CO_2 laser initiated by a gliding discharge

S. I. Andreev, I. M. Belousova, P. N. Dashuk, D. Yu. Zaroslov, E. A. Zobov, N. V. Karlov, G. P. Kuz'min, S. M. Nikiforov, A. M. Prokhorov, A. N. Sidorov, L. L. Chelnokov, and M. D. Yarysheva

P. N. Lebedev Physics Institute, USSR Academy of Sciences
(Submitted February 11, 1975)
ZhETF Pis. Red. **21**, No. 7, 424–426 (April 5, 1975)

We report initiation of an autonomous volume discharge in the working mixture of a CO_2 laser by the radiation of a gliding discharge. Lasing is obtained at working-mixture pressures up to 105 atm. At an energy input to the volume discharge up to 150 J/liter atm, the output radiation energy amounted to 10 J/liter atm.

Methods of controlling the discharge, either by a beam of charged particles[1–3] or by applying ultraviolet radiation to the discharge gap[4,5] are by now well known. We show in this paper that to produce a volume discharge in a CO_2 laser at atmospheric pressure of the working mixture and higher it is possible to make effective use of a gliding discharge[6] along the interface between solid and gaseous dielectrics.

When an oscillatory voltage pulse with a leading-front slope $du/dt = 10^{11}-10^{12}$ V/sec and with a period $T = 1-10$ μsec is applied to a system of electrodes, one of which is an extended metallic plate covered with a thin layer of dielectrics, a gliding discharge is produced over the surface of the dielectric.

Figure 1 shows the incompleted (a,b) and completed stages of the gliding discharge. If the applied voltage is not high enough, the progress of the gliding-discharge sparks is chaotic and with different velocities. This shortcoming is eliminated by coating the surface with a lacquer filled with finely dispersed powder of compounds of barium, copper, and graphite. The rate of development of the brightly glowing channels can be synchronized in this case (Figs. 1b and 1c). Thus, gliding-discharge channels of lengths from 20 to 200 cm were produced at voltage pulse amplitudes 50–200 kV. In the ultraviolet region of the spectrum, the brightness temperature of the plasma in the completed stage of the gliding discharge is $9-10^3$ °K.

A multichannel gliding discharge can be used to obtain a volume discharge in high-pressure CO_2 lasers, both to serve as a plasma cathode that is more effective than in[7] and to produce powerful ultraviolet illumination of the working volume of the laser.

The discharge characteristics of the gliding discharges do not satisfy the Paschen law. At a working-mixture pressure above 0.3 atm, the discharge voltage depends little on the gas pressure. Morever, with increasing working-mixture pressure the discharge channels fill the surface of the dielectric more uniformly and more densely. A homogeneously-filled plasma sheet was obtained in CO_2N_2, He, and in their mixtures at pressures up to 1.5 atm.

A model laser experiment with a small volume of the active medium was carried out using one gliding-discharge channel. This discharge, 45 cm long, was formed over the surface of a glass tube (wall thickness 1.5 mm). The diffuse volume discharge in the active medium of the laser was produced in the gap $2\times5\times40$ cm between two specially shaped electrodes.

The current-voltage characteristics of this volume discharge offer evidence that it become autonomous once it is initiated by the ultraviolet radiation of the gliding discharge. Its duration, depending on the storage capacity, range from 0.07 to 0.7 μsec. The laser resonator was made up by a total-reflection gold mirror with curvature radius 500 cm and a plane-parallel germanium plate. At a volume-discharge energy input up to 150 J/liter-atm, the output energy was 10 J/liter-atm. The radiation pulse duration at half height was 200 nsec. Generation was obtained at a working-mixture pressure up to 1.5 atm.

The intense ultraviolet exposure ensured lasing at a main-discharge delay from 0.1–0.5 to 50–100 μsec

FIG. 1. a) Gliding-discharge channels without a control coating; b, c) ordered channels. Dielectric layer (lavsan polyester and triacetate) 0.43 mm thick, length of discharge gap 62 cm, width 32 cm. Voltage amplitude 44 kV in cases a and b and 126 kV in case c.

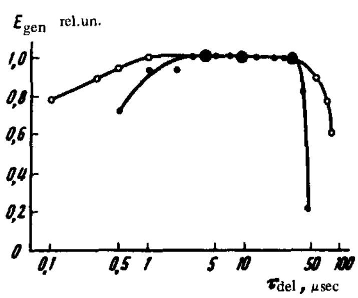

FIG. 2. Dependence of the energy of the generation pulses on the delay of the main supply pulse relative to the start of the formation of the gliding discharge. Voltage pulse amplitude: Δ—120 kV, ○—240 kV.

relative to the start of the formation of the gliding sparks, depending on the voltage applied to the gliding discharge, as shown in Fig. 2. When used with a non-autonomous discharge, this method of preionization can be useful for the development of high-pressure CO_2 lasers with long radiation pulses.

Thus, a gliding discharge can be realized in working mixtures of CO_2 lasers at high pressures and used to initiate a homogeneous discharge in a large volume.

[1]V. M. Andriyakhin, E. P. Velikhov, S. A. Golubev, S. S. Krasil'nikov, A. M. Prokhorov, V. D. Pis'mennyĭ, and A. T. Rakhimov, ZhETF Pis. Red. **8**, 346 (1968) [JETP Lett. **8**, 214 (1968).

[2]B. M. Koval'chuk, V. V. Kremnev, and G. A. Mesyats, Doklad. Akad. Nauk SSSR **191**, 76 (1970) [Sov. Phys.-Doklady **15**, 267 (1970)].

[3]C. A. Fenstermacher, M. I. Nutter, I. P. Rink, and K. Boyer, Bull. Amer. Phys. Soc. **16**, 42 (1971).

[4]O. P. Judd, Appl. Phys. Lett. **22**, 95 (1973).

[5]E. P. Velikhov, E. A. Muratov, V. D. Pis'mennyĭ, A. M. Prokhorov, and A. T. Rakhimov, ZhETF Pis. Red. **20**, 108 (1974) [JETP Lett. **20**, 47 (1974)].

[6]P. N. Dashuk, S. L. Zaĭents, V. S. Komel'kov, *et al.*, Tekhnika bol'shikh impul'snykh tokov i magnitnykh poleĭ (Large Pulse Current and Magnetic Field Engineering), Atomizdat (1970).

[7]D. Yu. Zaroslov, E. K. Karlova, N. V. Karlov, G. P. Kuz'min, and A. M. Prokhorov, ZhETF Pis. Red. **15**, 665 (1972) [JETP Lett. **15**, 470 (1972)].