Irradiation of spherical microtargets by a two-terawatt iodine laser

F. M. Abzaev, N. N. Beznasyuk, V. G. Bezuglov, A. V. Bessarab, A. V. Veselov, L. M. Vinogradskiĭ, V. A. Gaĭdash, I. V. Galakhov, A. S. Gasheev, V. A. Eroshenko, A. I. Zaretskiĭ, G. A. Kirillov, S. B. Kormer, G. G. Kochemasov, S. M. Kulikov, Yu. V. Kuratov, V. M. Murugov, V. D. Nikolaev, G. P. Okutin, V. I. Pankratov, V. T. Punin, N. N. Rukavishnikov, A. V. Ryadov, V. A. Samylin, A. V. Senik, S. A. Sukharev, and A. I. Funtikov

(Submitted 2 October 1981)
Zh. Eksp. Teor. Fiz. **82**, 459–461 (February 1982)

The power of the "Iskra IV" iodine laser is raised to 2 TW by reducing the laser-pulse duration without loss of energy. Irradiation of spherical microtargets filled with DT gas by the iodine laser yielded for the first time 10^5 neutrons in the exploding-pusher mode.

PACS numbers: 52.50.Jm, 42.55.Hq, 42.60.By

The single-channel iodine laser "Iskra IV" (Ref. 1) emitting at 1.315 μm was used to irradiate spherical microtargets of 150–170 μm diameter and glass thickness 1 μm, filled with DT gas to pressures 10–40 atm.

To irradiate the spherical targets, the output beam, of 270 mm diameter, was divided by beam-splitting plates into four beams, which were focused on the target by parabolic mirrors having $F = 270$ mm. The accuracy of aiming at the target in these experiments was 10–20 μm. For a more uniform irradiation, the target was placed in a plane where the spot dimension was 200 μm.

Optical decouplers in the form of bismuth films sputtered on a glass substrate, as well as saturating shutters based on dyes, were used to prevent self-excitation of the system consisting of the master generator, the amplifier stages, and the target. This made it possible to obtain in the output beam an energy contrast $K_E \gtrsim 10^7$ and a power contrast $K_P \gtrsim 2 \cdot 10^6$. The beam divergence at the output of the setup was $\approx(1-2) \cdot 10^{-4}$ rad.

In the first experiments, 500 J of laser energy was fed into the target chamber. At this energy, the exploding-pusher mode is preferable since it provides a large neutron yield.[2] It can be effected if the temperature of the fast electrons is high enough, $\gtrsim 10$ keV. This calls for a power density $\gtrsim 10^{15}$ W/cm^2 on the microtarget surface. To obtain such radiation power fluxes at the indicated energies and target dimensions, the laser pulse duration must be $\lesssim 0.3$ nsec. The pulse duration was shortened both by using a faster rise time of the master-generator laser pulse, and by choosing the appropriate operating conditions of the amplifying stages of the iodine laser. As a result of these measures, the laser output pulse duration was $\tau = 3 \pm 0.05$ nsec, which agreed with the calculation results. It is important that, in contrast to neodymium lasers, the energy at the output of the set-up hardly decreased when the pulse duration was shortened from 1 to 0.25 nsec.

The energy balance in the laser plasma was determined with specially developed calorimeters. For the experiment in which the largest neutron yield was registered ($\sim 1.5 \cdot 10^5$ neut/pulse), the energy input to the chamber was 480 J, the energy incident on the target was 280 J, and the energy absorbed by the target was 50 J. The laser-radiation flux density at the target was $\approx 10^{15}$ W/cm^2.

The continuous x-ray spectrum measured by the filter method is shown in Fig. 1. The temperatures corresponding to the soft and hard parts of the spectrum were found to be $T \approx 1$ keV and $T_h \approx 9$ keV, respectively. The temperature of the corona near the critical surface, determined from the line spectrum (the relative intensities of the resonant lines of the helium- and hydrogen-like silicon ions) was 0.8 keV. The temperature near the surface, where the electron density was $\approx \rho_{cr}/4$, was determined from the distance between the peaks of the $3\omega/2$ spectrum and found to be 0.9 keV.

A photograph of the target in its own x-radiation, taken with a pinpoint camera, has shown (see Fig. 2) that the DT gas was compressed by approximately 30 times.

The measured neutron yeild is shown in Fig. 3, where the ordinates represent the experimental values of the neutron yield and the abscissas the expected values. These values were determined with a semi-empirical model[2] that describes the results of the Livermore-Laboratory experiments in the exploding-shutter mode, which are shown on the same figure. It is seen that our results are in good agreement with the Livermore experimental data. The fast-electron (≈ 9 keV) temperature measured in the experiments at the indicated thickness of the glass microtargets (≈ 1 μm) shows that

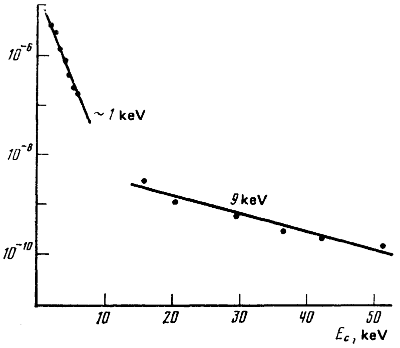

FIG. 1. Spectrum of plasma x-radiation.

© 1982 American Institute of Physics

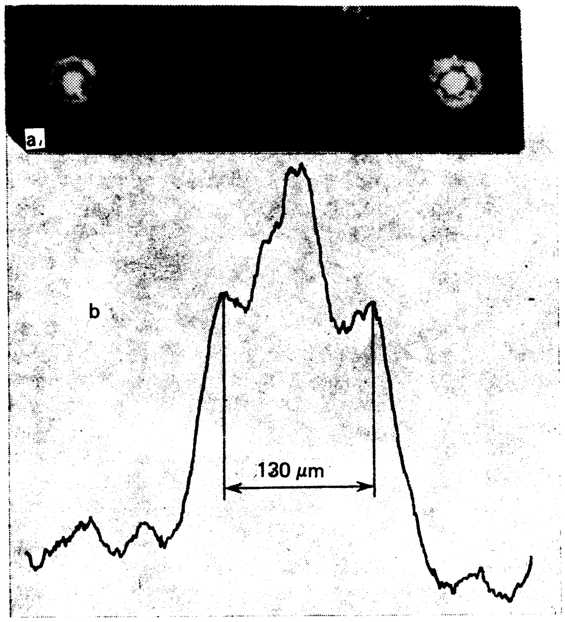

FIG. 2. Photograph of target in its own x-rays (a) and characteristic photographic-density pattern.

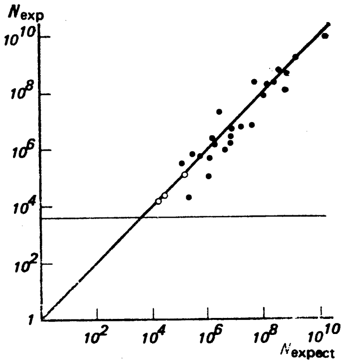

FIG. 3. Comparison of the results on the neutron yield with the results of the Livermore laboratory: o) experiments with the "Iskra IV" laser; ●) Livermore Laboratory data; the line parallel to the abscissa axis is the sensitivity threshold.

the exploding-pusher mode was likewise realized in our experiments.

As a result of the investigations, the power of the "Iskra IV" facility was raised to 2 TW by shortening the laser-pulse from 1 to 0.3 nsec with practically no loss in energy. A neutron yield of 10^5 and volume compression by approximately 30 times was obtained, for the first time ever, by using an iodine laser to irradiate spherical microtargets filled with DT gas.

[1] S. B. Kormer, Izv. AN SSSR, ser. fiz. **44**, 2002 (1980).
[2] E. K. Strom *et al*., Phys. Rev. Lett. **40**, 1570 (1978).

Translated by J. G. Adashko