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Distribution of Atomic and Ionic Densities in Copper Vapour Laser at Different Electron Temperatures

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Abstract:

Copper Vapour Lasers are high power, pulsed lasers that operate on the basis of transitions in copper atoms and ions. The performance of copper vapour Laser is critically dependent on the atomic and ionic densities in the gain medium. In this paper, the theoretical study of atomic and ionic densities in a copper vapour laser at different electron temperatures is presented. The results show that the atomic and ionic densities vary significantly with electron temperatures. The radial profiles of the electron temperature in the discharge are assumed to be given by the equation

$$T(R) = T_0 [1 - (R/R_0)^2] \quad \text{.... (1)}$$

Where T_0 is the axial temperature in eV
R is radial distance
R_0 is the radius of the discharge tube

Keywords: Copper Vapour Laser, Laser Radiation, Inversion Density.

Introduction:

The Copper Vapour Lasers are high power, pulsed lasers that operate on the basis of transitions in copper atoms and ions. The Copper Vapour Lasers have number of applications, including material processing, spectroscopy and medicine. The performance of copper vapour laser is critically dependent on the atomic and ionic densities in the gain medium.

Theory:

The laser medium is mixture of electrons, atoms and ions. The densities of these particles were found non-uniform in different parts of the discharge tube. As a result of which the plasma gets heated to different extent. This non-uniform heating of the plasma gives rise to variation of parameters across the discharge tube.

Izawa et al [1] in 1989 carried out some measurements for the radial profiles of densities of the laser state. The measurements were carried out in the Copper Vapour Laser discharge tube of diameter 4.2 cm. It showed that the radial profile show dip on the axis of the discharge tube. Moreover, they also observed that density of upper laser level showed slight radial dependence.

The radial profiles of densities of Cu I, Cu II and Cu III for different electron temperatures on the axis of tube where obtained. The results are displayed in Fig. 1, 2, and 3 respectively. When there is no discharge current passing through the laser medium, the entire copper is in atomic state and it is represented by horizontal line parallel to X-axis as shown in Fig. 1. If the electron temperature increases, the atomic copper on the axis of the discharge tube is converted into slightly ionzed copper. The ionization is maximum at the axis because the electron temperature is maximum at the axis of the discharge tube. The electron temperature goes on decreasing towards the wall. Therefore, the ionization also decreases towards the wall. The density of copper at goes on increasing from axis towards the wall. Further increase in electron temperature increases the ionization rate and more and more copper get ionized. As a result of this the density profile goes on deepening on the axis and the width of the well increases with increasing temperature.

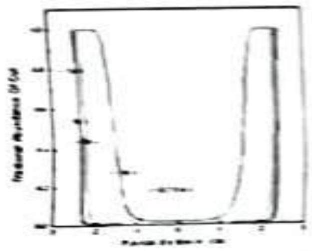


Fig 1 Normalised radial profile of fractional abundance of neutral copper for different electron temperature on the axis of the discharge tube

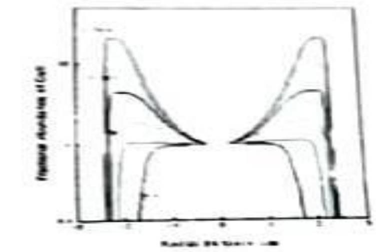


Fig 2 Normalised radial profile of fractional abundance of CuII for different electron temperature on the axis of the discharge tube

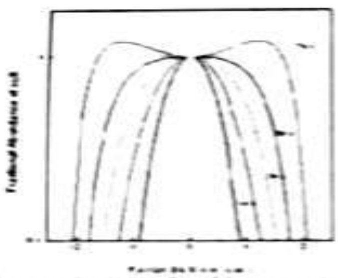


Fig 3 Normalised radial profile of fractional abundance of CuII for different electron temperature on the axis of the discharge tube

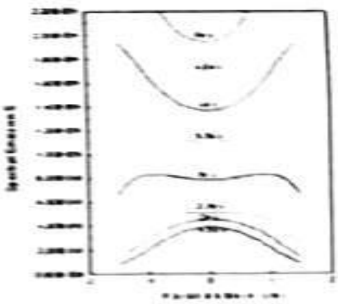


Fig4 Radial profile of spectral emission of ^2P — ^2D transition of the discharge at various electron temperature on the axis

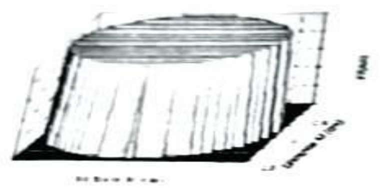
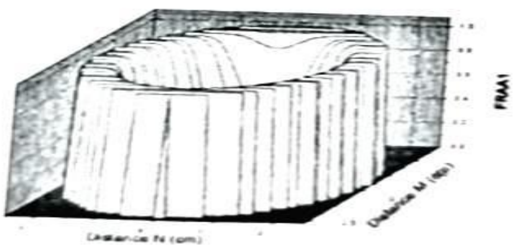


Fig 5 Radial distribution of copper atoms in the discharge tube for temp on the axis = 0.25 eV

Fig 6 Radial distribution of copper atoms in the discharge tube for temp on the axis = 0.75 eV



At low temperatures very few atoms on the axis of discharge tube get ionized and Cu II shows its appearance. The radial profile of Cu II at low temperature is bell shaped as shown in Fig. 2. The width of the bell goes on increasing as the temperature at the axis increases. When the temperature is further increased a step comes and the top of the bell gets broadened and the starts showing dip on the axis. The dip goes on deepening as the electron temperature is increased to higher values and the two side peaks shift towards the walls. The radial profiles of Cu III in Fig. 3 shows the same behavior as those of Cu III except the electron temperature at which the profile starts showing dip on the axis. The radial profiles have different shapes for different electron temperatures at the axis and the electron temperature does not remain uniform during the evolution of discharged pulse. as the electron temperature on the axis of the tube goes on increasing, the fractional density of the copper atom goes on decreasing and at the axial temperature of above 1.0 eV, the copper density decreases further and the fractional density of ionized copper atoms show its appearance.

Results:

The atomic and ionic densities in copper vapour laser at different electron temperatures are shown in figures above.

The radial profiles of the atomic density as function of electron temperature, the atomic density decreases with increase in electron temperature.

The ionic density as function of electron temperature, the ionic density decreases with increase in electron temperature.

Discussion:

Results show that the atomic and ionic densities in a copper vapour laser vary significantly with electron temperature. The optimal electron temperature for copper vapour laser is around 5000 K, where atomic and ionic densities are optimized.

Conclusion:

The theoretical study of atomic and ionic in copper vapour laser at different electron temperatures is presented. Results show that the atomic and ionic densities vary significantly with electron temperatures.

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