INFLUENCE OF DISSOCIATION OF THE INVERSION ON A CO_2 LASER WITH PULSED PUMPING

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We report in this paper the results of experiments aimed at determining the dependence of the inversion in a CO_2 laser on the pump pulse repetition frequency. We have found that the dissociation of the CO_2 molecules greatly decreases the inversion with increasing repetition frequency, and that an increase of the amount of helium in the gas-discharge mixture greatly weakens this decrease.

The dynamics of the inversion during the discharge-current pulse is determined essentially by the heat-conduction processes in the gas-discharge plasma [1]. In addition, the CO_2 molecules become dissociated by the discharge [2]. The characteristic dissociation times measured [3] under continuous pumping are such that the dissociation process cannot affect the dynamics of the inversion under pulsed pumping. At the same time, the heat-conduction and dissipation processes can determine the stationary conditions established in the laser plasma as a result of the action of many discharge pulses.

The experiments were performed on a laser amplifier 400 cm long with a gas-discharge tube diameter 2.7 cm. The amplified pulses were fed to the input of the amplifier in synchronism with the pump pulses and at any desired phase. The signal pulse duration (10 μsec) was much shorter than the pump pulse duration (2 - 4 μsec). The measurements were performed in a linear regime wherein the gain was proportional to the inversion.

We have investigated gas mixtures with CO_2, N_2, and He pressure ratios 1:2:0, 1:2:3, 1:2:6, and 1:2:12. An increase of the amount of helium increases the thermal conductivity of the medium. It has been observed that the dynamics of the inversion and its lifetime are determined by the helium content. The maximum gain in the presence of helium is determined by the partial pressure of CO_2. The dependence of the gain on the partial pressure of the CO_2, measured at a pump-pulse repetition frequency 0.5 Hz, is the same for the 1:2:3, 1:2:6, and 1:2:12 mixtures (Fig. 1). For the 1:2:0 mixture, a much lower inversion is attained, this being due to the influence of the helium on the relaxation of the lower laser level.

When the pump pulse repetition frequency is increased from 0.5 to 50 Hz, the character of the time development of the inversion remains unchanged, but the maximum inversion decreases strongly. In our experimental conditions, the stationary heating of the gas was small and could not cause the decrease of the inversion with increasing pulse repetition frequency. We therefore attribute this effect to the dissociation of the CO_2 molecules. The decreased inversion due to the dissociation is noticeable when the gas mixture does not have time to become replenished during the time between the discharge pulses. At a flow rate of 1 liter/sec in a laser-tube volume of 2.3 liters, this corresponds to a pulse repetition frequency of

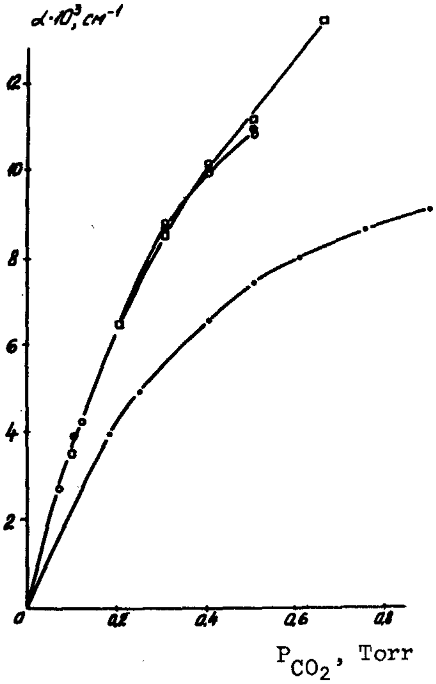

Fig. 1

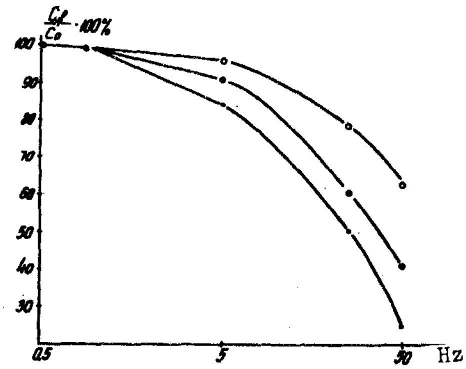

Fig. 2

Fig. 1. Gain vs. Partial pressure P_{CO_2} for CO_2, N_2, and He mixture ratios 1:2:0, 1:2:3, 1:2:6, and 1:2:12. Current 150 mA. For the 1:2:6 and 1:2:12 mixtures, a gain α = 0.03 corresponds to an upper laser level excitation rate 1.2 x 10^{18} $cm^{-3}sec^{-1}$.

Fig. 2. Ratio (per cent) of the number of undissociated CO_2 molecules to the number of initial molecules vs. the repetition frequency for mixture ratios 1:2:, 1:2:6, and 1:2:12 at a pressure 2 Torr and a current 150 mA.

5 Hz, as was indeed observed in the experiment. Comparison of the inversion vs. repetition frequency plot with the gain vs. partial pressure plot (see Fig. 1) leads to the plot of Fig. 2, which shows the dependence of the relative number of undissociated CO_2 molecules against the discharge pulse repetition frequency. At a pump repetition frequency 50 Hz, the dependence of the inversion on the partial pressure of CO_2 in the initial gas mixture becomes much weaker, and this apparently is also due to the equalization of the partial amount of CO_2 in the dissociation process. Thus, the curves of Fig. 1 give the true dependence of the gain on the amount of CO_2.

The influence of the dissociation was confirmed by the results of experiments performed with a sealed-off amplifier. The dissociation of the CO_2 molecules during one discharge pulse is small, and the process of establishment of the stationary dissociation level is easily observed at a pulse repetition frequency 0.5 Hz. This process lasts for several minutes, whereas at 50 Hz the stationary level is reached almost instantaneously. Under stationary conditions, the dynamics and the magnitude of the inversion remain constant at pulse repetition frequencies from 0.5 to 50 Hz, and coincide with the inversion established in a flow-through amplifier at a repetition frequency 50 Hz.

The dissociation rate is determined by the amount of helium in the discharge (see Fig. 2), this being apparently due to the fact that the helium facilitates the occurrence and the conditions for the existence of the discharge in the laser tube.

Thus, in CO_2 lasers the helium accelerates the relaxation of the lower laser level, reduces the temperature of the gas in the laser-discharge plasma, and lowers the dissociation level of the CO_2 molecules in the discharge.

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[1] N. V. Karlov, G. P. Kuz'min, A. M. Prokhorov and V. I. Shemyakin, Zh. Eksp. Teor. Fiz. 54, 1318 (1968) [Sov. Phys.-JETP 27, 704 (1968)].
[2] C. K. N. Patel, Phys. Rev. Lett. 12, 588 (1964).
[3] E. S. Gasilevich, V. A. Ivanov, E. N. Lotkova, V. N. Ochkin, N. N. Sobolev, and N. G. Yaroslavskii, FIAN Preprint No. 42, 1968.

SCATTERING OF LIGHT BY ELASTIC SURFACE WAVES

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In this paper we present the results of experiments on the scattering of light by elastic surface (Rayleigh) waves (ESW). We use as the light-scattering medium a crystal with trigonal synagony, α-quartz, in which direct piezoelectric excitation of ESW is possible by producing a spatial electromagnetic field in a periodic (offset-post) array consisting of metallic (silver) electrodes deposited on a polished surface of a crystal with a spatial pitch $d = \Lambda = v_R/f_0$. Here Λ is the length of the ESW, v_R the ESW velocity on the free surface of the crystal in a given direction, and f_0 the frequency of the excited ESW. The use of this method of exciting the ESW has enabled us to obtain relatively simply a large ESW amplitude by using an array with a large number of electrodes. The experimental setup is shown in the figure.

Polarized light from an He-Ne laser (type LG-36), designated 1 in the figure, with radiation power ∿ 30 MW, was directed to the surface of the crystal (2), along which the ESW propagated in the direction $\vec{k}_y$. An electric signal of frequency f_0 = 10 MHz and amplitude 20 V (effective) was applied to the exciting array (5) from a GCh-44 generator (3) through a UZ-5A amplifier (4). The presence of the ESW was monitored with the aid of a similar array (6) and an S1-20 oscilloscope (7).

The scattered light was registered with an FEU-27 photomultiplier (8) located at the focus of a spherical lens. A diaphragm (9) with inside diameter 1 mm was used to reduce the