In connection with progress in the field of CO\textsubscript{2} lasers, questions of the vibrational kinetics of molecules of CO\textsubscript{2} have been discussed in many communications. In a majority of cases of practical importance, the distribution of CO\textsubscript{2} is due to processes of vibrational exchange (V-V) on which is based the well-known thermodynamic model [1]. In other cases, the V-V exchange does not determine the vibrational distribution, since the perturbation is small; therefore, it is found sufficient to consider a small number of levels of CO\textsubscript{2} (usually three), whose populations satisfy the linear equations of the balance [2]. There is the possibility of conditions where the vibrations are strongly excited and, at the same time, V-V processes are insignificant (a very small CO\textsubscript{2} impurity in the inert gas, with a high degree of ionization). Then the number of equations becomes large. The present article discusses one such case: the excitation of a steady-state vibrational distribution in a glow discharge by laser radiation, whose solution is rather graphic.

The article considers conditions where the excitation of an antisymmetric mode of CO\textsubscript{2} by electrons takes place far more frequently than damping by heavy particles, and in paired modes (symmetrical longitudinal bending vibrations), the contrary, i.e., a Boltzmann distribution is established in the antisymmetric mode, with the temperature of the electrons, and in paired modes, with the temperature of the gas. Let us examine the variation of the distribution under the action of rather strong laser radiation, leading to induced transitions between the levels 00\textsuperscript{0} and 10\textsuperscript{0}.

Let us formulate the problem in more detail. In a harmonic investigation, digressing from the splitting of the levels due to Fermi resonance, the vibrational levels of CO\textsubscript{2} can be given by the vibrational number of the paired modes $v = 2v_1 + v_2$ ($v_1$, $v_2$ are the vibrational numbers of symmetrical longitudinal and bending vibrations) and the vibrational number of the antisymmetric mode $u$. Under these conditions, the levels are degenerate with a multiplicity factor

$$g_v = \begin{cases} (v + 2)^2/4, & v - \text{even}, \\ (v + 1)(v + 3)/4, & v - \text{odd}. \end{cases}$$

The vibrational levels form a square grid in the plane $vu$ (Fig. 1). Adjacent vibrational levels in the grid are connected by transitions along the $u$ axis with collisions with electrons, and along the $v$ axis with collisions with heavy particles. A laser transition is illustrated on the grid by the diagonal 01-20. By definition, other transitions are unimportant. In the absence of laser radiation the vibrational distribution is obviously the product of the Boltzmann distributions along $u$ with the temperature of the electrons, and along $v$ with the temperature of the gas. It is required to find the distribution over the levels with a given intensity of the laser radiation.

We define the current between two mesh points of the grid of the vibrational levels as the difference in the number of direct and reverse transitions between them in unit volume in unit time. The condition of the steady-state character of the populations then degenerated in accordance with the Kirchhoff rule: the...
algebraic sum of the currents at every mesh point is equal to zero. We introduce the potentials $\varphi_{vu}$ with respect to the distribution unperturbed by laser radiation

$$\varphi_{vu} = \frac{n_{vu}}{n_{00} e^{\frac{e}{h} \omega_a^2}}$$

where $n_{vu}$ is the population of the level $vu$; $\alpha_a = e^{-\hbar \omega_a^2}$; $\alpha_c = e^{-\hbar \omega_c^2}$; $\hbar \omega_c$, $\hbar \omega_a$ are the vibrational quanta of the paired and antisymmetric modes; $T_e$, $T$ are the temperatures of the electrons and the gas.

We adopt the normalization $\varphi_{00} = 1$. We note that the formulas for the currents between neighboring mesh points have the form of Ohm's law, for example:

$$J_{vu}^{v+1, u} = \sigma_{vu}^{v+1, u} (\varphi_{vu} - \varphi_{v+1, u})$$

where the conductivity is equal to $\sigma_{vu}^{v+1, u} = g_{vu} n_0 e^{\frac{e}{h} \omega_a^2} n_{vu}^{v+1, u} n_M$, $n_{vu}^{v+1, u}$ is the rate constant of the transition $vu \rightarrow v+1$, $u$ with a collision with heavy particles; $n_M$ is the density of the heavy particles.

The formula for the diagonal current $01 \rightarrow 20$ has another form:

$$J_{01}^{20} = \sigma_{01}^{20} \left( \varphi_{01} - \varphi_{20} \right)$$

where $\sigma_{01}^{20} = n_0 \alpha_a \sigma_0 I$; $\sigma_0$ is the cross section of the induced radiation; $I$ is the intensity of the laser radiation divided by the energy of a photon.

As can be seen, the problem is analogous to calculation of the electric circuit from a source included between the mesh points 01 and 20 (the analogy, however, is incomplete from the point of view that the emf is not determined previously). We note that the values of

$$a_{vu} = \frac{\varphi_{vu} - \varphi_{20}}{\varphi_{01} - \varphi_{20}}$$

are determined only by the conductivities of the grid and do not depend on the source. The $a_{vu}$ obviously coincides with the distribution of the potential in the grid with fixed potentials $\varphi_{01} = 1$ and $\varphi_{20} = 0$. This distribution is most conveniently measured in an analog machine, selecting the appropriate grid of the resistances. With values of $a_{vu}$ known from measurements, it is sufficient only to determine $\varphi_{01}$ and $\varphi_{20}$ in order to be able to use (2) to calculate the potential at all the other mesh points.

Let us consider the equivalent circuit, illustrated in Fig. 2. The heavy line with the effective conductivity $\sigma_{ef}$ replaces the grid. Thus, $\sigma_{ef}$ is the resistance of the grid (without diagonal) between the mesh points 01 and 20. This value is determined by the set of coefficients $a_{vu}$ but can be measured fairly well in an analog machine.