PULSED CO_2 LASER

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The results of investigations of lasing on CO_2 and N_2 molecules in the system employed for pumping excimer molecules with a self-maintained discharge are presented. Radiation pulses with energy of 2.5 J was obtained using the mixture CO_2:N_2:He = 2:4:6 at a pressure of 0.6 atm; the efficiency was 8% with respect to the stored energy.

The widespread application of CO_2 laser systems for solving scientific and technological problems raises the problem of developing new or improving existing methods for controlling the characteristics of laser radiation. It should be noted that CO_2 lasers are of interest for solving many problems in sounding of the atmosphere,[1] laser photochemistry,[2] diagnostics of gaseous media,[3] etc.

In this paper we present the results of investigations of the energy and temporal characteristics of CO_2 and N_2 laser excited with a self-maintained discharge. The experiments were performed on an excimer laser. Its structural features, the excitation system, and the parameters of the radiation are described in Ref. 4. The active volume of the interelectrode gap was 2.5×1×70 cm^3. The maximum energy stored in the storage capacitor was equal to 30 J. The illumination system consisted of two symmetric rows each containing 20 spark gaps, ignited when the peaking capacitor was charged. The resonator consisted of a flat gold-coated mirror and a plane-parallel plate made of KRS-6 material. A flat mirror with an aluminum coating and a plane-parallel quartz plate were employed in the resonator for UV-radiation on the molecule. The radiation energy was measured with an IMO-2N calorimeter. The shape of the radiation pulses was recorded on a S8-14 oscillograph with the help of an FP-3 or FEK-22SPUM photodetector. The discharge current from the peaking capacitor and the voltage across the gap were displayed on the oscillograph with the help of a voltage divider and a low-inductance shunt with a resistance of 0.1 Ω.

Figure 1 shows the dependence of the radiation energy for the gas mixture CO_2:N_2:He = 1:1:N on the helium content and the magnitude of the charging voltage. In this case and in all subsequent experiments one part of the gaseous component corresponded to 38 mm Hg. The maximum radiation energy was observed with U_0 = 300 kV. As the working voltage was increased the radiation energy increased linearly up to a pressure of 0.4 atm. Short pulses can be obtained from the CO_2 laser in mixtures with a low content of nitrogen and no helium; many investigators are working to achieve this. However such conditions can be realized only in systems with intense uniform preionization and short pump pulses. Thus in Refs. 5 and 6 radiation pulses with energy up to 0.29 J and pulse width of half-height from 30 to 70 nsec were obtained in small CO_2 lasers. The radiation energy can be further increased with the short CO_2 laser pulses (in mixture without helium) only in setups with a high rate of injection of energy into the discharge, for example, in excimer laser systems. An oscillogram of the radiation pulse in a mixture with no helium CO_2:N_2 = 4:1 is presented in the inset in Fig. 1. The delay time of the radiation pulse relative to the discharge current corresponded to ~ 300 nsec. The width of the radiation pulse at half-height was equal to ~ 50 nsec. As the working pressure of He was increased the total pulse width reached 1 μsec (Fig. 2).

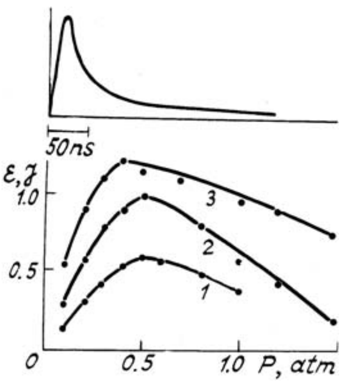

Fig. 1. The energy of radiation for the gas mixture CO_2:N_2:He = 1:1:N as a function of the helium content and the magnitude of the charging voltage: 20 kV (1), 25 kV (2), and 30 kV (3). The graph at the top shows the radiation pulse in a mixture with no helium CO_2:N_2 = 4:1.

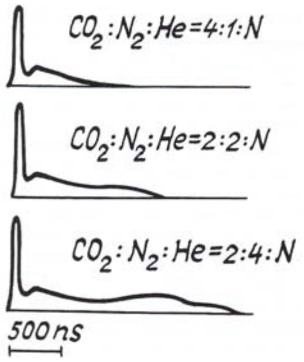

Fig. 2. Typical oscillograms of radiation for the gas mixtures CO_2:N_2:He with P = 0.6–1 atm.

Figure 3a shows the radiation energy as a function of the content of CO_2 and N_2 and the total working pressure of the mixture with U_0 = 30 kV. The maximum energy of the radiation in a mixture with no helium was observed with the ratio CO_2:N_2 = 4:4. Further increase of the pressure of the gaseous components resulted in termination of lasing owing to unstable burning of the discharge. This situation was also observed for the mixture CO_2:N_2 = 4:4 when the He content was increased. The optimal mixture turned out to be CO_2:N_2:He = 3:3:6 at 0.6 atm. Figure 3b shows curves of the radiation energy of gas mixtures with different ratios of CO_2 and N_2 as a function of the total working pressure. As the N_2 content is increased the radiation energy increases. The maximum radiation energy of 2.5 J with a total efficiency of ~ 8% was observed with the mixture CO_2: N_2:He = 2:4:6 at 0.6 atm. The results obtained illustrated well the typical oscillogram of the radiation (Fig. 2) as a function of the ratio of the gaseous components. The duration of the radiation pulse increases from 1 to 2.5 μsec as the N_2 content is increased. The divergence of the radiation for a flat resonator was equal to 3×4 mrad.

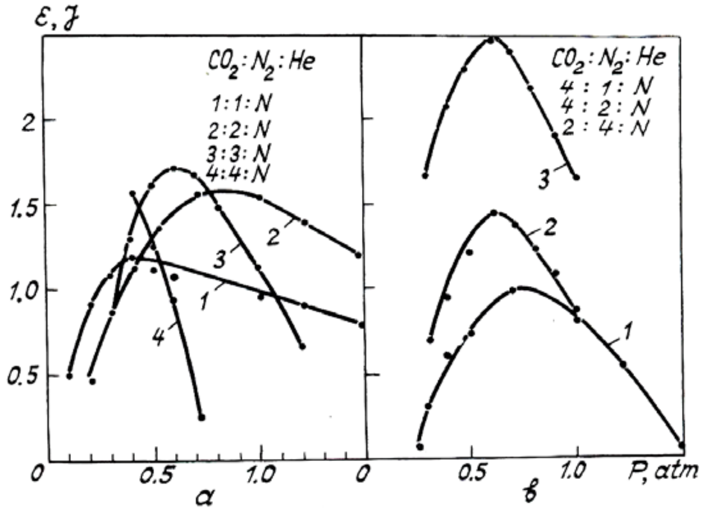

Fig. 3. The optimal dependences of the radiation energy on the content of CO_2, N_2 (a), and N_2(b) and the total working pressure of the mixture with U_0 = 30 kV.

We also investigated UV-radiation on N_2 (λ = 337.1 nm). Figure 4 shows the dependence of the radiation energy on the and He pressure. The maximum radiation energy was observed with N_2 ~ 0.15 atm. When He was added to 0.1 atm the N_2 radiation energy dropped, but the range of working pressures became wider. The maximum the radiation pulse corresponds to the maximum of the discharge current. The pulse width at half-height was equal to ~ 5 nsec and the peak radiation power was equal to ~ 2 MW.

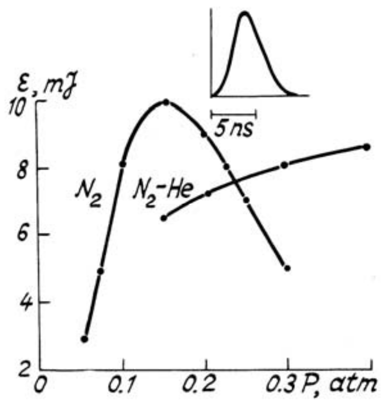

Fig. 4. The radiation energy as a function of the N_2 and He content. The inset shows the radiation pulse of a N_2 laser.

In conclusion we note that short pulses of radiation can be obtained in an excimer laser system based on CO_2 and N_2 molecules. The pulse width of the CO_2 laser can be regulated by varying the ratio of the gaseous components.

REFERENCES

1. V.E. Zuev, A.A. Zemlyanov, and Yu.D. Kopytin. *Nonlinear Optics of the Atmosphere* (Gidrimeteoizdat, Leningrad, 1989).
2. V.S. Letokhov, *Nonlinear Selective Photoprocesses in Atoms and Molecules* (Nauka, Moscow, 1983).
3. Yu.M. Andreev, P.P. Geyko, A.I. Gribenyukov, et al., Opt. Atm., **1**, 126 (1988).
4. A.I. Fedorov and S.A. Brichkov, Opt. Atm.., **2**, No. 7, 772 (1989).
5. V.V. Osipov, V.A. Tel'nov, et al., Prib. Tekh. Eksp. No. 1, 181 (1988).
6. V.A. Vizir', V.V. Osipov, V.A. Tel'nov, et al., Kvant. Electron., **12**, No. 6 1256 (1988).