

Investigation of laser-plasma emission in the x-ray band

Yu. S. Kas'yanov, V. V. Korobkin, P. P. Pashinin, A. M. Prokhorov, V. K. Chevokin, and M. Ya. Shchelev

P.N. Lebedev Physics Institute, USSR Academy of Sciences

(Submitted September 16, 1974)

ZhETF Pis. Red. 20, No. 11, 719-721 (December 5, 1974)

Investigations of a laser plasma were made in the x-ray band. It is shown that instabilities can occur in the plasma.

In connection with the prospects of using laser plasma for controlled thermonuclear fusion, it is very important to investigate the parameters of such a plasma. Since the laser-plasma temperature reaches $\sim 1-2$ keV, the principal radiation lies in the x-ray band. An investigation of this radiation makes it possible in principle to obtain information on the electron temperature, on the electron-velocity distribution, on the onset and development of various instabilities, etc.

The purpose of the present study was mainly to investigate, at high temporal and spatial resolution, x rays from a laser plasma. To this end we developed a special image converter sensitive to soft x rays. The experimental setup is shown in Fig. 1. We used a neodymium-glass laser system consisting of a driving laser and a multistage amplifier. The laser operated on one axial and one angular mode TEM_{00q} . A square-wave pulse was shaped with duration variable from 2 to 10 nsec and with fronts of ~ 0.5 nsec. The energy output of the entire system was as high as 30 J at a pulse duration 2.0 nsec and as high as 60 J at 10 nsec. The radiation was focused by a lens of $f = 10$ cm on a target placed in a vacuum chamber. The diameter of the focusing area was 100μ and the flux density on the target reached 2×10^{14} W/cm². Metallic titanium targets were used in the experiment.

The x-ray electron-optical chamber consisted of a special scintillator with a time resolution of approximately 0.5 nsec, an image converter of the UMI-93 type, and an electronic control circuit. A pinpoint camera projected the magnified image of the laser plasma on the scintillator. An aluminum filter 10μ thick placed in front of the scintillator cut off the visible radiation of the plasma. The lens projected the front surface of the scintillator on the photo-cathode of the

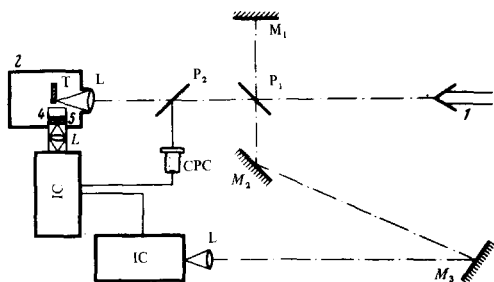


FIG. 1. Experimental setup: 1—direction of laser beam; 2—vacuum chamber; 3—pinpoint camera. 4—x-ray filter; 5—plastic scintillator; M_{1-3} —mirrors; L —lenses; T —target; P_{1-2} —beam-splitting plates; CPC—coaxial photocell; IC—image converter.

image converter. When operating in a linear-sweep regime, a slit was placed in the immediate vicinity of the front surface of the scintillator. Simultaneously with the investigation of the x rays from the plasma, we studied the laser light reflected from the target. This was done by using a second electron optical camera triggered in synchronism with the first. In addition to the laser light reflected from the target, a fraction of the output laser radiation was applied to the camera with a mirror. It was thus possible to register simultaneously the x rays and the laser light incident on the target and reflected from it.

Typical experimental results are shown in Fig. 2. We see that while the incident pulse is smooth, the reflected pulse is rather strongly modulated. This modulation was already reported earlier.^[1,2] The laser-plasma x radiation was also amplitude-modulated. Owing to the relatively low time resolution of the x-ray apparatus, it is impossible to draw unequivocal conclusions concerning the depth of modulation. We note that modulation of the reflected radiation is seen on all the frames, whereas modulation of the x rays is seen only

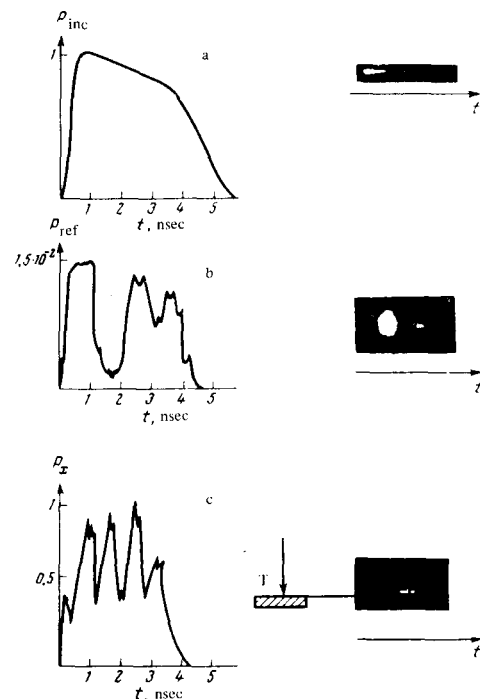


FIG. 2. Experimental results. Right—streak photographs: a—incident laser radiation; b—radiation reflected from the target; c—x radiation. Left—microphotograms of photographs.

approximately in every third frame. A typical modulation period is 1 ± 0.5 nsec, and the characteristic modulation period of the x rays is 0.7 ± 0.2 nsec. The presence of modulation of the laser-plasma x rays shows that considerable turbulences are present in the laser plasma.

We note that the characteristic modulation period agrees quite satisfactorily with the time $\tau = a/v$, where a is the characteristic plasma dimension, $v = [(jk/m_i) \times (T_i + \bar{z}T_e)]^{1/2}$ is the velocity of the ion should, j is the adiabatic exponent, m_i and \bar{z} are the mass and average charge of the ion, and T_e and T_i are the temperature. In our case, $T_e \sim 1$ keV, $\bar{z} = 18$, $j = 1.35$ and $v = 2 \times 10^7$ cm/sec, so that $\tau \approx 0.5$ nsec.

It appears that the same turbulences determine also the modulation of the reflection coefficient of the laser plasma, although other mechanisms are possible in principle, for example those proposed in^[2].

¹Yu. S. Kas'yanov, V. V. Korobkin, and P. P. Pashinin, Paper at Conference on the Interaction of Laser Radiation with Matter, Hull, England, 1971.

²N. G. Basov, O. N. Krokhin, V. V. Pustovalov, A. A. Rupasov, V. V. Silin, G. V. Sklizkov, V. T. Tikhonchuk, and A. S. Shikanov, Zh. Eksp. Teor. Fiz. 67, 118 (1974) [Sov. Phys.-JETP 40, No. 1 (1975)].