QUASISTATIONARY CO_2 LASER WITH "PULSED" EXCITATION

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Several methods of achieving significant population inversion in CO_2-N_2-He lasers were discussed in [1-3]. This paper describes a laser model which combines the advantages of a pulsed excitation of molecules in a discharge [3] with a nonequilibrium emanation of a supersonic flow into vacuum [1,2].

The experimental arrangement is shown in Fig. 1. The working CO_2-N_2-He mixture (in the ratio of 1 : 3 : 6, respectively), pre-mixed in the chamber 1, enters into the Laval nozzle 3 through the fast valve 2 (opening time $5 \cdot 10^{-4}$ sec), and is accelerated to a velocity of $5 \cdot 10^4$ cm/sec. The initial vacuum in the system is about 10^{-2} torr. The booster volume 6 acts as a high-capacity pump allowing the supersonic flow to escape into vacuum in $20 \cdot 10^{-3}$ sec. In $5 \cdot 10^{-3}$ sec after the action of the valve a steady-state flow is established, and a square-wave voltage pulse of duration $2 \cdot 10^{-2}$ sec is applied to the discharge gaps whose assembly formed the array 4. The length of each separate discharge channel in the direction of the flow is 2 cm, its diameter is 0.5 cm. The total transmittance of the array is 40%.

The main difference between this design and that described in [4], which uses the increased pump-through speed of the gas to increase the energy contribution to the discharge, is the fact that the time of flight of the gas molecule through the discharge gap for typical experimental conditions (total density of the mixture in the discharge region is about $4 \cdot 10^{17}$-$1.5 \cdot 10^{18}$ cm^{-3}) is significantly less than the lifetime of the 00°1 level of CO_2 (τ_*), and in this sense the excitation process has a pulsed character. As follows from [3], the effectiveness of molecular excitation by a short pump pulse ($\tau < \tau_*$) is significantly less than by a long pulse ($\tau > \tau_*$). The reserve of vibrational energy and the inversion magnitude for $\tau < \tau_*$ considerably exceed (by more than an order of magnitude) those quantities for a long excitation pulse, and must be proportional to the discharge current. The use of the reserve energy in the proposed model is facilitated by the fact that in the region bounded by the resonator mirrors 5 the excited gas expands rapidly, and the difference between the vibrational relaxation times of the 00°1 level and of the ONO level system in the CO_2 molecule leads to a growth of the total inversion.

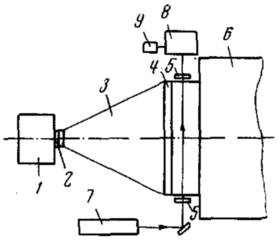

Fig. 1

The limiting power which can be applied to the discharge without overheating of the gas is, as in [4], determined by the finite heat capacity of the gas mixture.

Figure 2 shows typical oscillograms of the generation power (a) and of the discharge voltage (b). The generation reaches maximum about 10^{-4} sec after the application of voltage, and remains at constant level during the entire pulse. At a density of the mixture in the discharge region of about 10^{18} cm^{-3} and voltage pulse duration $t = 2 \cdot 10^{-2}$ sec, the measured energy of the stimulated radiation was 21 J.

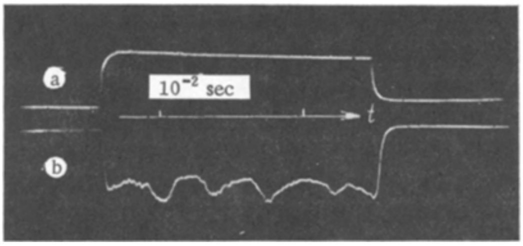

Fig. 2

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The resonator 5 was formed by a spherical ($R = 10$ m) and a flat metallic mirror coated with aluminum. The radiation was extracted through a slot in the flat mirror (the geometrical transmissivity of the mirror was 15%). The resonator mirror separation was 30 cm.

A change in the density of the working mixture over the range $4 \cdot 10^{17}$–$1.5 \cdot 10^{18}$ cm^{-3} resulted in a proportional increase in the generation power, which agrees with the calculations in [3].

The gain was measured using a low-power steady-state CO_2-N_2-He laser 7, whose radiation passed through the volume under study and a IKM-1 monochromator 8, and was detected by a Ge–Au detector 9. The resonator mirrors were in this case replaced with NaCl plates oriented relative to each other such as to avoid self-excitation. Over the length of the medium equal to 30 cm (mixture density in the discharge 10^{18} cm^{-3}) the power of the probe signal increased twofold, which corresponds to gain of 2.3 m^{-1}.

Using these results we can determine the lower limit of the total inversion. Since the number of energy radiating particles is nsvt [n is the density of the radiating particles, s is the product of the resonator length (30 cm) and height (4 cm), v is the flow rate, and t is the duration of operation of the system] then, knowing the energy measured with a calorimeter, we can determine n. The calculations give $n \sim 10^{16}$ cm^{-3}, which agrees satisfactorily with the total inversion determined from the measured gain. The magnitude of the total inversion $\sim 10^{16}$ cm^{-3} is typical of powerful pulsed lasers, and exceeds by more than an order of magnitude the value of ΔN achieved in steady-state discharges.

The described model is very sensitive to gas-dynamic characteristics and to the resonator configuration, and is evidently far from optimum at the present time.

LITERATURE CITED

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