POWER DISTRIBUTION ACROSS THE OUTPUT LASER BEAM FOR DIFFERENT TEMPERATURES ON THE AXIS OF THE DISCHARGE TUBE

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Abstract : The annular shape of the output laser beam has its origin in the radial distribution of the electron temperature and electron density as the electron impact excitation is the dominant process of excitation. In the present paper we have tried to show the reasons behind the annular shape of the laser beam.

Key Words **- radial profiles of the spectral emission, electron impact excitation, fractional abundance**

I. INTRODUCTION

The parameters which influence the laser output power do not have uniform value along and across the discharge tube. The factors that influence the laser output power are electron temperature, electron density, copper atom density etc. Thus the total power output would be summation of all such contributions. As the discharge tube employed for operating discharges is cylindrical the plasma column is also supposed to have cylindrical symmetry. We assume that radial profiles of electron temperature and electron density to have shape like zero order Bessel's function of first kind with maxima on the axis of the discharge tube. The simulating radiations travelling parallel to the laser axis and perpendicular to the mirror plane are the most effective because the radiation travelling in the other direction may be treated as oblique radiation and they escape laser cavity after travelling certain distance through the laser plasma column. Thus the volume element parallel to the tube axis and perpendicular to the mirror plane is responsible for the intensity of the out coming laser radiation at a particular position.

The first CVL was invented in 1966 by Walter [1] having average power of 20 mW at 660 Hz. The discharge tube of diameter 1 cm length and length 80 cm was used since then number of workers in the field have put in their efforts to increase the laser power and the quality of laser output power [2-6].Consequently the laser average power of 100 W at 5 KHz pulse repetition rate was obtained from 8 cm diameter tube. The increase in the average power was due to increase in the pulse repetition rate, more sophisticated discharge circuit and thermo design and volumetric scaling of the discharge region. It was thought that the power can be increased by increasing the volume of the laser medium. This can be achieved either by increasing the length or by increasing the diameter of the discharge tube. The length of the laser plasma can be increased by increasing the length of the discharge tube but it is limited by the available high voltage pulse technology and the inversion life time of the laser transitions. Thus the length of the discharge tube must be optimum so that the laser radiation should come out from before the inversion density is exhausted. The volume of the discharge plasma can also be increased by increasing the diameter of the tube but it leads to the generation of the annular shape of the laser beam. Due to these reasons the volume of the discharge tube has to be fixed to a certain fixed value. The output power can be increased by increasing the density of the medium. But the increase in the density is limited by voltage available for firing of the discharge. The average laser power can be increased above the limit by increasing the pulse repetition rate. Increase in the pulse repetition rate decreases the time between two consecutive pulses. As a result of this succeeding pulse sees high metastable state density left by previous pulse. The increase in the metastable state density decreases the pulse peak power..The output laser power would be made proportional to the volume of the laser medium provided that the density of the copper atoms, density of the electrons and the electron temperature are uniform along and across the discharge tube. But several experimental studies have shown that the parameters responsible for the excitation of the laser state do not have uniform values across the discharge tube. As a result of this laser beam does not have uniform power across it. Several workers in this field have observed that the laser output is annular in shape. Kushner and Warner had studied the annular shape and they explained the origin of annular shape in the output of the laser beam is due to Skin Effect. Hayashi [7] had studied the annular shape of the beam. He used neon as a buffer gas and studied the effect of hydrogen on the annular shape of the beam. As the charging voltage is 20 KV the beam is less annular. As the charging voltage is increased to 21 KV, the beam becomes more annular and at charging voltage is increased to 22 KV the beam becomes completely annular. He found that beam becomes more annular as the charging voltage is increased because of increase in the metastable density. At 20 KV charging voltage the leading part of the pulse is more annular than the lagging part of the pulse. At 22 KV charging voltage, when hydrogen was added to the discharge the beam becomes less annular. The phenomenon of annular shape was attributed to the high thermal conductivity of hydrogen. Because of high thermal conductivity of hydrogen, the metastable density increases and laser output power decreases.

Annular Shape Of The Laser Beam

In order to study the annular shape of the laser beam in detail we have studies the radial profiles of the spectral emission of the discharge at laser wavelength in detail. The laser action in CVL is observed on two transitions of the copper atom. Higher copper densities would be favored for getting high power from the laser medium. In the calculations of the radial profiles of the spectral emission of the discharge we had considered the contribution of only electron impact excitation as it is the most dominant process of excitation compared to other processes of excitation. The excitation of a state by the electron impact excitation process is equal to $Cu^{*}R_{u}n_{e}$. When the discharge is in the steady state the rate of emission of radiation at a certain wavelength is equal to the rate of excitation of upper state of transition emitting the radiation at that wavelength. Thus the intensity of the spectral emission at wavelength λ would be proportional to $Cu^{*}R_{u}n_{e}$. The study of the variation of these parameters gives the radial profiles of the spectral emission. The values of the radial profiles are evaluated by using the values of fractional abundance of CuI at some particular electron temperature and corresponding electron impact excitation coefficient values at that temperature.

II. RESULT

We have studied the radial profiles of spectral emission for different axial temperatures and the results are displayed in the figures 1, 2, 3 and 4. We have considered a square array of 5 cm x 5 cm. At the centre of the array we have considered the origin of the system. The axis of the discharge is supposed to be coinciding with the origin. The distance of any point x(m,n) from the axis is calculated by drawing the radius vector R from the origin to that point by the formula $R= (m^2+n^2)^{1/2}$. We have computed the intensity at different points around the axis and the results are displayed in the figures.

The radial profiles of spectral emission for axial electron temperatures 0.5 eV are displayed in the figure 1. The intensity profile shows a peak on the axis. As we move away from the axis the intensity gradually decreases and attains zero value. This is because the fractional density of neutral copper atoms is reasonably high along the axis of the discharge tube for low electron temperature like 0.5 eV and the EIE rate coefficient is maximum. The fractional density of the neutral copper atom decreases as we move away from the axis. The intensity profile shows a Gaussian shape for 0.5 eV electron temperature on the axis.

The radial profiles of spectral emission for axial electron temperatures 4 eV are displayed in the figure 2. The intensity profile shows a dip on the axis with two side peaks. It is a well shaped structure. This is because the fractional abundance density of neutral copper atoms get converted into highly ionized species. The profiles of neutral copper shows well shaped structure at the electron temperature 4 eV on the discharge axis. The fractional density of the neutral copper atoms shifts towards the walls of the discharge tube. Hence the spectral intensity profile shows annular shape.

The radial profiles of spectral emission for axial electron temperatures 7 eV are displayed in the figure 3. The intensity profile shows a dip on the axis with two side peaks. The dip on the axis is further deepened and the two side peaks have shifted more towards the walls of the discharge tube. Due to the reason explained above the annular shape of the laser beam is more prominent in this case.

We have obtained an interesting profile of the spectral emission for the axial temperature 1 eV. The corresponding results are displayed in figure 4. The intensity is maximum on the axis. As we move away from the axis initially the intensity decreased slightly, becomes minimum and then it increases and attains the maximum value, then further decreases gradually attains zero value. The computation shows very good agreement with the experimental results of Izawa [8]. The discharge pulse has a fast rise time so the electron temperature also increases rapidly and then decreases slowly. It is implied that the electron temperature is maximum when the discharge pulse is fired and as time advances the electron temperature decreases.

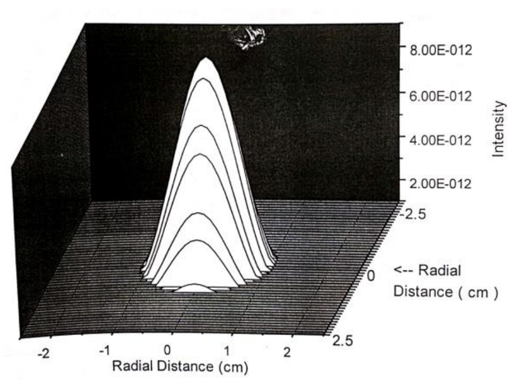

Fig.1 Power distribution across the output laser beam when temperature = 0.5eV on the axis

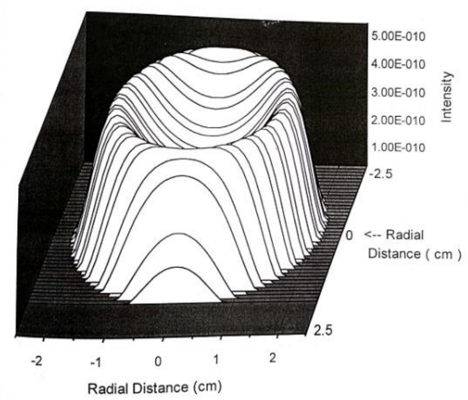

Fig.2 Power distribution across the output laser beam when temperature = 4eV on the axis

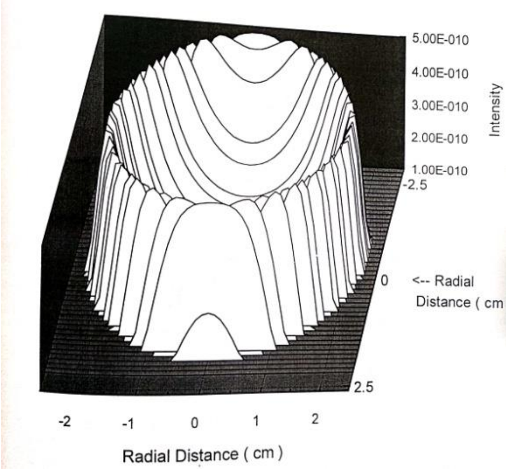

Fig.3 Power distribution across the output laser beam when temperature = 7eV on the axis

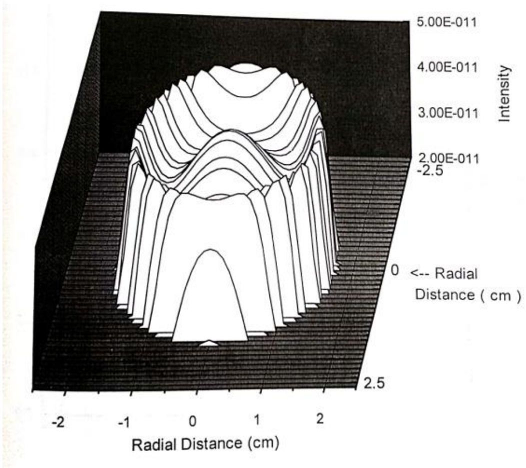

Fig.4 Power distribution across the output laser beam when temperature = 1eV on the axis

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