RADIAL DISTRIBUTION OF COPPER ATOM AND SINGLY IONIZED COPPER IONS IN THE DISCHARGE TUBE OF CVL FOR VARIOUS ELECTRON TEMPERATURES ON THE AXIS

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Abstract : In order to calculate the power delivered by the laser discharge column it is essential to study the variation of the densities and other parameters along the radius of the tube which are known as radial profiles. The investigation of the radial distribution of the densities and spectral emission in the discharge gives large amount of information. The temporal profiles also provide information about the physical processes taking place in the discharge. The designing of the oscillator amplifier configuration need knowledge of the spatial distribution of copper atoms and the electron temperature. With this information the radius of the oscillator and the amplifier tube are determined. Unless the designer has the knowledge about the plasma conditions, the efficient amplifier configuration cannot be built

***Key Words* - radial profiles, spectral emission of discharge, temporal profiles, electron temperature**

I. INTRODUCTION

The gas laser medium in the discharge tube consists of mixture of electrons, atoms and ions of rare gas as well as active materials. The densities of these particles are found to be non uniform in the different parts of the discharge tube. As a result of this different parts of the plasma get heated to different extent. This non uniform heating of plasma gives rise to variation of plasma parameters across the discharge tube. This plasma parameter affects the contribution of the excitation process to the laser plasma output. In order to calculate the power delivered by the laser discharge column it is essential to study the variation of the densities and other parameters along the radius of the tube which are known as radial profiles. The laser discharge is characterized by several profiles. The important among them are radial profiles of densities of electrons, atoms and ions. The radial profiles of the electrons and ion temperature plays vital role. Several radial profiles in the gas discharge laser and the plasma like Tokomak plasma have been experimentally observed by several workers [1-10].The radial profiles in the Tokomak plasma have been investigated in detail to study the heating of the plasma, the impurity losses of the plasma. To increase the laser power it was thought that increasing the diameter of the discharge tube would increase the laser power. However the increase in the diameter tube posed other problem like annular shape of the beam, reduction in the total output power. Kushner and Warner [11] showed that annular shape of the laser beam is due to Skin effect.

Izawa [12] carried out measurements of the radial and temporal profiles of the densities of the laser state.. The measurements of spatial profiles showed that the profiles show a dip on the axis before certain time after firing of the discharge pulse and then the profile do not show any dip. For the time less than 50 nanoseconds after firing of the discharge pulse the profiles show dip and at later the profiles show peak on the axis. They observed that density of the upper laser state show slight radial dependence

In the present work we have investigated the radial and temporal profiles in the CVL discharge. We have divided the work into two categories as the radial profiles of the discharge parameters like the electron density, electron temperature copper atom and ion densities and the profiles of the spectral emission. The variation of electron temperature across the discharge plays a vital role in the determination of the shape of the various radial profiles. Therefore an appropriate temperature profile must be considered. The fractional abundance in the gas discharge is mainly determined by the electron temperature. In fact electron temperature is the fundamental parameter of the laser plasma which is determined together by the accelerating electric field, collision between particles and cooling of the plasma electrons due to walls. The radial profile of the electron temperature in the discharge tube is assumed to be given by following equation

$$T(R) = T_0 \{1-(R/R_0)^2\}$$

where T_0 is axial temperature in eV ,R is radial distance at a point in the tube and R_0 is radius of the discharge tube.

The radial profile of the electron density is also assumed to have shape similar to the zero order Bessel function of first kind. Therefore for our present calculations we assume these profiles to have the same shape as that of electron temperature profile.

II RESULTS AND DISCUSSION

Radial profiles of Densities

In order to get clear idea about the distribution of the densities in the discharge tube, we have studied the three dimensional appearance of the radial profiles of the ions CuI, CuII and CuIII at different electron temperatures on the axis. The three dimensional representation of the densities as a function of the radial distance are displayed in different figures. When there is no discharge current passing through the laser medium entire copper is in the atomic state. As the electron temperature is increased, initially the atomic copper along and near the axis of the discharge tube is converted into singly ionized copper. Further increase in the electron temperature increases the ionization rate and more copper get ionized. The density profile goes on deepening on the axis and the width of the well go on increasing as the temperature is increased. This can be observed from the figures 1, 2 and 3 for the electron temperature on the axis as 0.5 eV, 1 eV and 1.5 eV respectively.

At low electron temperature very few atoms on the axis of the discharge tube get ionized and CuII shows its appearance. The radial profile of CuII at low electron temperature is hill shaped. The width of the hill goes on increasing as the temperature on the axis increases. The hill shaped distribution shows a flattening on the axis at the temperature of about 1.5 eV. The distribution shows deepening on the axis at about the electron temperature of 2.5 eV. This can be observed from the figures 4, 5 and 6 for the electron temperature on the axis 0.5 eV, 1.5 eV and 2.5 eV respectively. The figures 7, 8 and 9 are the radial profiles of CuIII for the electron temperature on the axis 2 eV, 4 eV and 6 eV respectively. At low electron temperature the radial profile of Cu II is again hill shaped. This can be observed from figure 7 for 2 eV electron temperatures on the axis. The width of the hill goes on increasing as the electron temperature on the axis is increased. When temperature is further increased, a stage comes and the top of the hill gets broadened and the curve starts showing dip on the axis. The dip goes on deepening as the electron temperature is further increased to the higher values and the two side peaks shifts towards the wall. This can be observed from the figures 8 and 9 for the electron temperature on the axis 4 eV and 6 eV.

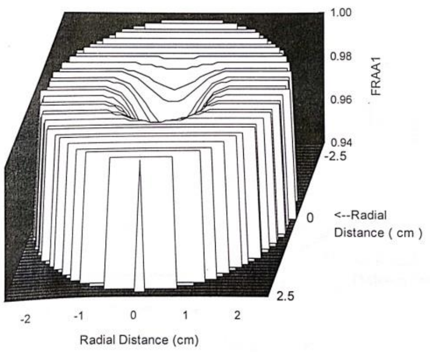

Fig.1 Radial distribution of Copper atoms (CuI) in the discharge tube for the electron temperature on the axis =0.5eV

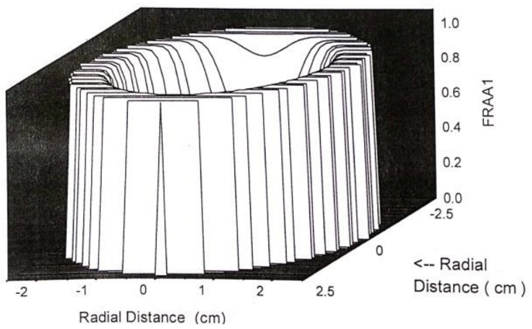

Fig.2 Radial distribution of Copper atoms (CuI) in the discharge tube for the electron temperature on the axis =1eV

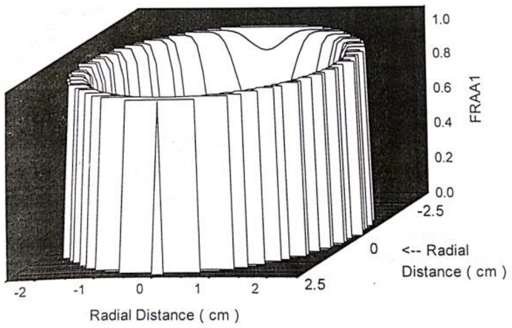

Fig.3 Radial distribution of Copper atoms (CuI) in the discharge tube for the electron temperature on the axis =1.5eV

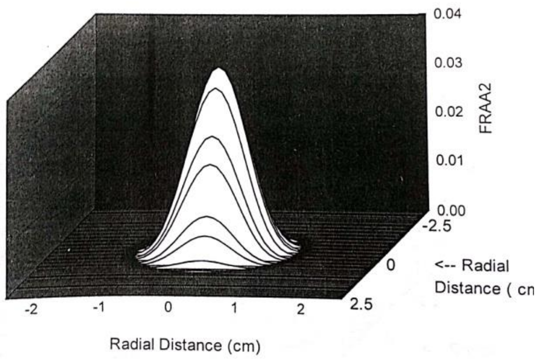

Fig.4 Radial distribution of singly ionized Copper ions (CuII) in the discharge tube for the electron temperature on the axis =0.5eV

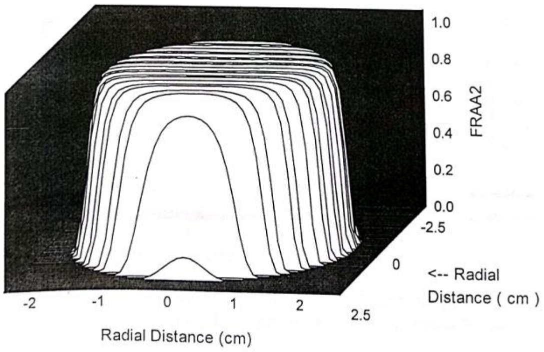

Fig.5 Radial distribution of singly ionized Copper ions (CuII) in the discharge tube for the electron temperature on the axis =1.5eV

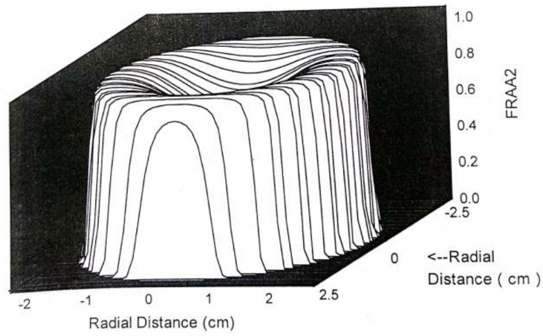

Fig.6 Radial distribution of singly ionized Copper ions (CuII) in the discharge tube for the electron temperature on the axis =2.5eV

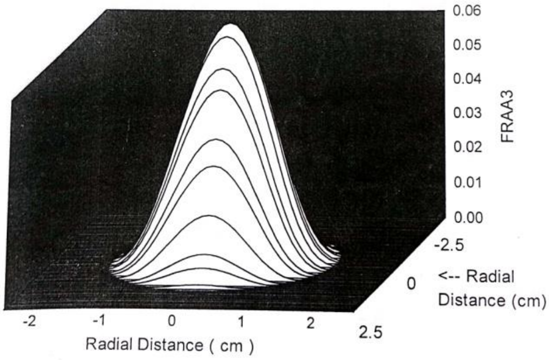

Fig.7 Radial distribution of doubly ionized Copper ions (CuIII) in the discharge tube for the electron temperature on the axis =2eV

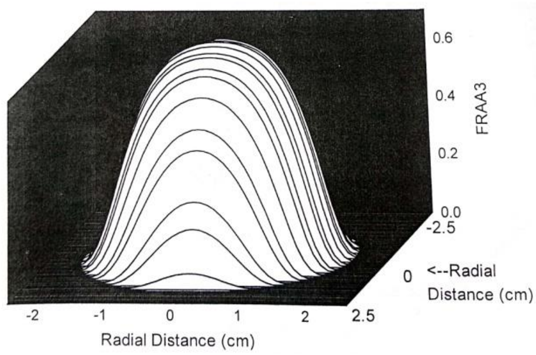

Fig.8 Radial distribution of doubly ionized Copper ions (CuIII) in the discharge tube for the electron temperature on the axis =4eV

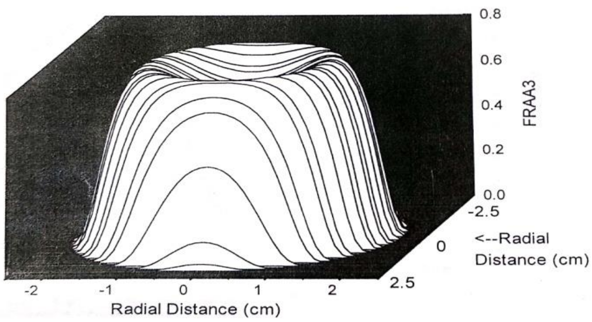

Fig.8 Radial distribution of doubly ionized Copper ions (CuIII) in the discharge tube for the electron temperature on the axis =6eV

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