QUALITATIVE ANALYSIS OF THE POSSIBILITY OF IGNITION OF CONTROLLABLE THERMONUCLEAR FUSION

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Results of a preliminary experiment on excitation of gaseous active media by hard radiation of an uncontrolled thermonuclear explosion are presented. Pulsed lasing of an HF laser with an energy output of ≈ 10 kJ and efficiency of ≈ 3% and of an excimer XeF laser with an output of ≈ 1 kJ and efficiency of ≈ 9% with a pulse duration of ≈ 2 nsec is obtaned.

Further development of inertial thermonuclear fusion is immediately connected with investigations in the field of lasers with output energy sufficient for ignition of a controllable fusion reaction in a small volume. The sufficiency condition is the weak spot of all presently existing research programs. Earlier [1, 2], we have proposed using travelling-wave gas lasers pumped by the hard radiation component of a low-power (less than 10 kton) thermonuclear explosion. The minimum existing dimensions of this source, the highest densities of the pump energy injected, and the high degree of spatial and temporal symmetry of target irradiation are the substantial advantages of the device [2] compared to multistage laser systems already built or under development. It is evident that the use of these lasers will obviate achieving conditions of optimal pumping of microtargets.

Already in our early works [1, 2] we have pointed out that travelling-wave lasers should be used upon pumping by pulses of the hard radiation of the thermonuclear explosion, since the radiation field has no time to be formed during ~1 nsec in multipass cavities. In this case, the axis of the laser unit should necessarily pass through the load center.

In experiment [1], cells with gaseous lasing media 1 were installed is special boxes in the radial direction with respect to the source of penetrating radiation 2 at different distances r from the source (Fig. 1) during underground thermonuclear tests. From the constructive point of view, the cell comprised a metal tube one of the ends of which 3 had a calculated chamfering with radius R. Traces recorded by gage and background calorimeters were processed by a special software. The time dependence of the lasing pulse was detected by a high-current strip photodetector. Prior to mounting, cells were cleaned, evacuated, and filled with premixed gas mixtures at certain pressures.

The XeF laser comprised a tube with internal diameter $d_{\text{cell}} = 200$ mm and length $L_{\text{cell}} = 2.5$ m filled with the Ne:Xe:NF_3 mixture with a ratio of 1000:30:1 at a pressure of ≈ 0.6 MPa.

The HF laser comprised a tube with internal diameter $d_{\text{cell}} = 500$ mm and length $L_{\text{cell}} = 3.5$ m filled with the SF_6:H_2 mixture with a ratio of 9:1 at a pressure of ≈ 0.22 MPa.

Figure 2 presents an oscillographic trace of a penetrating radiation pulse (the time scale is given by a sine function with a period of 1 nsec); the FWHM of the pulse is 2.2 nsec. The laser radiation fluence at the output end of the HF laser was ≈ 5 J/cm^2, which corresponds to a total energy of ≈ 10 kJ, specific energy output of ≈ 17 mJ/cm^3, and efficiency with respect to the input energy of ≈ 3%. For the XeF laser, the laser radiation fluence was ≈ 3 J/cm^2, which corresponds to a total energy of ≈ 1 kJ, specific energy output of ≈ 12 mJ/cm^3, and efficiency with respect to the input energy of ≈ 9%.

Figure 3 presents time dependences of signals from the gage (trace b_1) and background (trace b_2) calorimeters for XeF and HF lasers (time marks have a period of 2 μsec). The error of measurements in both cases did not exceed 50%. The fast response of the calorimeters is due to the obvious effect of their short lifetime under

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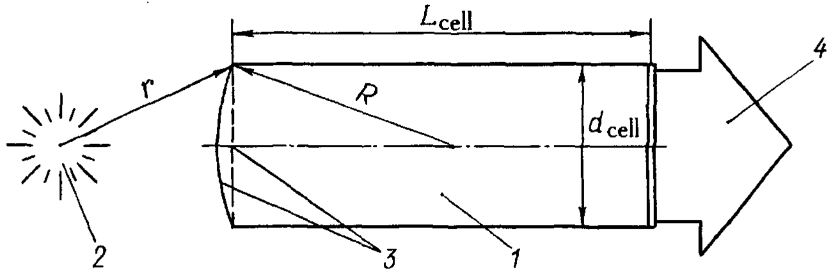

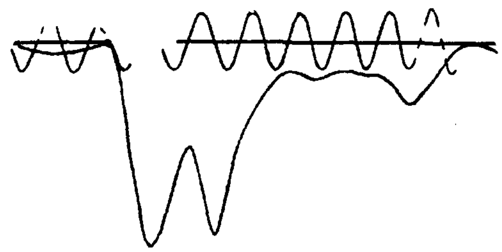

Fig. 1. Schematic of experimental setup: cell (1), γ-radiation source (2), source with correcting device (3), and laser beam (4).

Fig. 2. Pumping radiation pulse.

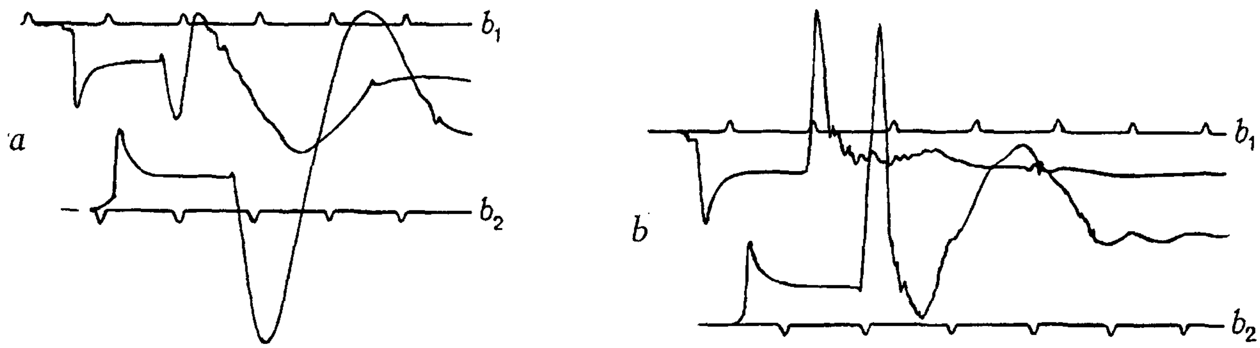

Fig. 3. Oscillograms of signals from calorimeters recorded for XeF (a) and HF laser (b).

the specific pumping conditions. However, as is evident from the figure, the signal and pick-up pulses detected are well-resolved in the oscilloscopic traces and can rather easily be identified. The divergence of radiation is close to geometrical, which is indirectly evidenced by the virtually uniform distribution of the laser radiation energy over the faces of the lasers. Bonyushkin et al. [3] reported on further investigations following the research program outlined in [1].

The research program proposed can obviously be realized only on an international cooperation level and it should expediently be started with an experiment on determining the conditions of ignition of a fusion reaction upon direct irradiation of microtargets by shortwave radiation of a thermonuclear explosion. This investigation is necessary for obtaining initial data for quantitative simulation of processes in nonequilibrium plasma. In addition, to provide a basis for subsequent extrapolations, comparative analysis of the conditions of ignition of the reaction upon immediate irradiation and upon laser irradiation in an experiment with one and the same source should most likely be carried out.

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