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The divergence of the laser beam emitted by this segment would have less angle of divergence because the plasma has less thickness

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Abstract:-

The angle of divergence of output beam are different for Copper Vapour Laser and pulsed laser. The angle of divergence determine the photon flux when the beam is focused using focusing optics. Further the output beam is focused the diverging beam converges and get focused at the same point. In the present work, the analytical expressions are obtained for the peak power output of the CVL without mirror, the intensity of the laser radiation across the laser beam and peak power angle of divergence along the diameter of the discharge tube. The angle of divergence is determined by the absorption coefficients, initial inversion density and the dimensions of the laser plasma column in a direction perpendicular to the direction of propagation of the beam. The angle of divergence also increase with the dimensions of the plasma column in a direction perpendicular to the direction of propagation of the beam. From the calculation of peak power across the laser beam desired angle of divergence may be obtained. The half peak power angle of divergence for initial inversion density 0.2 and 0.4 are 20mrad and 30mrad respectively in Copper Vapour Laser.

Keywords:- Copper Vapour Laser, laser radiation, inversion density, dimensions of the laser plasma.

INTRODUCTION

Especially in the copper vapour laser the vapours of the chemical elements are extensively used as the active medium [1]. In some designs the bids of copper metal are used as the source of copper. The laser beam is characterized by spectral band-width, the wavelength, output power, polarization and angle of divergence. The most important characteristics of any laser is the divergence of its output radiation which plays very important role in the determination of photon flux. The angles of divergence of output beams are different for CV lasers and pulsed lasers. In case of pulsed lasers the divergence may vary during the formation of the output pulse. The angle of divergence determines the photon flux when the beam is focused using focusing optics. Further when the output beam is focused the diverging beam converges and gets focused at some point. There are many methods for measuring the angle of divergence, such as the methods of sections, recording of the angular distribution and of intensity methods of focal spot [2]. A method for on line analysis by line scanning of a focal spot is suggested in work of A.P.Anerovov et al [3]. However, all these methods are not sufficient to give the idea about the evolution of the divergence during the formation of output pulse. O. Burihinskir [4] describe a method for recording changes in the divergence during the formation of output pulse.

The stimulating action in the laser medium starts with the signal produced by spontaneous emission and subsequent amplification of the radiation by the laser medium. In case of cyclic lasers, X-ray laser and high power solid state lasers the gain of the amplifying medium is relatively high and the amplification rate is also high and the intensity builds up immediately

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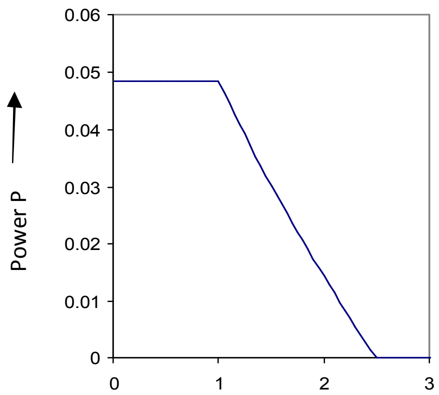
after the production of spontaneous emission. In case of copper vapour laser [5,6], nitrogen laser [7,8], lead vapour laser [9] the gain of the media is high and the production of population inversion is transient phenomenon, the single pass of the radiation is sufficient for building up of the laser intensity. On the other hand the laser like He-SeII [10], He-CdII [11] and He-ZnII [12], the optical gain of the medium is small and multiple pass of the radiation is essential for building up of the laser intensity. In case of multiple pass laser the radiation having less angle of divergence gets amplified. However, in transient laser the spontaneous radiation gets amplified and comes out of the cavity in a very short interval of time consequently the radiation having large angle of divergence gets amplified. Thus, the pulsed laser having narrow pulse width, have large angle of divergence and the CW lasers have low angle of divergence[13]. Being high gain lasers the X-ray lasers and high power solid state lasers have large angle of divergence.

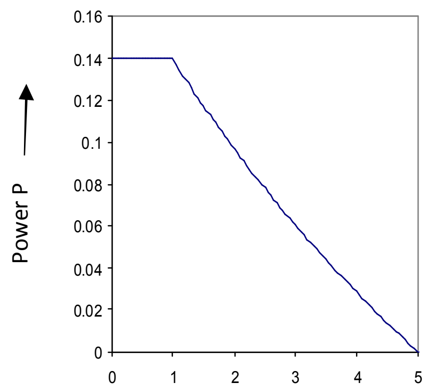
The theoretical and experimental study has not been extensively done as far as the angle of divergence is concerned. But few computations in the branch of angle of divergence of pulsed laser are carried out by Pawar and his co-workers[14].

In the present work the analytical expressions are obtained for the peak power output of the CVL without mirror, the intensity of the laser radiation across the laser beam and half peak power angle of divergence of the copper vapour laser beam. The angle of divergence is obtained by graphical method. The peak output power of the laser beam at various inversion density and at various radial points across the laser beam is studied.

The absorption coefficient of the transition of 3371A pulsed nitrogen laser is about 0.4 per cm. The dimension of laser plasma lies between 0.1 to 1 cm. Therefore the operating parameters of the pulsed ultraviolet nitrogen laser are very much similar to the copper vapour laser. Hence the behavior of the angle of divergence in nitrogen and X-ray lasers are very much similar to that in the copper vapour laser.



Distance edge of the plasma column X
Fig 1: The laser power across the laser beam
[Horizantal div for Nti=0.2]



Distance edge of the plasma column X
Fig 2: The laser power across the laser beam
[Horizantal div for Nti=0.2]

The figures 1 and 2 show that the power across the laser beam is nearly constant between B and C in if the inversion density is uniform across the laser medium. If the point P on the observation plane shifts from B' to D' i.e. from x = 0 to x = L'D/L. The beam intensity increases very slowly. For the points

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beyond D the beam power goes on decreasing as x increases and it becomes zero for $x = x_0 = L\, d\, \alpha_0\, n(t_i)/2$ or for a beam traveling in the direction making an angle $\theta_0 = d\alpha_0 n(t_i)/2$ with the plane of the nearest edge of the laser tube. It may be clearly stated that, if θ_0, d and α_0 are known, $n(t_i)$ may be calculated using above relation. Hence, the value of initial inversion density may be obtained by measuring θ_0. The inversion experienced by photon flux traveling parallel to laser axis and the photon flux traveling in oblique direction is the same. The energy stored in terms of inversion density is shared by two fluxes. Hence, the inversion density obtained by this method may be slightly lower than the actual value of the inversion density.

We also calculated peak power for different values of x along the diameter of the discharge tube at different diameters and results are plotted in figures 3 and figure 4 for the initial inversion density 0.1, and 0.3 respectively. The results clearly indicate that as the initial inversion density goes on increasing, the peak power goes on increasing. The magnitude of the peak power is unchanged as the diameter of the laser tube is changed. Thus, we may conclude that the output peak power depends on initial inversion density rather than the diameter of the discharge tube.

From the calculations of peak power[21,22] across the laser beam desired angle of divergence may be obtained. The half peak power angle of divergence for $n(t_i) = 0.2$ and 0.4 are 20 mrad and 30

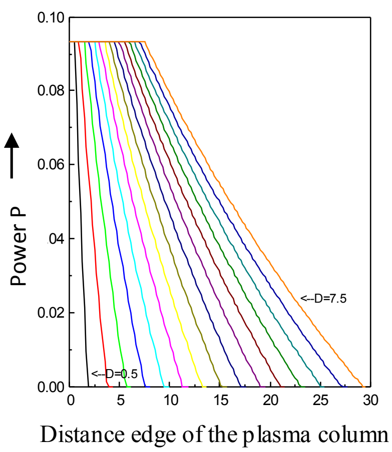

Fig 3: The peak power for the different values for the diameter of the discharge tube at different diameter at initial inversion density is 0.1

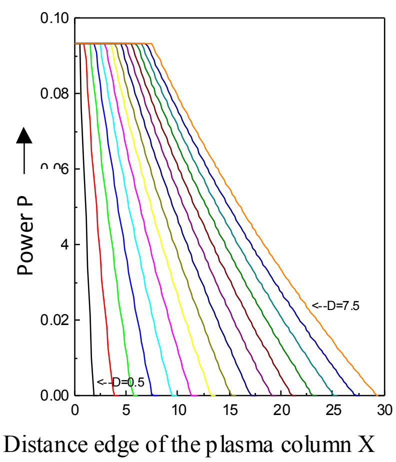

Fig 4: The peak power for the different values for the diameter of the discharge tube at different diameter at initial inversion density is 0.1

mrad respectively in T.E. field pumped CVL. In this we may say that also the leading part of the output laser beam has large angle of divergence and that of lagging part has less angle of divergence. In case of the A.E. field pumped CVL the angle of divergence is much less than the above mentioned figures. This is because reason that the laser beam makes many passes before coming out of the laser cavity and the rate of production of population inversion is relatively low compared T. E. field pumped laser as the current density is low in case of A. E field pumped laser. The results of the experimental measurements of the angle of divergence may be compared with the computation carried out in the present work. The comparison shows good agreement between the theoretical calculations and the experimental results.

While obtaining the results in the present work, it is assumed that the initial inversion density in the laser medium is constant across the discharge tube. But it has been shown that the electron temperature is not constant across the discharge tube and the population density of the upper and lower laser states are different. This leads to the variation in the inversion density across the discharge tube. The study of the angle of divergence now becomes crucial and the calculation of angle of divergence becomes complicated if the beam becomes annular in shape while it is easy when beam is not annular. The laser discharge consists of thin hallow, cylindrical shells of constant inversion densities. This indicates that a part of the cylindrical shell parallel to the laser axis treated as segment of discharge and the angle of divergence may be calculated. The divergence of the laser beam emitted by this segment would have less angle of divergence because the plasma has less thickness.

Results and discussion:-

We assume that the initial inversion density is constant through out the laser medium for calculating radial variation of peak power across the laser beam of copper vapour laser operating at 5106A or 5782A. The length of the laser discharge tube is taken to be about 100cm and the diameter is to be 1 cm (specification of these values due to our laser parameters). The plane of observation is assumed to be located at a distance of 100cm from the exit end of the laser. The absorption cross section for the copper atoms at wavelengths 5106A or 5782A is about 0.393 cm^{-1}. The initial inversion density is about 0.25 when the laser discharge conditions are optimized. We have calculated peak power for different values of x along the diameter of the discharge tube by using equation 17 and the results are plotted in figures 1 and 2 for the initial inversion densities of 0.2 and 0.4 respectively. The figures show that if the value of x is increased, the peak power also increases till the point comes to a position for which x = L'd/L for the values of x more than Ld/L the peak power of the laser radiation go on decreasing as the value of x is increased. Finally the peak power goes to zero for a certain value of x.

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