DETONATION GASDYNAMIC LASER

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Submitted 12 May 1971
ZhETF Pis. Red. 14, No. 2, 73 - 76 (20 July 1971)

This article is devoted to a description of a new type of gasdynamic laser, in which the initial high-temperature gas mixture is obtained by detonating a solid.

Gasdynamic lasers were proposed in [1, 2]. The general ideas on which they are based were considered by the authors of [3]. A more detailed theoretical examination of the processes determining the operation of gasdynamic lasers is given in a number of papers [4, 5]. They were realized by a number of Soviet and foreign scientists [6 - 10].

Until recently, the high-temperature mixture in the gasdynamic lasers was obtained by the passage of a shock wave through a gaseous medium (pulsed lasers [6, 8]), by heating with an electric arc, or else by combustion of the initial gases (cw lasers [8, 10]).

In the laser described here we used detonation of a solid, making it possible to vary the initial pressure and temperature of the gas mixture within a wide range and to simplify greatly the experimental setup and reduce its dimensions. A diagram of the setup is shown in Fig. 1.

The initial substance used in the experiments was a mixture of HN_3 with nitrogen dioxide and xenon. The gaseous mixture was fed into volume 5 (Fig. 1) and then frozen on metallic rod 3 by filling cavity 4 with liquid nitrogen. The detonation was initiated by an electric spark.

The expansion of the detonation products in the high-pressure chamber 1 occurred within a time on the order of several dozen microseconds, and the escape of the gas through the slit took about a millisecond (the ratio of the chamber volume to the product of the slit area by the speed of sound in the

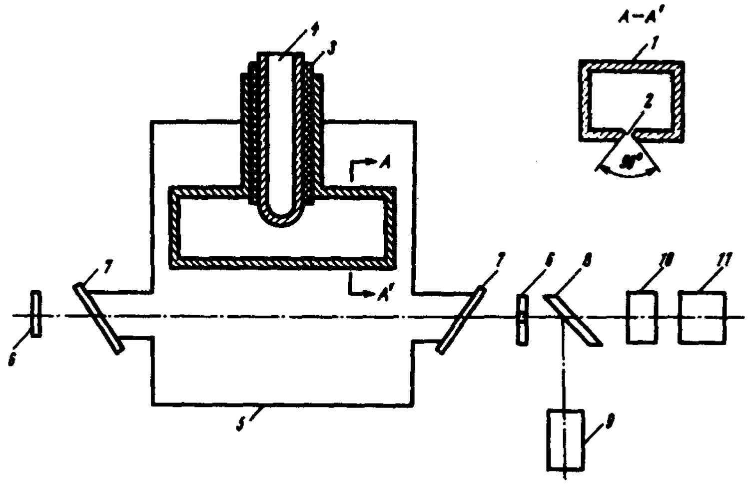

Fig. 1. Diagram of experimental setup: 1 - high-pressure chamber with volume 0.3 liters; 2 - slit measuring 200 × 0.4 mm; 3 - metallic rod with cavity 4 thermally insulated from the remaining part of the setup; 5 - ballast volume of 12 liter capacity; 6 - gold-coated mirrors of 25 mm diameter with one of the mirrors provided with an aperture of 2.5 mm diameter; 7 - Brewster windows of NaCl; 8 - plane-parallel germanium plate; 9 - calorimeter; 10, 11 - photoreceiver and oscilloscope.

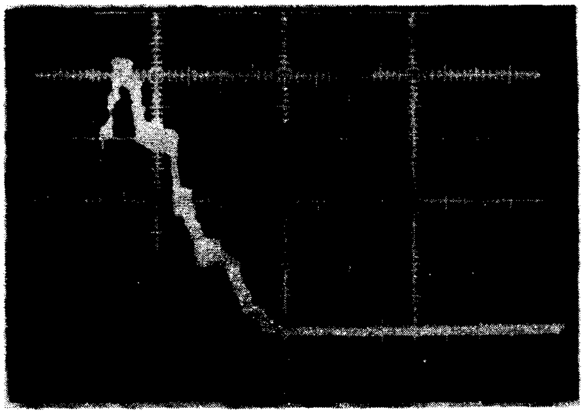

Fig. 2

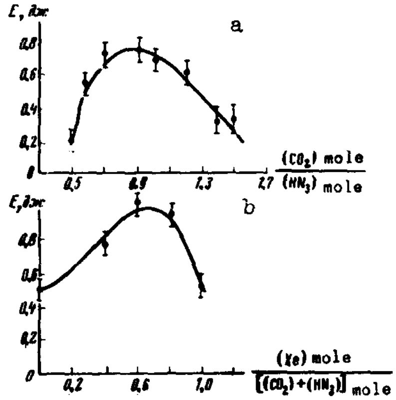

Fig. 3

Fig. 2. Oscillogram of generation pulse, 500 μsec/division.

Fig. 3. Dependence of output energy on the content of the CO_2 in the $HN_3 + CO_2$ mixture at a given amount of HN_3(0.5 g) (a) and on the content of the xenon in the mixture $HN_3 + CO_2 + Xe$ at a given amount of HN_3 (0.5 g) and CO_2 (0.33 g) (b).

critical cross section). The pressure and temperature in the high-pressure chamber after the expansion of the detonation products were, according to our estimates, of the order of 10 - 20 atm and 2000 - 3000°, depending on the amount and composition of the mixture. A thermodynamic calculation and an IR analysis of the explosion products have shown that practically all the hydrogen (about 90%) was oxidized to water, reducing part of the carbon dioxide to carbon monoxide. The water content in the mixture then reached 15 - 20%.

The distance from the slit to the resonator axis was regulated in the experiment, the optimal distance being about 3 cm.

Figure 2 shows a typical oscillogram of the generated pulse. The pulse duration at the optimal composition of the mixture was close to the time of escape of the gas through the slit.

Figure 3 shows the dependence of the output energy: a) on the content of the CO_2 in the $HN_3 + CO_2$ mixture at a given amount of HN_3 (0.5 g) and b) on the content of the xenon in the $HN_3 + CO_2 + Xe$ mixture at given amounts of HN_3 (0.5 g) and CO_2 (0.33 g). It is interesting that the maximum energy (on the order of 1 J) was obtained at a relative content of the components corresponding to an approximate initial detonation-product temperature 2500°K. This temperature greatly exceeds the temperatures that are optimal in accordance with [8] for $N_2 + CO_2 + He$ mixtures. This difference can be explained, first, as being due to the difference in the gasdynamic parameters of the installations, and, second, to the fact that in the described experiments the mixture temperature changed simultaneously with its composition. Preliminary experiments have shown that addition of chlorine to the investigated mixtures, in an amount close to stoichiometric with respect to hydrogen, leads to a sharp (approximately threefold) increase of the generated energy. The content of the water in the products then decreases to 2 - 4%.

In conclusion, it should be noted that the use of liquid nitrogen in the described setup is an experimental means of placing the initial substance in the reaction volume. In principle, the experiment can be carried out at room temperatures using other substances.

[1] V.K. Konyukhov and A.M. Prokhorov, Author's Certificate (Patent) No. 223954, Priority 19 February 1966, Invention Bulletin No. 25, 1968.
[2] V.K. Konyukhov and A.M. Prokhorov, ZhETF Pis. Red. 3, 436 (1966) [JETP Lett. 3, 286 (1966)].
[3] N.G. Basov and A.N. Oraevskii, Zh. Eksp. Teor. Fiz. 44, 1742 (1963) [Sov. Phys.-JETP 17, 1171 (1963)].
[4] N.G. Basov, A.M. Oraevskii, and V.A. Shcheglov, Zh. Tekh. Fiz. 37, 339 (1967) and 38, 200 (1968) [Sov. Phys.-Tech. Phys. 12, 243 (1967) and 13, 143 (1968)].
[5] A.S. Biryukov, B.F. Gordiets, and A.A. Shelegin, Zh. Eksp. Teor. Fiz. 57, 585 (1969) [Sov. Phys.-JETP 30, 321 (1970)].
[6] V.N. Konyukhov, N.B. Matrosov, A.M. Prokhorov, D.T. Shalunov, and N.N. Shirokov, ZhETF Pis. Red. 10, 84 (1969) [JETP Lett. 10, 53 (1969)].
[7] A.P. Dronov, A.S. D'yakov, E.M. Kudryavtsev, and N.N. Sobolev, ibid. 11, 516 (1970) [11, 353 (1970)].
[8] D.M. Kuehn and D.T. Monson, Appl. Phys. Lett. 16, 48 (1970).
[9] B.R. Bronfin, L.R. Boedeker, and J.P. Cheyer, Appl. Phys. Lett. 16, 214 (1970).
[10] E.T. Gerry, IEEE, Spectrum 7, 51 (1970).

EXPERIMENTAL INVESTIGATION OF STOCHASTIC ACCELERATION OF IONS IN AN INTENSE PLASMA-BEAM DISCHARGE

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Submitted 24 May 1971
ZhETF Pis. Red. 14, No. 2, 77 - 80 (20 July 1971)

As shown in [1], in an intense pulsed plasma-beam discharge it is possible to distinguish between two regimes of excitation of low-frequency (LF) oscillations: the first regime (relatively low pressures) is characterized by excitation of ion-acoustic oscillations [2], which go over in time (after 30 - 40 μsec) into oscillations pertaining to the second regime. The second regime includes also oscillations generated during the entire duration of the current pulse at higher gas pressure of the system (above 6×10^{-4} Torr), since for these oscillations the first regime lasts only several microseconds.

We present in this paper results of an investigation of the stochastic acceleration of ions in the excitation of LF oscillations in the second regime.

The experiments were performed with a setup [2] having the following parameters: electron beam current 5 A, energy 10 - 12 keV, current pulse duration 110 μsec, electron density of the plasma produced by the beam 5×10^{12} - 2×10^{13} cm^{-3}, longitudinal magnetic field intensity up to 2 kOe, working gas - hydrogen.

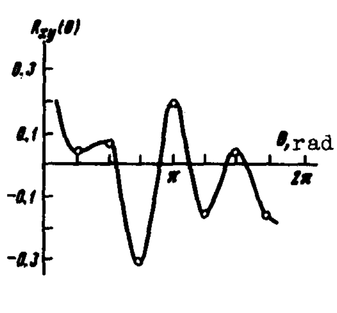

Fig. 1

Using the procedure of computer reduction of the experimentally obtained realizations [1], we determined the following characteristics: the function of mutual correlation of the oscillations in azimuth, the space-time correlation function, the frequency spectrum and the spectral energy density of the excited oscillations; we also investigated the time variation of the phases of the investigated oscillations.

The oscillations in the second regime, unlike in the first, are axially-asymmetrical. Figure 1 shows the function of the mutual correlation of the excited oscillations in azimuth, obtained with the