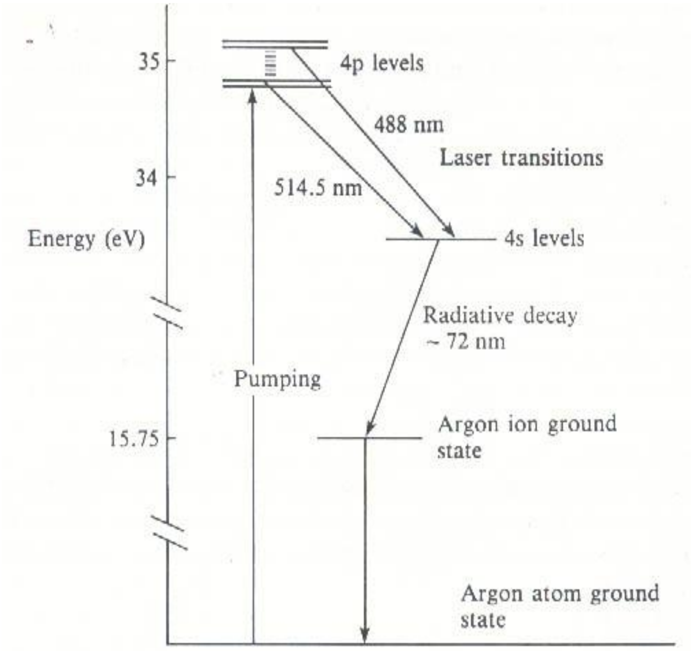
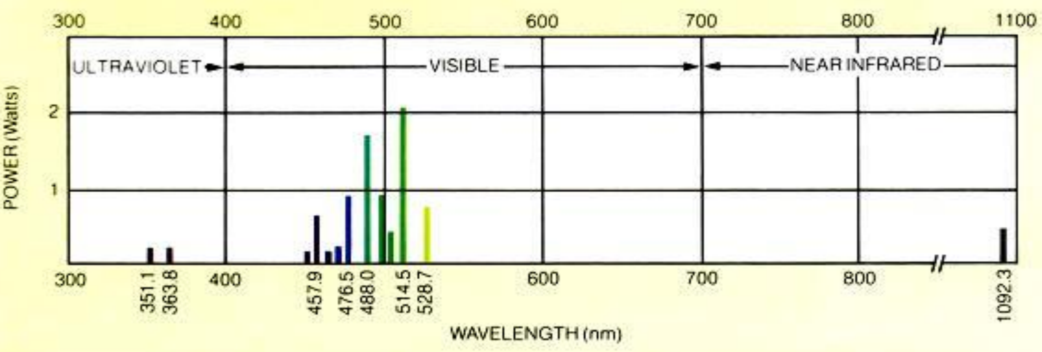


Figure 2.8: Energy Level Diagram of Ion Argon Laser.

Transitions take place between the 4p and 4s levels, resulting in a group of different lines through the UV and visible spectrum that may be emitted simultaneously. The two main and most intense laser transitions are at visible wavelengths: Blue 488 nm and Green 514.5 nm. Argon ion laser emits also in the UV spectrum: 351.1 nm and 363.8 nm.

Argon ion lasers produce the highest visible power levels and have up to ten lasing wavelengths in the blue and green portion of the spectrum.

The chart below shows the typical lasing wavelengths and relative power levels obtainable from a 4-Watt size argon laser.



Typical lasing wavelengths and relative power levels from a 4 Watt size Argon laser

Argon (Ar^+) laser efficiency

The relatively large excitation energies and the fact that a two–stage process is involved would lead us to expect a rather low overall power efficiency for this laser, and indeed typical values are only a few hundredths of a percent.

Power Output from Argon Laser

The gain of the active medium in Argon ion lasers is very high, so high power can be achieved from Argon ion lasers (tens of Watts), although as we saw, with low efficiency. The output power increases as a nonlinear function of the current density in the tube. Thus it is common to use narrow tubes (small cross section) and very high current densities (100-500 A/cm^2). The specific power output of the Ar^+ laser could be given by the following empirical equation:

$$\mathbf{P/V = 10^{-5} \times J^2 \ W/cm^3}$$

Where P/V is the power (P) emitted per unit volume (V) of the gas, and J is the current density (I / area, in units of A/cm^2) in the tube.

From the above equation, the following three conclusions could be obtained:

1. The output power increases as a nonlinear function of the current density in the tube. Thus to maximize the power output, the current density in the laser tube must be as high as possible(of the order of 100-500 A/cm^2).

2. Output power varies roughly with the square of the tube current ,thus doubling the current, for a certain ion laser, would produce four times the output power.

3. Ion lasers are constructed to have the smallest bore diameters possible (of the order of 0.5- 2 mm) without introducing excessive diffraction loss. i.e., smaller bores produce higher powers for the same current values.

Example. If the tube diameter, D= 0.4cm, I= 50A, tube length. L=71cm. Then the cross-sectional area, $A = \pi D^2 / 4 = 0.13\ cm^2$ .Tube volume, V= 0.13 x 71 = 9.23 cm^3 and the current density, $J = 50 / 0.13 = 385\ A/cm^2$.

$P/V = 10^{-5} (385)^2 = 1.48\ W/cm^3$.

$P = 1.48 \times 9.23 = 13.7\ W$.

When considering the power output of the Argon laser, it is important to state if the power output is at all the laser lines together(i.e., multiline output), or at a specific wavelength. By using mirrors that are sufficiently reflective over a wide wavelength range output can be obtained at a number of wavelengths simultaneously; the highest–power argon ion lasers are operated in this way because the multiline output power is the sum of the powers in all the wavelengths that are simultaneously present in the output. Some applications require specific wavelength (single line operation) which can be achieved by introducing a tuning element, such as a prism or grating, at the end of the optical cavity as shown in the lower part of figure 2.9.

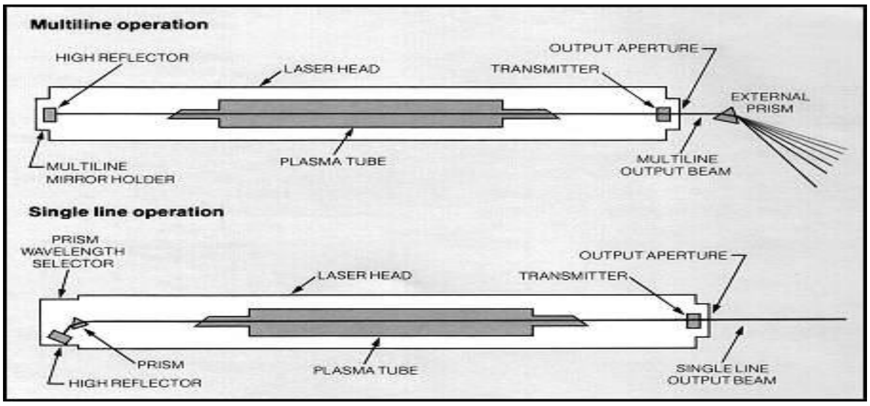


Figure 2.9:The optical configuration of a basic multiline and single line.