Q-SWITCHING IN A CO_2 LASER WITH AN ACTIVE GAS CELL

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We present a method of Q-switching of a CO_2 laser using an active gas cell filled with carbon dioxide and excited by an electric discharge.

The power of molecular lasers operating on vibrational-rotational transitions can be significantly increased by Q-switching [1]. The possibility of formation of microsecond pulses with the lifetime of the upper laser level 00^01 in CO_2 of the order of a millisecond makes it possible to obtain pulsed output power a hundred times higher than the steady-state power. Passive Q-switching of a CO_2 laser by a cell located within the resonator and filled with one or another gas [2-4] does not solve the problem of "driven" operation of the laser synchronized with an external electric signal. This note suggests the use of an "active" cell, filled with carbon dioxide and excited by a pulsed electrical discharge. The distinctive features of this system are: a) a wide range of conditions of the modulated medium – from gain to absorption (thermal population of laser levels) – in contrast to the transition from large to small absorption in the usual modulators, and b) simplicity and reliability of the Q-switching control.

The experimental schematic is shown in Fig. 1. The laser resonator is formed by a spherical mirror 1 with radius of curvature 10 m and by a flat mirror 2 with an aperture in the center of diameter 1.5 mm. The resonator cavity contains a CO_2 discharge tube 3, a gas cell 4, and an iris diaphragm 5. The length of the laser discharge tube is 125 cm, that of the cell is 20 cm, the resonator is 250 cm long, and the power is about 2 W.

The cell is controlled by an electrical system which allows us to combine a glow discharge regime with periodic application of high-current pulses.

The presence of a glow discharge has a number of important consequences: a) the pre-ionization assures good reproducibility of the shape and geometrical characteristics of pulsed discharges, and they fill the active cell rather well; b) the gas temperature increases, which alone contributes to increased absorption; c) the upper laser level 00^01 is preferentially populated by electron excitation, which leads to a decrease in the absorption down to a change in its sign. To separate the second and third effects, the glow discharge was maintained by a rectified but unfiltered voltage. With this discharge in the cell, the operating CO_2 laser had the following generation characteristics.

At the beginning of the regular half-period some amplification of the generation was observed, which then was followed by the reverse effect – attenuation, which dominated in the time intervals between current flow. The latter is due to the fact that after the cessation of current the equilibrium population is established in accordance with the gas temperature. By a judicial choice of the effective current of the glow discharge an absorption coefficient sufficient to suppress the generation at those instants was achieved. The general generation pattern had a periodicity of 100 Hz.

With further increase of the glow discharge current the generation was inhibited at all times. However, this regime was not used, since for Q-switching it is most advantageous to operate near the generation threshold.

To illuminate the resonator, a pulsed discharge was passed through the cell from the condenser C, which was driven by pulses on the grid of the thyratron T.

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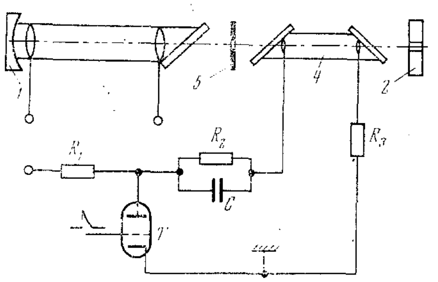

Fig. 1

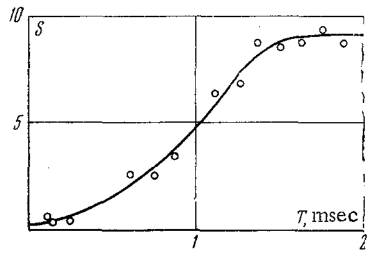

Fig. 2

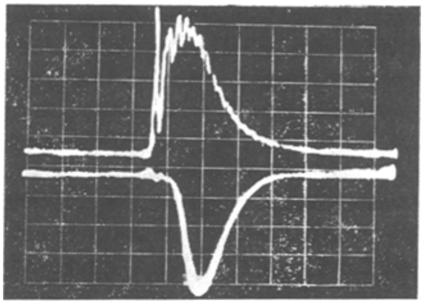

Fig. 3

During breakdown in the cell while the resonator was blanked, giant pulses were formed. The intensity and shape of these pulses depended significantly on the "delay" of the switch-on. The gain in the cell was smaller than in the discharge tube of a steady-state CO_2 laser (generation did not occur at the time of pulsed discharge through the cell with the laser off). Thus the role of the cell consisted of compensating the losses in the cell itself and in other resonator components; the latter was possible due to the absorption in the cell becoming negative.

It should be noted that the pressure of the CO_2 gas, which was varied over a broad range of 0.5-7 torr, did not play an important role in this case, since every time we selected the thermal regime near the threshold of inhibition of the laser and therefore corresponding to the same population of the lower laser level. With the pulsed discharge turned on at the beginning of the half-period of the glow discharge the additional gain was very small, about 20-30%. With departure away from the instant of thermal inhibition of generation the giant pulse magnitude increased rapidly in a time of the order of 1.5 msec, and then remained constant up to the next half-period of the glow discharge current. The characteristic rise time of the giant pulse was of the same order as in [1], and was determined by the time for populating the upper laser level. The dependence of the power of the first pulse S on the delay in switching on the potential across the cell relative to the instant of thermal suppression of generation T is shown in Fig. 2.

Figure 3 shows oscillograms of the pulsed current in the cell (upper trace) and of the pulsed generation (lower trace). The current amplitude is 7.5 kA, and the amplitude of generation exceeds by a factor of 300 the generation level in the steady-state regime. The generation pulse begins to rise almost at the instant of breakdown. The generation maximum occurs 1.5 μsec after breakdown, and the pulse half-width is about 1 μsec. The shift of the generation maximum relative to the instant of breakdown is characterized by high reproducibility (spread $< 5\%$). Further increase of the pulsed generation power can be achieved by separately regulating the cell temperature, the glow discharge current, and the pulsed current.

It is interesting to note that with incomplete suppression of generation by the glow·discharge a second giant pulse is observed (sometimes a series of pulses) during several tens of microseconds following the switching on of the pulsed current. The separation of the second pulse from the first increases monotonically with current. A possible explanation is as follows. The pulsed discharge causes additional population of the lower laser level, which leads to a complete blanking of the resonator. Subsequent relaxation of this level returns the resonator to its initial state, and the energy storage during this period in the CO_2 laser results in the delayed giant pulses.

We also made experiments with a cell filled with the gas mixture $CO_2 + N_2 + He$, similar to that in the CO_2 laser tube. Blanking of the resonator was achieved in this case by decreasing the opening of the iris diaphragm. When the pulsed discharge was turned on,a giant pulse was generated in the cell, exceeding by a factor of 50-70 the level of steady-state generation with the diaphragm open. Experiments were than made with the discharge gap decreased to 2.5 cm. The general relationships described above were preserved, and pulses were obtained of the same order of magnitude as in the long cell. Thus it is possible to locate the control spark gap directly in the CO_2 laser discharge tube, i.e., to create a unique laser-triode.

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