MEASUREMENT OF THE TIME VARIATION OF THE TEMPERATURE OF THE PLASMA OF A LASER FLARE BY MEANS OF ITS X-RADIATION

N. G. Basov, V. A. Boiko, V. A. Gribkov, S. M. Zakharov, O. N. Krokhin, and G. V. Sklizkov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 3 March 1969
ZhETF Pis. Red. 9, No. 9, 520-523 (5 May 1969)

1. Measurements of the time variation of the temperature are undoubtedly of interest for the understanding of the processes accompanying high-temperature heating of matter by powerful laser radiation [1]. As shown by earlier experiments [2], the maximum electron temperature T_e of the plasma produced when a laser pulse of several GW power is focused on the surface of a solid in vacuum (laser flare) reaches 200 - 300 eV at an electron density $n_e \approx 10^{21} - 10^{22}$. The characteristic thermal x-radiation occurring under such conditions was used in the present experiments for temporal diagnostics of the plasma of a laser flare.

2. The plasma was produced with the aid of a laser having the following radiation-pulse parameters: energy — up to 30 J, duration at half-height — 15 nsec, at the base — 35 nsec. The radiation was focused with a lens of f = 5 cm on the surface of a carbon target placed in a vacuum of 10^{-6} Torr. The temperature of the hottest part of the flare was

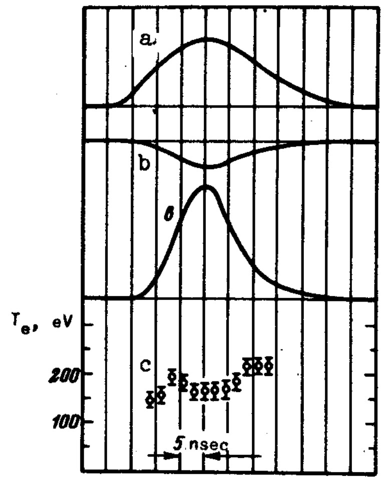

Fig. 1. Oscillograms of recorded signals and time dependence of T_e: a - laser radiation pulse; b - signal from photomultiplier at a filter thickness 31 mg/cm^2; c - signal from photomultiplier, filter 15.5 mg/cm^2; d - electron temperature. Time resolution of photmultipliers 5 nsec. Signal correlation accuracy not worse than 1 nsec. Laser energy 27 J.

measured by the absorber method using the soft x-radiation, which was registered with two photomultipliers with plastic scintillators [3]. The procedure makes it possible to determine (with a resolution ± 2.5 nsec) the time variation of the x-rays from the plasma passing through beryllium filters of 15.5 and 31 mg/cm^2 density, with simultaneous monitoring of the waveform of the laser pulse. The time correlation of all three channels was not worse than 1 nsec. The figure shows oscillograms of the pulses and the electron temperature T_4, determined from the ratio of the photomultiplier signals, using the calculated data of [4]. Estimates show that in our case the dominant role in the radiation registered through the beryllium filters is played by the recombination radiation of the freely bound transitions to the ground level of the hydrogenlike C VI ions, and that the optical density of the plasma is less than 0.03 if $\lambda < 10$ Å.

3. In spite of the appreciable change of the intensity of the laser emission F(t) during the pulse duration, the electron temperature T_e changes little (see the figure). This result can be interpreted as follows.

The temperature of the hot plasma produced on the surface of the target under the conditions of our experiment (flux density $\sim 10^{12}$ W/cm^2, focal-spot diameter $\sim 10^{-2}$ cm, pulse duration $\sim$ 15 nsec) is determined by the instantaneous value of the radiation flux density [5]. The time variation of the average flux density $q = F/\pi d^2$ ($d = 2f\theta(t)$ is the characteristic dimension of the focal spot) is due to the time dependence of the laser-beam divergence $\theta(t)$. According to [6], $\theta(t)$ increases during the pulse rise time from 2.5×10^{-4} to 3×10^{-3} rad, and then decreases on the descending part. With this, d changes in the range from 0.025 to 0.3 mm. Thus, at the corresponding variations of F (t) and $\theta(t)$, the value of q can remain constant, thereby ensuring constance of T_e during the greater part of the laser pulse.

In conclusion, we note on the basis of the foregoing data that in order to increase the temperature of the heated plasma it is necessary, besides increasing the energy and power of the lasers, to take special measures to increase the radiation flux density, mainly be reducing the beam divergence and using a special optical system.

The results of the measurements of the time dependence of the temperature during the time of plasma heating by radiation pulses, at different laser-emission parameters, and a detailed discussion of the results, will be published in a separate paper.

The authors thank I. L. Beigman and A. V. Vinogradov for discussions and O. V. Guseva and I. P. Tindo for useful consultations.

[1] N. G. Basov and O. N. Krokhin, Zh. Eksp. Teor. Fiz. 46, 171 (1964) [Sov. Phys.-JETP 19, 123 (1964)].

[2] N. G. Basov, V. A. Gribkov, O. N. Krokhin, and G. V. Sklizkov, ibid. 54, 1073 (1968) [27, 575 (1968)]; N. G. Basov, V. A. Boiko, Yu. P. Voinov, et al., Revue Roumaine de Physique 13, 97 (1968); N. G. Basov, O. N. Krokhin, and G. V. Sklizkov. Applied Optics 6, 1814 (1967); D. D. Burgess, B. C. Faurett, and N. T. Peacock, Proc. Phys. Soc. 92, 805 (1967); B. C. Boland, F. E. Irons, and R. W. P. Mc Whirter, Proc. Phys. Soc. 1, 1180 (1968).

[3] N. G. Basov, V. A. Boiko, V. A. Gribov et al., FIAN Preprint No. 111.

[4] F. C. Iahoda, E. M. Little, W. E. Quinn, G. A. Sawyer, and T. F. Stratton, Phys. Rev. 119, 843 (1960); R. S. Elton, and N. V. Koth, Applied Optics 6, 2071 (1967).

[5] I. V. Nemchinov, Prikl. Mat. Mekh. 31, 300 (1967).

[6] N. G. Basov, V. A. Boiko, O. N. Krokhin, and G. V. Sklizkov, Dokl. Akad. Nauk SSSR 173, 538 (1967) [Sov. Phys.-Dokl. 12, 248 (1967)].