INTRODUCTION

There is a considerable interest to develop high power electrically excited molecular lasers and the CO_2 and CO electric discharge lasers have received the most attention. This is because the CO_2 and CO lasers operate very efficiently at high power levels, and are promising for many practical appliquations. It is also because their operating principles are generally well understood.

The different sections of the paper review the essential factors affecting the performance of the CO_2 and CO lasers and give the current status of these lasers.

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I - PHYSICS OF ELECTRIC MOLECULAR LASER DISCHARGES

The plasma physics of the electric discharge plays an important role in molecular laser performance. .However, electron kinetic processes in CO_2 and CO lasers discharge are difficult to analyze because of the numerous vibrational and electronic excitation processes of importance in molecular gases. Calculation of excitation rates is complicated by the fact that the electron energy distribution are non-Maxwellion in most conditions typical of CO_2 laser operation. W.L. Nighan and more recently J.J. Lowke (1) (2) have made calculations of the distribution function, the fractional power transfer and the vibrational excitation rates in gas mixtures for several ratios CO_2 : N_2 : He. Using these calculated electron-molecule rate constants along with those for molecule-molecule energy relaxation, it is possible to develop a model of CO_2 or CO molecular kinetics processes to predict the laser performance. In the paragraphs to follow, basic results of investigations on CO_2 laser discharges will be presented.

A/ - ELECTRON ENERGY DISTRIBUTION

The electron energy distribution function is obtained by solving the Boltzmann-Fokker-Planck equation in the form appropriated to the behavior of low and moderate energy electron in a uniform d.c. electric field. The following simplified form can be used :

$$(1) \quad -\frac{E^2}{3}\frac{d}{du}\left(N\frac{u}{Q_m}\frac{df}{du}\right) = \sum_k \Big[N(u+u_k)\, f(u+u_k)\, Q_k(u+u_k) - N u\, f(u)\, Q(u)\Big]$$

Here f is the isotropic part of the distribution function, N is the neutral density, e and m are the electrical charge and mass, respectively, k is Boltzmann constants ($1.38.10^{-23}$ J. deg^{-1}), and u is the electron energy in volts. Thus $u = mv^2/2e$ where v is the electron speed. The elastic cross section is Q_m and Q_k is the inelastic cross section for the k^{th} inelastic process.

The left hand side of equation 1 accounts for the gain in energy due to the electric field E, the first term on the right hand side involving a summation over accounts for electrons of energy $u + u_k$ losing energy u_k and the second term accounts for electrons of energy u losing energy u_k.

The effect of electron collisions with vibrationnally excited molecules has been neglected as also the elastic energy losses due to collisions with the gas molecules. A more elaborated treatment can be found in (3) (4). A working equation for f (u) is obtained by integrating equation 1 and dividing by N. The following first-order integro differential equation results :

$$(2) \qquad -\frac{1}{3}\left(\frac{E}{N}\right)^2 u \frac{df}{du}\left[Q_m\right]^{-1} = \int_u^{u+u_k} Q_k(u)\, u\, f(u)\, du$$

For a specific value of E/N, $f(u)$ is determined by solution of equation (2). In a gas mixture, equations (2) becomes :

$$(3) \qquad -\frac{1}{3}\left(\frac{E}{N}\right)^2 u \frac{df}{du}\left(\sum_j \delta_j Q_{mj}\right)^{-1} = \sum_{j,k} \delta_j \int_u^{u+u_{jk}} Q_{jk}(u)\, u\, f(u)\, du$$

where δ_j is the fractional concentration of the jth neutral species N_j/N.

Solution of this equation requires knowledge of all the cross-sections for vibrational and electronic excitation of the molecules over an energy range of approximatively 0 - 20 eV for CO_2 and CO lasers. Knowledge of elastic cross-sections is also required. Figures 1 to 4 give the cross-sections for electrons in the relevant gases.(ref. 5 to 7).

Shown in fig. 5 and 6 are electron energy distribution functions f (u) calculated for various E/N values for CO_2 - N_2 - He mixture ratios 1-1-8 and 1-2-3. The function f (u) is normalized by :

$$(4) \qquad \int_0^\infty \sqrt{u}\, f(u)\, du = 1$$

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