PULSED CO_2 LASER WITH EMISSION ENERGY 150 J

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Submitted 15 January 1974
ZhETF Pis. Red. 19, No. 4, 212 – 215 (20 February 1974)

We report the design and parameters of a pulsed CO_2 laser of energy 150 J and pulse duration ∿ 100 nsec. The stability of the homogeneous phase of the discharge is considered. The times of instability development and the arc formation in molecular gases are measured.

Several electric-discharge lasers with high per-unit radiation parameters have been reported [1 - 3]. The present paper is devoted to the features of the emission of high-output-energy laser, and also to problems of discharge stability.

Figure 1 shows the electric circuit and the construction features of our pulsed CO_2 laser with transverse electric excitation. The laser consisted of 12 sections. The length of active section was 5 meters, and the transverse cross section 4×7 cm. The circuit parameters of each individual section were C_1 = 0.25 μF, C_2 = 0.1 μF, L ∿ 10 μH, and R = 47 Ω. The circuits were switched with a single discharge gap operating at a pressure ∿ 2 atm. The radiation energy was measured with two types of calibrated parameters.

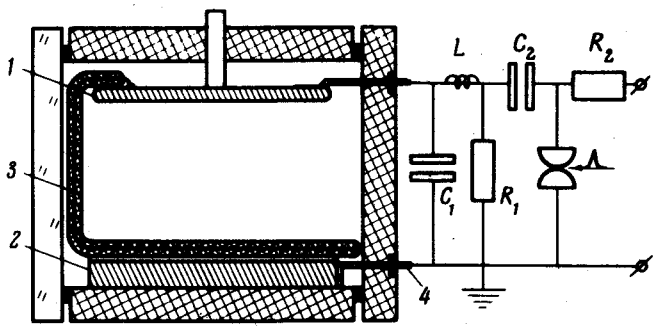

Fig. 1. Electric circuit and structure elements of laser chamber: 1 – anode, 2 – ridge cathode, 3 – auxiliary electrode, 4 – low-inductance lead-in.

The resonator length was 10 m. When a plane-parallel NaCl plate (δ = 10 mm) was used as the output mirror the output radiation energy was approximately 1.5 times larger than with a germanium mirror. The maximum energy 150 J was obtained for the mixture CO_2:N_2:He = 2:2:3 at a pressure 300 mm Hg. The maximum capacitor voltage was 30 kV. The largest per-unit energy was

obtained with a semi-confocal resonator and amounted to 18 J/liter at an efficiency ∿ 17%.

Figure 2a shows the waveform of the radiation pulse, measured with a germanium photodiode doped with zinc and with a radiation receiver of the "photon drag" type, made of a germanium crystal doped with gold. The pulse duration at half-height was ∿ 100 nsec (peak power $\geq 10^9$ W). When the output mirror was replaced with an NaCl plate at the Brewster angle, a radiation pulse of similar wave form, of energy up to 30 J, was observed. In our opinion, this was due to the onset of lasing by diffuse scattering [4].

A separate block was used to investigate a pulsed discharge in the gases making up the laser mixture and in the mixture itself at pressures 0.4 - 1 atm. At the chosen circuit parameters, breakdown of the main gap occurred at a considerable electron concentration on the cathode. The electron density and the thickness of their localization layer, needed to produce a homogeneous breakdown of the gap in the case of multielectron localization, can be estimated by starting with the initial cascades and the cascade overlap necessary to reach the critical concentration of the cascades in the streamers [5].

Typical current and voltage oscillograms for a homogeneous discharge are shown in Fig. 2b. With increasing discharge voltage of the capacitor C_1, formation of an arc is observed, with a time delay relative to the homogeneous breakdown of Fig. 2a. The time τ_p of arc production after a homogeneous breakdown we took to be the time from the maximum of the first peak to the start of the oscillatory process.

The times of energy transfer from the vibrational degrees of freedom of the nitrogen atoms to the translational degrees of freedom via quenching collisions are larger by several orders of magnitude than the times of instability development (10^{-6} - 10^{-7} sec). This excludes the possibility of a thermal mechanism of contraction in the nitrogen.

A possible mechanism of contraction in a molecular gas is considered in [5, 6]. When a positive fluctuation of the electron concentration n_e occurs, the population of the vibrational levels at the location of the fluctuation increases, the electron temperature rises, and this leads to further increase of n_e, so that instability sets in. The growth increment is given by [5] $\gamma = 1/\tau_p = \text{const} \cdot n_e$, where const $\approx 10^{-8}$ cm^3/sec. Since the time of energy input is shorter

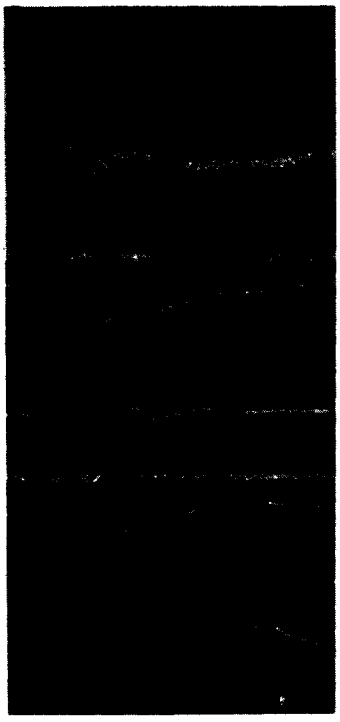

Fig. 2

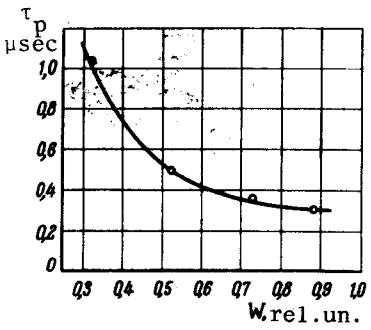

Fig. 3

Fig. 2. Typical oscillograms: a — radiation pulse, b — voltage and current of homogeneous discharge, c — voltage and current of discharge with subsequent arc production.

Fig. 3. Dependence of instability development increment on W in nitrogen.

than the recombination time, the electron density is $n_e = W/I^*$, where I^* is per-unit ionization, $W = \int_0^{\tau_0} jEdt$ is the density of the energy input, $\lambda = 10^{-2} - 10^{-3}$ (8) is the fraction of energy consumed in ionization, and τ_0 is the time of the main energy input. Figure 3 shows a plot of γ against W. In carbon dioxide at the same values of W the times of arc formation are approximately 1.5 times larger. The qualitative differences in the case of helium may be due to a different discharge-contraction mechanism, such as multistep ionization [6] or thermal instability. The field intensity and accordingly the total energy input to the discharge, which corresponds to the transition from the homogeneous phase to the arc phase, is much lower for helium than for nitrogen and for carbon dioxide. The role of the inert-gas atoms is probably limited to depopulation of the lower laser level, and this is why it was advantageous to use a laser mixture with a relatively low partial gas pressure (CO_2:N_2:He = 2:2:3).

The authors are grateful to A. A. Vedenov and A. P. Napartovich for interest in the work and for constant discussions.

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