Continuous x-ray emission spectra from picosecond-ruby laser-produced plasma

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We measured the energy spectrum and the angular distribution of the continuous x-ray radiation of plasma produced by picosecond ruby laser pulses at a flux density of $\sim 10^{14}$ W/cm^2 at the surface of the target. The effective temperature of epithermal electrons reached 5 keV in massive targets made of different metals.

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The so-called anomalous absorption mechanisms—resonance absorption and paramagnetic plasma instabilities—are developed as a result of interaction of a laser radiation with massive targets at a radiation flux density of $\gtrsim 10^{12}$ W/cm^2 (for a wavelength ~ 1 μm). They tend to diverge the electron distribution function from the Maxwell function (production of epithermal electrons) and increase the intensity of bremsstrahlung in the region $h\nu \gg kT_e$. Investigation of the spectrum and of the angular distribution of this radiation can yield information on the plasma parameters and on the mechanisms of absorption by it of the laser radiation. The continuous x-ray radiation spectrum was investigated in Refs. 1–4 using a neodymium and CO_2 lasers.

We investigated the spectrum and angular distribution of continuous x-ray radiation of a laser plasma in the cutoff energy region 12–42 keV for massive Al, Fe, Cu, and W targets. We used a ruby laser with self-synchronizing modes, which operated at a low (100 K) temperature.[5] The radiation was a short train consisting of 1–3 pulses of 10–20 psec duration and a total energy of 0.5 J. The laser beam was focused by a lens with $f = 60$ mm on a 70-μm-diam spot (at half intensity).[6] The flux density at the target's surface reached $\sim 10^{14}$ W/cm^2. The laser radiation was linearly polarized. The targets were placed in a thin-walled (0.15 mm) aluminum vacuum chamber.

The measurements were carried out using a multichannel, automated facility based on the PDP-11/05 mini computer and the KAMAK system.[7] We used 16

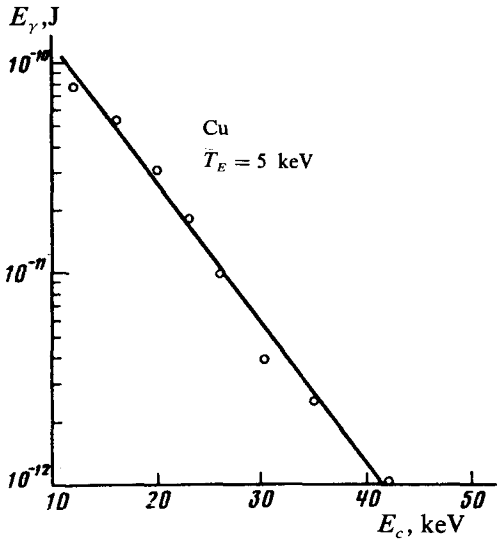

FIG. 1. Dependence of the x-ray energy on the cutoff energy for the copper target.

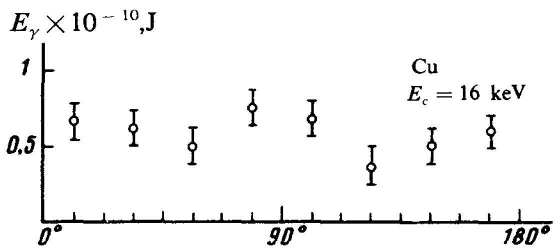

FIG. 2. Angular distribution of x-ray radiation for the copper target.

NaI(Tl) scintillation spectrometers with photomultipliers FEU-85 as x-ray radiation detectors. The detectors were distributed around the circumference of the target in two rows in the perpendicular planes to the optical axis. Eight spectrometers of one row, which had absorbent filters of different thicknesses, were used to measure the spectrum and the other eight spectrometers (with the same filters) were used to record the angular distribution and the total x-ray radiation energy. We used Al filters ranging from 300 μm to 8.6 mm in thickness.

The results of measuring the x-ray radiation energy as a function of the cutoff energy for a copper target (normal incidence) are shown in Fig. 1. The temperature of the epithermal electrons T_E, which was determined by the absorption method,[8] was equal to 5 keV. The energy in Fig. 1 was scaled to the total solid angle 4π. Within the accuracy of the measurements we did not observed a difference in the temperature T_E for targets made of other materials.

The angular distributon of the x-ray radiation was measured for different cutoff energies. Figure 2 shows the results of measurements for a Cu target at a cutoff energy of 16 keV. The direction of the polarization vector corresponds to a 90° angle in the figure. The obtained distributions seem to indicate that there is a small (up to 30%) deviation from isotropy, which exceeds the statistical error of the measurements.

We measured the radiation reflected from the plasma to the aperture of the focusing lens. The relative values of the reflection coefficient at a normal incidence for the Cu, Al, Fe, and W targets were equal to 1.0, 0.8, 0.6, and 0.4, respectively. We also measured the dependence of the reflection coefficient on the angle of incidence of the laser beam on the target. The relative values of the reflection coefficient for the copper target were equal to 1.0, 0.9, 0.65, 0.4, and 0.35 for the angles of incidence 0, 10, 30, 45, and 70°. These values were obtained for a laser beam polarized in the incidence plane.

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