depend [3]. In addition, generation of longitudinal waves may set in and also contribute to a decrease of the transverse component of the acoustoelectric force (its sign may even reverse when the voltage is increased).

There was no change in the sign and magnitude of the magnetic field when the polarity of the applied voltage was reversed. This even behavior remained in force in all the experiments and, together with the threshold, is a distinguishing attribute of the effect. The magnetic field direction was reversed when the sample was rotated 180° relative to the current lines; the reason for this reversal is that such a rotation reverses the direction of the transverse component of the acoustoelectric force in the laboratory coordinate frame.

Theoretical estimates based on [2, 3] yield, at the experimental values of the current, a magnetic field $10^{-3} - 10^{-2}$ Oe, which agrees in order of magnitude with the results obtained here.

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[1] V.I. Pustovoit and Yu.P. Mukhortov, ZhETF Pis. Red. 13, 211 (1971) [JETP Lett. 13, 149 (1971)].
[2] Yu.P. Mukhortov and V.I. Pustovoit, Zh. Eksp. Teor. Fiz. 61, 1157 (1971) [Sov. Phys.-JETP 34, 617 (1972)].
[3] Yu.P. Mukhortov, V.I. Pustovoit, I.S. Ravvin, and L.A. Chernozatonskii, Fiz. Tverd. Tela 14, 2664 (1972) [Sov. Phys.-Solid State 14, No. 9, 1973)].
[4] V.I. Pustovoit and L.A. Chernozatonskii, Fiz. Tekh. Poluprov. 6, 1311 (1972) [Sov. Phys.-Semicond. 6, 1147 (1973)].
[5] Yu.V. Gulyaev, A.Yu. Karabanov, A.M. Kmita, A.V. Medved', and Sh.S. Tursunov, Fiz. Tverd. Tela 12, 2595 (1970) [Sov. Phys.-Solid State 12, 2085 (1971)].

POPULATION INVERSION IN THE ACTIVE MEDIUM OF AN ELECTROIONIZATION CO_2 LASER AT A WORKING-MIXTURE PRESSURE UP TO 20 ATMOSPHERES

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The present study, devoted to the time dependence of the inverted population in an active medium of an electroionization laser, has shown experimentally that raising the pressure of the working mixture to 20 atm does not lead to any qualitative changes of the processes of excitation and relaxation of the laser levels. The rates of all the excitation and relaxation processes increase with pressure without a change in their ratios, which are known for TEA lasers and low-pressure lasers [1, 2].

The experimental procedure consisted of measuring the value of the time dependence of the gain of the active medium of an electroionization CO_2 laser [3, 4] operating with compressed carbon dioxide, using a TEA test laser (λ = 10.59 μ). The radiation receiver was a Ge:Au photoresistor cooled with liquid nitrogen. The resolution of the recording apparatus was $\sim 2 \times 10^{-7}$ sec.

Measurements of the gain distribution over the cross section (1.8 × 2 cm) of the active medium have shown that the gain is almost uniform over the entire cross section. The gain decreased by ~25% on going from the anode to the cathode and by ~20% on going in the perpendicular direction from the center to the edge of the active region. Figures 1 and 2 show the gain averaged over the active-region cross section as a function of the pump energy (W_p) and the

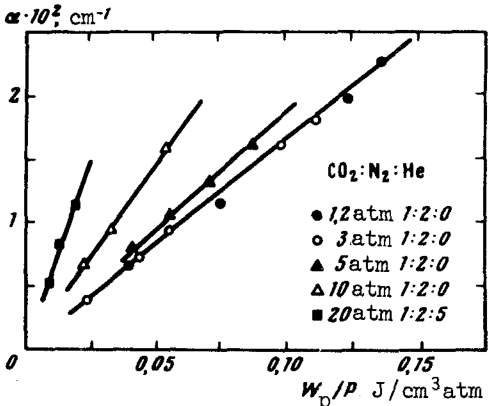

Fig. 1

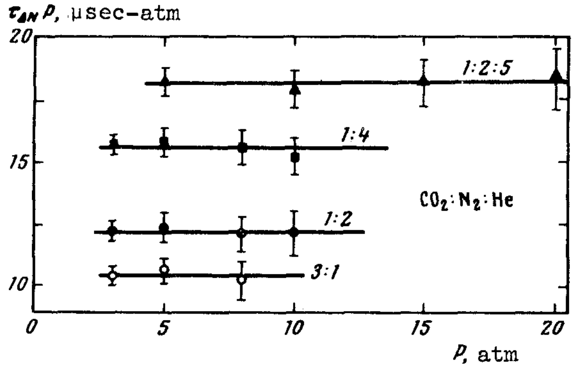

Fig. 2

Fig. 1. Gain of active medium of electroionization CO_2 laser vs. the pump energy.

Fig. 2. Lifetime of the inversion in the active medium of an electroionization CO_2 laser vs. the pressure of the working mixture (CO_2:N_2:He).

inversion lifetime ($\tau_{\Delta N}$) as a function of the working-mixture pressure. The values of $\tau_{\Delta N}$ were measured at low pump energies, at which the heat rise of the working mixture was negligible ($\Delta T < 30°$).

The linear dependence of the gain on W_p/P shows that the inverted population is determined by the pump energy, just as in low-pressure gas-discharge CO_2 lasers [1]. The experimental values of the population inversions are described with good accuracy by formula (26) of [3]. For a mixture consisting of one part CO_2 and two parts of N_2, at P = 1.2 atm and a pump energy $W_p = 0.17$ J/cm³, the experimental value of the population inversion is $\Delta N_{exp} = 10^8$ cm⁻³. Calculations with formula (26) of [3] yield for the upper laser level a value of the same order, $\Delta N_{theor} = N_{00°1} - N_{10°0} \simeq N_{00°1} = 1.3 \times 10^{18}$ cm⁻³. Thus, in the active medium of the electroionization CO_2 laser the population of the lower laser level by electron impact is negligible ($N_{10°0} << N_{00°1}$) and the measured lifetime of the inversion is determined by the relaxation time of the upper laser level. The time needed to reach maximum inversion in CO_2:N mixtures, obtained in the present experiments, is given by $P\tau_{CO_2-N_2} = 0.4 \pm 0.1$ μsec-atm and is determined by the rate of excitation transfer from the N_2 to the CO_2. The cross section of this process, calculated from these experimental data, is $\sigma_{N_2-CO_2} = (1.6 \pm 0.4) \times 10^{-18}$ cm², which practically coincides with the cross section obtained in other studies at low pressures [5, 6]. The measurement results allow us to conclude that when the working-mixture pressure is increased to several times ten atmospheres the excitation and relaxation of the laser levels will be qualitatively altered.

It is seen from Fig. 1 that when the working-mixture pressure is increased to 3 atm the gain remains constant at a fixed value of W_p/P, and increases with further increase of pressure. For $P \leq 3$ atm, the increase of the population inversion is offset by the increase, in direct proportion to the pressure, of the line width of vibrational-rotational transition. At pressures above 3 atm, the contribution made to the gain of the vibrational-rotational line by the wings of the neighboring lines becomes significant, and the gain for the same values of W_p/P is larger. The calculated frequency dependence of the gain [7] is in good agreement with our measurement results. From the data of Fig. 1 we can

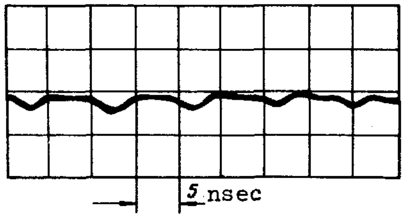

Fig. 3. Oscillogram of emission spikes of an electroionization CO_2 laser.

calculate the line widths of the vibrational-rotational transitions assuming a Lorentz line shape, and obtain for the P(20) line $\Delta\nu_L = 0.21 \pm 0.04\ cm^{-1}$ atm (2:1 mixture of CO_2 and N_2). Thus, at pressures above 10 atm, owing to the overlap of a large number of vibrational-rotational lines, the gain contour becomes continuous, and its width increases to 100 cm^{-1} (λ = 10.6 μ, P-branch). At 20 atm it is apparently possible to obtain powerful radiation pulses of duration $\sim10^{-11}$ sec and high efficiency (∿10%) close to the efficiency in the long-pulse regime, and at a duration $\sim10^{-12}$ sec with the efficiency decreated by one order of magnitude. The decrease of the efficiency when the pulse duration is shorter than 10^{-11} sec is connected with the insufficient rate of rotational relaxation [8]. The possibility of obtaining, with high efficiency, short radiation pulses from an electroionization CO_2 laser is confirmed by the experimental and theoretical research reported in [9], where pulses of 10^{-9} sec were obtained, with the energy in the pulse amounting to 70% of the energy stored at the upper laser level. We used our setup to perform experiments aimed at obtaining short pulses in a scheme analogous to that of [10]. We observed mode locking at all the investigated pressures and compositions of the $CO_2:N_2:He$ mixture. Figure 3 shows a photograph of the radiation spikes of an electroionization CO_2 laser with a 1:2:54 $CO_2:N_2:He$ mixture at P = 10 atm. The spike width (∿3 nsec) was determined by the resolution of the recording apparatus and of the receiver (Ge:Sb:Zn, T = 77°K).

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[1] N.N. Sobolev and V.V. Sokovikov, Usp. Fiz. Nauk 91, 425 (1967) [Sov. Phys.-Usp. 10, 153 (1967)].
[2] A.M. Robinson, Can. J. Phys. 48,1996 (1970); D.C. Johnson, IEEE J.W.E. QE-7, 185 (1971); A.K. Laflamme, Rev. Sci. Instr. 41, 1578 (1970).
[3] N.G. Basov, E.M. Belenov, V.A. Danilychev, O.M. Kerimov, I.B. Kovsh, A.S. Podsosonnyi, and A.F. Suchkov, FIAN Preprint No. 56, 1972.
[4] N.G. Basov. E.M. Belenov, V.A. Danilychev, O.M. Kerimov, I.B. Kovsh, A.S. Podsosonnyi, and A.F. Suchkov, Zh. Eksp. Teor. Fiz. 64, 121 (1973) [Sov. Phys.-JETP 37, No. 1 (1973)].
[5] A.A. Offenberger and D.J. Rose, J. Appl. Phys. 41, 3908 (1970).
[6] R.L. Tayler, M. Camoc, and R.M. Feinberg, Proc. Int. Symp. Combustion Pittsburgh 1 th, 49 (1966).
[7] N.G. Basov, E.M. Belenov, V.A. Danilychev, O.M. Kerimov, A.S. Podsosonnyi, and A.F. Suchkov, FIAN Preprint No. 58, 1972.
[8] Ya.B. Zel'dovich and Yu.P. Raizer, Fizika udarnykh voln i vysokotemperaturnykh gidrodinamicheskikh yavlenii (Physics of Shock Waves and High-temperature Hydrodynamic Phenomena), Fizmatgiz, 1966.
[9] K. Boyer, Los Alamos Scientific Laboratory Presentation at Japan-U.S. Seminar on Laser Interaction with Matter in Kyoto, Japan, September 24 thru September 29, 1972.
[10] A.F. Gibson, M.F. Kimitt, and C.A. Posito, Appl. Phys. Lett. 15, 546 (1971).