Heavy ions (Mg, Cd, etc.) are accelerated in electron beams by using vacuum arcs [3] as the plasma sources. The acceleration process is repeated in this case at the same frequency as the relaxations of the electron current in the nonstationary mode [4]. Relaxation oscillations of this kind were observed also in electron-current separation with a duo-plasmatron.*

The mechanism of ion acceleration in electron beams is not sufficiently understood. The high values of the internal ion-accelerating fields, up to 10^5 - 10^6 V/cm (for sparks), points to the development of strong collective interactions. This is also evidenced by the smearing of the electron-beam energy and the excitation of a broad oscillation spectrum. The waves that are generated thereby can accelerate the ions.

The experimentally observed energies and numbers of accelerated ions can be explained by starting from the coherent-acceleration mechanism proposed by the late V. I. Veksler [5,6]. The real ion-acceleration picture, however, is more complicated and its elucidation calls for additional experiments.

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PLASMA GAS TEMPERATURES IN THE DISCHARGES USED FOR CO_2 LASERS

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The main physical processes that lead to population inversion and generation in CO_2 lasers were established in [1,2]. However, a quantitative analysis of the phenomena occurring in the discharges used for CO_2 lasers is greatly hindered by the almost complete lack of data on the composition of the plasma and on the temperatures of the components. In particular, there is no information on the gas temperature T_2. Yet the experimental data on the dependence of the generation power on the discharge-tube wall temperature clearly points to the noticeable influence of the gas temperature [3]. The same conclusion follows also from the dedection made in [2] that vibrational relaxation plays a decisive role in the establishment of population inversion between the CO_2 levels. The rate of vibrational relaxation depends in turn on T_2.

The present communication is devoted to the result of an investigation of the dependence of T_2 on different parameters of the discharges used for CO_2 lasers. The experiments were made with a continuous flow of the gas mixtures, at velocities up to 1 m/sec. T_2 was measured by determining the relative intensity of the rotational lines of the (0,0) band of the second positive system of N_2 (edge of band λ = 3371 Å). The spectrum was registered photographically from the anode end of the discharge tube, using a DFS-8 spectrograph (linear dispersion 6 Å/mm). Consequently, we essentially measured the effective temperature of the entire gas discharge. We used for the measurements the rotational lines of the R-branch with quantum numbers j = 15 - 27. The error ΔT in the determination of T_2 was ±10°K and ±60°K at 400 and 1000°K, respectively. The experiments were performed with three discharge tubes having different diameters d and different lengths ℓ: 1) ℓ = 284 cm, d = 6.2 cm; 2) ℓ = 75 cm, d = 2.5 cm; 3) ℓ = 90 cm, d = 3.0 cm. The last tube had a water-cooling jacket.

The gas-mixture components were fed to the discharge tube from separate cylinders. The flow was measured manometrically by determining the pressure drop across between the high-pressure cylinder and the discharge tube.

The experimental results (some of which are shown in Figs. 1-3) can be briefly summarized as follows:

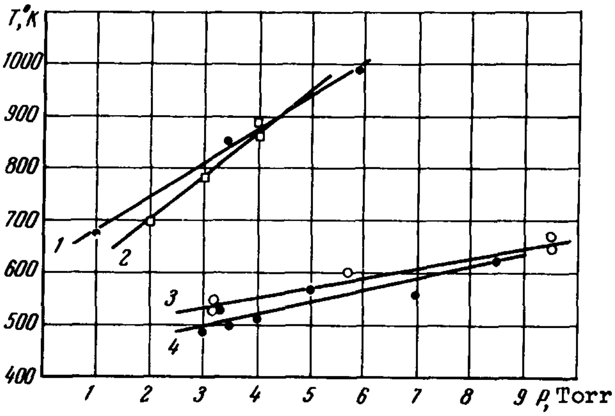

Fig. 1. Gas temperature vs. total gas pressure in discharge tube: 1 - I = 80 mA, $Q(N_2)$ = 0.28, $Q(CO_2)$ = 0.10; 2 - I = 80 mA, $Q(N_2)$ = 0.40; 3 - I =80 mA, $Q(N_2)$ = 0.28, $Q(CO_2)$ = 0.10, $Q(He)$ = 2.20; 4 - I = 60 mA, $Q(N_2)$ = 0.40, $Q(CO_2)$ = 0.13, $Q(He)$ = 2.40. The data of (1) and (3) were obtained with a 2.5 cm diam. discharge tube, and those of (2) and (4) with 6.2 cm diam. The flow is given in l-Torr/sec.

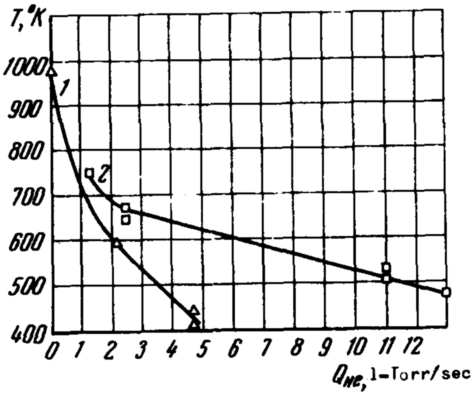

Fig. 2. Effect of addition of He on the temperature: 1 - I = 80 mA, P = 5.8, $Q(N_2)$ = 0.28, $Q(CO_2)$ = 0.10; 2 - I = 80 mA, P = 9.5, $Q(N_2)$ = 0.28, $Q(CO_2)$ = 0.10. The data were obtained in a discharge tube of 2.5 cm diameter; the pressures P are in Torr, the flow is in l-Torr/sec.

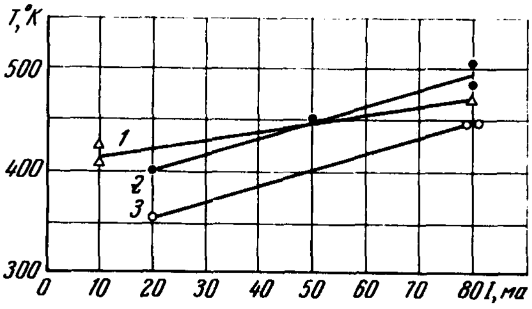

Fig. 3. Temperature vs. current. 1 - P = 5.8, $Q(N_2)$ = 0.28, $Q(CO_2)$ = 0.10, $Q(He)$ = 4.70; 2 - P = 7.5, $Q(N_2)$ = 1.50, $Q(CO_2)$ = 0.50, $Q(He)$ = 1.20; 3 - P = 3.4, $Q(N_2)$ = 0.33, $Q(CO_2)$ = 0.11, $Q(He)$ = 2.7. The data of (1) pertain to a discharge tube of 2.5 cm diam. and those of (2) and (3) to a tube of 3.0 cm diam. with water cooling. The pressures P are in Torr and the flows Q are in l-Torr/sec.

1. The gas temperature in a discharge in a CO_2+N_2 mixture depends little on the total mixture flow Q and on the relative CO_2 and N_2 concentrations. Thus, for example, addition of CO_2 in amounts exceeding the N_2 flow by a factor of three does not change T_2, nor does a change of the total flow from 0.32 to 1.12 l-Torr/sec.

2. The gas temperature varies little when the tube diameter changes from 30 to 60 mm, in spite of the change of the current density I (see Fig. 1).

3. An increase of the total pressure of the CO_2+N_2 mixture from 1 to 6 Torr raises the temperature from 700 to 1000°K (see Fig. 1).

4. Addition of He to the CO_2+N_2 mixture lowers T_2 to 500-600°K (see Figs. 1 and 2). In the presence of appreciable amounts of He, the influence of the total pressure of the mixture on T_2 is weaker than in the case of the binary mixture CO_2+N_2 (see Fig. 1).

5. An increase of the current I from 10 to 80 mA in the CO_2+N_2+He mixture increases T_2 by only 100°K.

6. Water-cooling of the discharge tube can lower T_2 of the CO_2+N_2+He mixture to 350-400°K.

A complete analysis of the results can be carried out only by considering in detail the energy balance of the discharge with allowance for the possible changes of the current and temperature distributions over the cross section. Such an analysis is hardly possible or necessary at present. One of the results, however, namely the decrease of T_2 when He is added, can be qualitatively understood because the thermal conductivity of the He is higher by one order of magnitude than the thermal conductivities of CO_2 and N_2, and this indeed leads to large heat losses.

The same result can be used to interpret the increase in the power of a CO_2+N_2 laser when He is added [4,5] and when the gas-discharge tube is cooled with water [3]. As seen from Figs. 1 and 2, addition of He to CO_2+N_2 lowers T_2 from 1000° to 600-500°K, and additional water cooling lowers it further to 450-350°K. This means that the rate of the vibrational relaxation of the upper 00^01 CO_2 laser level is decreased thereby by not less than one order of magnitude [6] ($\tau \approx 10^{-4}$ at P_{CO_2} = 1 Torr and 1000°K, and $\tau \approx 10^{-3}$ at 500°K, with the $\tau(T)$ dependence normalized to the experimental data [7]), and this leads to an increase of the population of the upper laser level. On the other hand, although the decay rate of the population of the deformational levels by collision with the CO_2 molecules is decreased [6], this decrease is offset by the decay of the deformational levels of CO_2 as a result of collisions with the He atoms [2]. The efficiency of these collisions is higher by one order of magnitude than the efficiency of collisions with the CO_2 molecules; what is more important, it depends little on the temperature [8]. Thus, the addition of He plays a double role. On the one hand, it increases the population of the upper laser level, and on the other it increases the rate of decay of the lower level [2]. This conclusion is in good agreement with the result of an experimental estimate [9] of the populations of the upper and lower laser levels of CO_2 with and without He, by determining the spontaneous emission, and explains the appreciable increase of the CO_2 laser power when He is added. Further cooling of the gas-discharge tube with water, which lowers the temperature by approximately 150°K, leads to a decrease in the decay rate of the upper 00^01 CO_2 level (due to collisions with the CO_2 molecules) by another factor 2-3;

this increases further the inverted population and the generation power [3].

We note also that at CO_2+N_2 working pressures on the order of 6 Torr, as follows from Fig. 1, $T_2 \approx 1000°K$. At this temperature the population of the lower laser vibrational level is one-tenth the population of the CO_2 ground level, and at a CO_2 concentration close to 10^{17} cm^{-3} the population at the lower laser level will be on the order of 10^{16} cm^{-3} (owing to the Boltzmann population at the gas temperature), and this can greatly decrease the inversion of the lower laser leve relative to the upper one.

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REAL PART OF THE ELASTIC π^-p SCATTERING AMPLITUDE IN THE COULOMB INTERFERENCE REGION AT 3.48 AND 6.13 GeV/c

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Several recent papers [1] are devoted to a check on the dispersion relations. The present communication deals with the same problem.

We measured the real part of the nuclear amplitude of elastic π^-p scattering, using the effect of the interference of the Coulomb and nuclear interactions in the squared 4-momentum transfer interval $1.22 \times 10^{-3} \le -t \le 4.22 \times 10^{-3}$ $(GeV/c)^2$ 10^{-2} $(GeV/c)^2$. An analysis of the experimental data (see Fig. 1) with the aid of the Bethe formula [2] derived within the framework of nonrelativistic quantum mechanics yields values $\alpha_B = (ReA_{nuc}/ImA_{nuc}) = -(0.17\pm0.7)$ at 3.48 GeV/c and $\alpha_B = -(0.22\pm0.09)$ at 6.13 GeV/c. Reduction of the same data in accord with the Solov'ev formula, derived on the basis of relativistic quantum field theory [3], yields the values shown in Fig. 3: $\alpha_S = -(0.12\pm0.07$ and $\alpha_S = -(0.17\ 0.09)$ at 3.48 and 6.13 GeV/c, respectively.

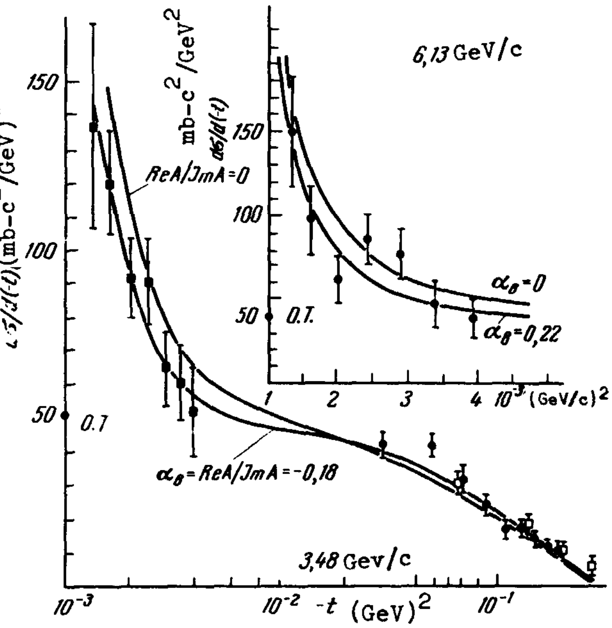

Fig. 1. Differential elastic π^-p scattering cross section at 3.48 GeV/c (■ - our data, □ - data of [11], o - from data of [8]) and 6.13 GeV/c (● - our data).