REPETITEVELY PULSED TE–CO_2 LASER WITH A Q–SWITCHED RESONATOR AND LONG RADIATION PULSE

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The construction and specifications of a compact TE–CO_2 *laser with the pulse energy up to* 2 J, *pulse duration up to* 36 μs, *and pulse repetition frequency up to* 100 Hz *are presented. Pulse duration and output energy are analyzed as functions of the medium composition, pressure, and input energy for the case of using of a Q–switched resonator.*

In recent years an area of application of electric–discharge repetitively pulsed (RP) CO_2 lasers is continuously expanding. Then various requirements are imposed on the energy and time characteristics of the lasers. The problem of increasing the pulse duration in high–pressure CO_2 laser is most difficult. The lasers of such a kind usually generate the pulses of 1–3 μs duration. The pulse shape has a short powerful peak with the subsequent long low–power decrease of radiation.

The initial radiation peak produces an optically thick plasm on a target, that leads to significant absorption, scattering, and reflection of the subsequent part of the pulse. As a result, great portion of laser energy does not reach the target, and in some cases practical application of CO_2 laser is less effective.

Known ways of increasing the pulse duration are connected with the increase of N_2 and CO_2 content in the active medium[1] and/or with the decrease of its pressure.[2] However, in this case the difficulties appear due to a decrease in the amplification coefficient of the active medium and to the necessity of changing of the resonator Q–factor for operation in the optimum mode.

This paper presents a description of a Q–switched TE–CO_2 laser developed. The main purpose is to study the temporal and energy characteristics of the RP CO_2 laser for seeking for the optimum resonator Q–factor under wide variations of energy input, composition and pressure of the active medium.

Block diagram of a RP CO_2 laser is shown in Fig. 1. The principal discharge space is formed by two stainless steel electrodes and has the 10×12×72 cm^3 active zone. The total volume of laser chamber is ≈ 50 liter. The working medium is pre–ionized by a diffuse–channel discharge,[3] excited between the principal anode A and multisection additional electrode placed at 3 mm from each other.

The additional electrode is made of thin copper lanes 5 mm wide sticked on a more thick dielectric base in 5 mm intervals. The length of this electrode equals the length of the laser active zone. Each copper lane of the electrode is connected with its own capacitor C_2 of 22 pF capacity. The resonator is formed by a blind copper mirror of 11 m curvature radius contiguous to the working medium and the output plane copper mirror with the shape of 42 mm–diameter semicircle, separated from the working volume by a KCl plate installed at the Brewster angle. The resonator length is 1.28 m.

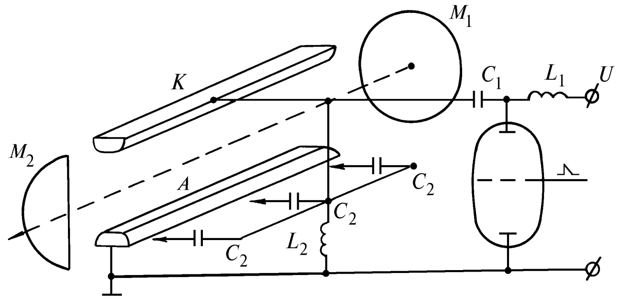

FIG. 1. Block diagram of repetitively pulsed TE–CO_2 laser: M_1 and M_2 are the *resonator mirrors; U is the charge voltage.*

The output mirror is mounded on the adjustment table. It is possible to move it smoothly perpendicularly to its optical axis that makes it possible to vary its transparency up to 100%.

The high–voltage pulse generator involves an accumulative capacitor C_1 of 44 nF, commutator (EXTRA–2 thyratron), charging inductance L_1 of 1 μH and a sharpening capacitors consisting of the capacitors C_2 providing the initiation of the additional discharge. Total capacity of the sharpening capacitor was C = 140×22 = 3.08 nF. The laser pulse shape was observed on a dual–beam memorizing C8–14 oscilloscope by means of FP–1 sensor. The KCL light dividing plate is placed in front of the photodetector at the angle of 7° to the resonator axis. It directes a part of the energy to the IKT–1N energy measurer. Such an arrangement of the detectors made it possible to record the pulse shape and energy simultaneously.

The characteristic pulse shapes realized at different composition and pressure of the working gas mixture are shown in Fig. 2. The pulse width at the level of 0.2 of the maximum pulse power was taken as a pulse duration τ. These values were used for constructing the dependencies of τ on different experimental parameters of the medium and pumping.

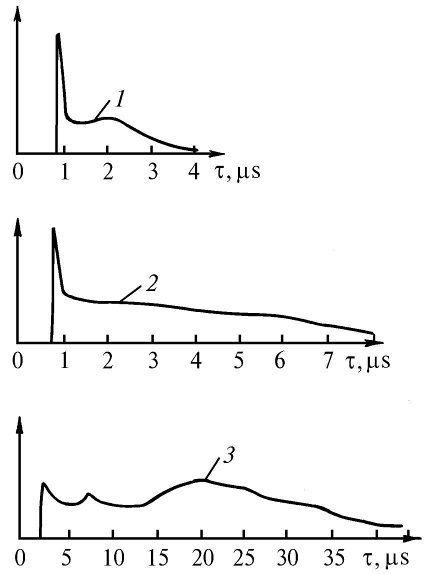

FIG. 2. Oscillograms of radiation pulses. 1) CO_2:N_2:He=1:1:4, *p*=1 atm, 2) CO_2:N_2:He=1:4:8, *p* = 0.4 atm, 3) CO_2:N_2:He = 1:10:25, *p* = 0.2 atm

The main attention was paid to revealing the modes of generation of the laser pulses of long duration and acceptable energy. The pulse durations and energies are shown in Fig. 3 as functions of pressure and working gas mixture composition. It is seen that as the nitrogen concentration in the gas mixture decreases, the pulse duration increases. These facts are mainly caused by a decrease in the rate of the energy transmission to the process of collision of moleculas from the vibrational level ν= 1 of nitrogen to the 001 CO_2 level.

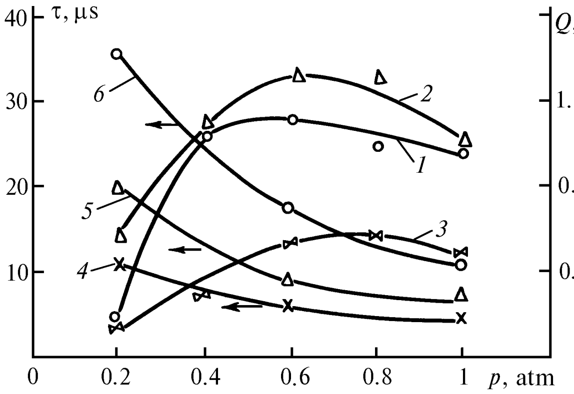

FIG. 3. Pulse duration τ (1–3) and energy Q (4–6) as functions of pressure for the input energy W = 10.7 J: *1) and 4) mixture composition* CO_2:N_2:He = 1:1:4; *2) and 5)* CO_2:N_2:He = 1:4:8; *3) and 6)* CO_2:N_2:He = 1:10:25.

The longest pulse was reached in the CO_2:N_2:He = 1:10:25 mixture, and the greatest energy was obtained in the CO_2:N_2:He = 1:4:8 mixture. These data were obtained for the constant input energy 10.7 J. The output mirror transmission coefficient was selected to be optimum from the standpoint of obtaining the maximum pulse duration τ.

An example of selection of the optimum generation conditions is shown in Fig. 4 for the CO_2:N_2:He = 1:1:4 mixture at the atmospheric pressure. It is seen that the conditions of reflection from the output mirror are different for the pulse energy and duration maxima due to different requirements to the amplification coefficients in these cases.

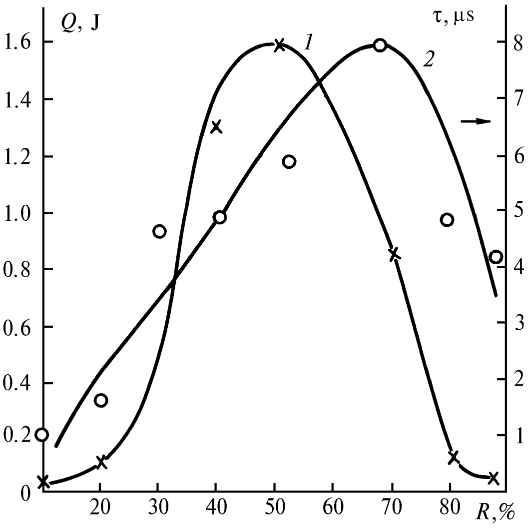

FIG. 4. Pulse energy (1) and duration (2) as functions of output mirror reflection coefficient for the gas mixture CO_2:N_2:He = 1:1:4 *at the atmospheric pressure*

Thus, the results obtained make it possible to correctly select the laser operation modes accurate for different technological operations such as drilling, cutting of brittle and solid materials. It should be noted that when using such a resonator, the radiation intensity in the light spot was quite inhomogeneous. So after selecting the laser operation mode, the plane output mirror was replaced by a convex one that satisfies the telescopic resonator conditions and has analogous reflection coefficient.

ACKNOWLEDGMENT

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REFERENCES

1. A. Girard, Opt. Commun., No. 11, 346–351 (1974).
2. A. Vedenov, et al., Kvant. Elektron. **7**, No. 6, 1186–1190 (1980).
3. V.A. Vizir', V.V. Osipov, V.A. Tel'nov, and G.M. Khamidulin, Kvant. Elektron. **15**, No. 6, 1256 (1988).