INFLUENCE OF THE CHOICE OF THE INSTANT OF Q-SWITCHING IN PULSED PUMPING OF A CO_2 LASER ON THE INTENSITY OF THE GENERATED PULSES

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A combination of the Q-switching method with pulsed pumping of a CO_2 laser has made it possible to observe the existence of an optimal Q-switching instant and to find that the energy of the laser pulses increases by three times when a transition is made in the Q-switching regime from continuous to pulsed discharges.

1. The purpose of this paper is to report results of experiments in the course of which establishment and vanishing of inversion was observed in the case of pulsed pumping of a CO_2-N_2-He laser by turning on the Q-switching pulses at the required instant of time. The short duration of the Q-switching pulses and the possibility of turning them on at an arbitrary phase of the discharge-current pulse and in the afterglow, made it possible to investigate in detail the dynamics of the occurrence and vanishing of the inversion.

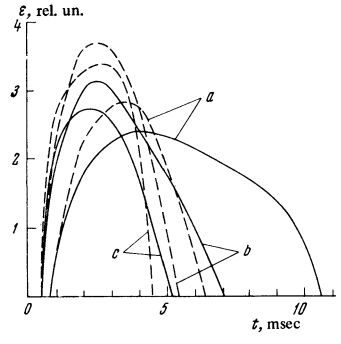
2. It is obvious that the rates of population and depletion of the laser levels determine to a considerable degree the attained inversion. These rates are best determined by pulsed methods.

Frapard, Roulot, and Zeigler[1], in investigations of a CO_2 laser pumped with short strong-current pulses, found that generation occurs not only during the discharge time, but also during 0.5 msec following the interruption of the current. Flynn et al.[2] synchronized pulses of a high-frequency discharge in a laser tube with the Q-switching pulses and found that after the termination of the discharge, at pressures ~1 Torr, a vanishing of inversion in the absence of generation takes place within several milliseconds. Clark and Smith[3] found that in the case of pulsed pumping the generation begins at 10–20 μsec after the discharge is turned on, and increases with the characteristic time 100–200 μsec.

In our investigation, we used the Q-switching technique to study the dynamics of the occurrence of vanishing of inversion during the entire pump pulse.

3. The discharge tube of the investigated laser is 65 cm long and its diameter is 5 cm. Internal electrodes were used. The resonator length was 110 cm. The spherical output mirror of 500 cm radius had an aperture of 1 cm diameter. The discharge tube was sealed with NaCl of high quality. The tube was cooled with running water. The discharge was excited either with dc or with pulses. The CO_2-N_2-He gas mixture was drawn through the discharge tube. The generation power in the continuous regime was 3–5 W.

The Q switching was by rotating a plane mirror of 6 cm diameter with an SD-09 synchronous motor. The Q-switching frequency was 50 Hz. The generation-pulse duration at dc discharge was 10 μsec. The optimal pressure was 2 Torr, and the optimal current was 60 mA. The optimum with respect to current and pressure was weakly pronounced.



Dependence of the generation pulse energy ϵ on the instant of Q-switching, a – discharge current 22 mA, b–discharge current 80 mA, c–discharge current 110 mA.

Pulsed pumping of the laser was effected with the aid of a thyratron circuit, the triggering of which was synchronized with the rotation of the mirror. A phase shifter in the triggering circuit made it possible to excite the Q-switching pulse at any point of the discharge-current pulse, and also after the interruption of the current. The pump-pulse duration was adjustable from 4 to 12 msec.

The generation pulses were registered with the aid of a Ge : Au receiver cooled to 77°K and an IO-4 oscilloscope. The discharge-tube voltage and current pulses were observed with the oscilloscope.

4. A noticeable increase, by a factor of two, was observed in the intensity of the generation pulses in the Q-switching regime when the change was made from the dc to the pulsed discharge. Since the generation-pulse duration increased by 1.5 times in this case, this corresponds to a threefold inversion increase. The characteristic times of the growth and decay of the inversion, both during the discharge and in the afterglow, were determined at a given pump level the values of the pulse current and by the pulse durations. These times greatly exceeded the times of establishment of the discharge current.

When the current was increased but the pump-pulse duration was kept constant at 10 msec, the inversion first increased, reached a maximum, and then decreased somewhat. The inversion growth time decreases with increasing pulse current. The time of existence of the inversion in this case was decreased.

When the pressure was increased from 2 to 6 Torr, the inversion increased, going through a maximum at

4 Torr. When the current pulse duration was decreased to 4 msec, the inversion increased further.

The figure shows examples of the experimentally obtained dependences of the energy of the Q-switching pulse on the instant of Q-switching at different currents for a pressure of 4 Torr, at a pump-pulse duration 10 msec (solid curves) and 4 msec (dashed).

In the case of a long pump pulse, the growth time of the maximum attained inversion is 2.5 msec, and its decay time is 4 msec. In the case of a short pulse, the growth time is 2—2.5 msec, and the decay duration in the afterglow depends strongly on the current (see the figure).

5. In the interpretation of the obtained results, it must be borne in mind that the times of rotational relaxation and the times of establishment of equilibrium within each of the modes of the CO_2 molecule are much smaller than the duration of the generation pulses. Therefore, on the basis of the obtained data, we can speak of processes of population of the laser levels, without considering their rotational structure or their connection with the higher vibrational states.

The increase of the inversion under pulsed pumping and the acceleration of the attainment of maximum inversion with increasing discharge current are connected with the more intense pumping of the upper level. The presence of an optimal current is due both to the intense population of the lower level and to the increased rate of relaxation of the upper level when the gas is heated by the strong discharge current. The vanishing of the inversion during the current pulse is also due to the heating of the gas. The increase of the inversion when the current pulses are shortened is connected with the decrease of the average power dissipated in the discharge.

We note that the results point also to the possibility of increasing the power and efficiency of pulsed CO_2 lasers by selecting the optimal strength and duration of the discharge-current pulse, in conjunction with a selection of the instant of the Q-switching.

[1] Ch. Frapard, M. Roulot, and K. Zeigler, Phys. Lett. 20, 384 (1966).

[2] G. M. Flynn, M. A. Kovacs, C. K. Rhodes, and A. Javan, Appl. Phys. Lett. 8, 63 (1966).

[3] P. O. Clark and M. R. Smith, Appl. Phys. Lett. 9, 369 (1966).

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