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Temporal and Spatial Distribution of Output Power from Different Electron Temperature in Copper Vapour Laser

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ABSTRACT

We have investigated the radial profiles at different times during the formation of the laser pulse. It is found that the radial profile of the spectral emission is not same at all the times during the formation of the laser pulse. The radial profile go on changing the shape as a function of time. During the formation of a laser pulse the electron temperature dose not remain same consequently the radial profile of spectral emission also change. In some cases, when the electron temperature is relatively low, the radial profiles are almost Gaussian at all the times, however the peak height goes on changing. In some other cases in a part of the beam the radial profiles are like Gaussian and in remaining part they exhibit dip non-Gaussian distribution. If the exciting pulse parameters are change the profiles remains non-Gaussian through out the formation of a beam. If the temperature is made very high beam may become annular in shape.

I. INTRODUCTION

The CVL (Copper Vapour Laser) is well recognized source of light delivering pulsed laser beam at 5106 and 5782A at the pulse repetition frequency more than 5 KHz with power levels up to about 100 watts or more. The CVL has been successfully applied in the fields like medicine (Ainsworth and Piper 1989[1]), isotope separation, under water ranging, high speed photography, micromatching[2-3,4,], drilling and cutting[2,3] etc. The high power, high energy and high precision CVL are needed by the research workers in different fields of applications.

The design calculations of the high power and high precision lasers need the detail information about the parameters like electron temperature, electron density, ion density, fractional abundances, electron impact excitation etc. The spatial and temporal profiles of these parameters, also must be known in order to design efficient and sophisticated laser systems. The technique of volumetric scaling of the laser output power also needs the detailed study of the spatial profiles of the parameters in the laser discharge. Furthermore, the investigations of the spatial distribution of the density and spectral emission (Kushner and Warner 1983[6], Carman et al. 1994[7],) in the discharge gives large amount of information about various mechanisms taking place in the discharge. With the help of the knowledge of the radial profiles the total output power calculation also may be carried out and the power distribution across the laser output beam also may be obtained. The use of the efficient data acquisation system for monitoring the discharge parameters may give the desired data for the analysis of several processes taking place in the discharge. This is because of the fact that in case of temporal and radial profiles the fundamental parameters like discharge current, the discharge voltage, the electron temperature, electron density, ion density varies from zero through their maximum values. In design of amplifier oscillator configuration system the detailed knowledge of the spatial distribution of the densities is very much important because different parts in the discharge tube have different densities and inversion times. Therefore, the study of the spatial and temporal profiles of the parameters is very much essential.

In the present work we calculate fractional abundances of CuI (copper atoms), CuII (singly ionized copper atoms), CuIII (doubly ionized copper atoms) and CuIV (triply ionized copper atoms) as a function of electron temperature. The electron impact excitation rate coefficients are also obtained as a function of electron temperature from zero through 10ev. The radial profiles of the densities of the electronic states $^2P_{3/2}$ and $^2D_{5/2}$ of CuI are obtained as a function of electron temperature at the axis of the discharge tube. The radial profiles of the spectral emission of the discharge are also obtained. The temporal and spatial distribution of the laser output power are studied in details. The present results are compared with the experimental results of the research worker in the field. When the discharge pulse is fired the electron temperature is maximum as the electric field is maximum. Afterwards the time passes the electron temperature go on decreasing. The temporal profiles of electron temperature is assumed to be exponentially after firing the discharge pulse decreasing and power distribution along and across the laser beam are obtained[8,9].

II. RADIAL PROFILES OF SPECTRAL EMISSION

Under the steady state condition rate of decay of density of atomic level is equal to the rate of electron impact excitation of the level and therefore, if the laser plasma is considered to be in the steady state, the radiation emitted by a volume element because of a transition starting from a level is proportional to the factor N_{cu} N_e R where N_{cu} is the density of copper atoms, N_e is the density of the electrons and R is the electron impact excitation rate coefficient of the upper level of the transition. If the radial profiles of electron density, neutral copper density and the excitation rate is known, the radial profiles of the spectral emission may be obtained.

While building up of the discharge current pulse, the rate of excitation and ionization would be more than the rate of decay and recombination consequently the densities of highly ionized species go on increasing. While cooling of the discharge electrons the rate of decay and recombination would be more than the rate of excitation and ionization consequently the densities of less ionized species go on increasing. The computation of the factor N_{cu} N_e R_u for different values of the radial distance would give the radial profiles of spectral emission.

III. VARATION OF OUTPUT POWER ALONG AND ACROSS THE LASER BEAM

If the pulse forming network is having low impedance the rise time of the pumping pulse may be of the order of few nsec. When the discharge pulse is fired the plasma electrons get heated suddenly to a high value within about 5-10 nsec because of the process of acceleration of electrons by the electric field generated by pump pulse. As time passes the plasma electrons undergo collisions with other particles and discharge tube wall and consequently start getting cooled. We have studied the temporal behavior of the spectral emission of the discharge pulse from the knowledge of radial profiles of spectral emission[10]. And decay time is assumed to be of the order of 120 nsec. In most of the CVL systems the heating time is shorter than the cooling time τ. The temporal behavior of the electron temperature is assumed to be given by the expression

$$T_0 = T_{inio} \exp(-t/\tau) \qquad (1)$$

Where T_{inio} is the initial electron temperature at the axis i.e. the electron temperature when the discharge pulse is fired and the plasma gets heated to maximum temperature. T_0 is the temperature at the axis of the discharge tube at the time t. The temperature T_0 at the axis at any time t may be obtained using equation (1).

IV. RESULTS AND DISCUSSION

We compute the temporal profiles of the spectral emission of the discharge for the initial electron temperature T_{into} = 2, 4, 6, 8, and 10 eV and the results are displayed in the figures. 1, 2, 3, 4 and 5 respectively. For the low initial electron temperature (2eV) the radial profile of the spectral emission is almost Gaussian in shape and remains Gaussian during the building up of complete output pulse. Initially the peak intensity is low, then it increase reaches its maximum value and then go on decreasing.

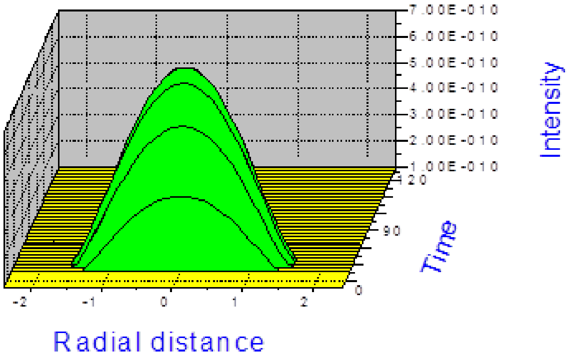

Figure 1. Temporal and Spatial distribution of laser output power for initial electron temperatureT_{in}=2eV

When the electron temperature at the axis is 4eV the radial and temporal profiles change their shapes. In the leading portion of the beam the profile shows dip at the axis and two side peaks. In the lagging portion of the pulse the radial profiles are flat. The dip at the axis is exhibited for about 25 nsec after the laser pulse starts building up after firing of the pumping pulse.

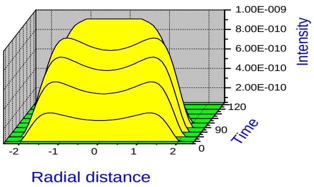

Figure 2. Temporal and Spatial distribution of laser output power for initial electron temperatureT_{in}=4eV

The computation of radial and temporal profiles at 6eV exhibits entirely different shape. The leading part of the beam becomes completely annular. The beam coming after about 15 nsec shows the dip at the axis. At later times the radial profile go on changing the shape and the dip in the profile go on becoming shallower. It is noticeable that at all the times during the emission of output pulse the radial profiles exhibit the dip at the axis when the initial temperature at the axis is 6eV. The dip go on decreasing from leading part to the lagging part. For the initial electron temperature of 8eV the beam remains annular for considerably longer time duration and the radial profiles exhibit dip at the axis and the dip go on becoming shallower in the lagging part of the beam. For initial electron temperature of 10 eV the beam becomes completely annular. We investigate the diameter of the annular beam by changing the electron temperature in the neighborhood of 10eV.

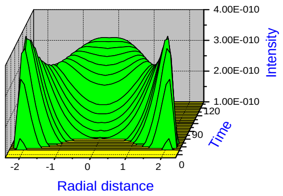

Figure 3. Temporal and Spatial distribution of laser output power for initial electron temperatureT_{in}=10eV

It is found that the diameter of the ring of the radiation is determined by the initial electron temperature at the axis. If the electron temperature is increased the diameter of the ring increases. The computed results are compared with the experimental results of Hayashi et al (Hayashi et al 1992)[11]. The profiles in the Hayashi et al experiment are measured at different charging voltages 20, 21 and 22 kV respectively. They have measured one more temporal profile by adding hydrogen gas to the dischargeby keeping the charging voltage 22kV.

V. REFERENCES

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