ANGULAR DISTRIBUTION OF THE IONS OF A LASER PLASMA

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To explain the formation, spreading, and acceleration of the ions of a plasma produced by the action of a giant laser pulse on a solid target, it is of interest to study the angular distributions of the ions.

A mass-spectrometric procedure makes it possible to measure the angular distribution of ions with different charges and energies, unlike collector measurements [1], which yield information only on the total charge in a given solid angle. However, even the results obtained in [2] have shown that the ionized component has an angular distribution different from that of the entire substance (e.g., [3, 4]).

I. To plot the angular distribution we used a special ion-source chamber, in which the angle between the plane of the target and the laser radiation direction remained unchanged with changing angle between the target plane and the ion-optical axis of the instrument. To exclude the influence of the "crater" on the angular distributions of the ions, the sample was moved in its own plane. The laser radiation energy was varied with an optical filter and monitored with the aid of a system consisting of a coaxial photocell, an expansion attachment, and a digital voltmeter. The radiation fluctuations amounted to ∿10%.

The angular distributions were plotted in steps of -6° in the range from 0° to 90° (the direction of the ion-optical axis of the instruments correspond to 0°), and the experiment demonstrated the symmetry of the angular distribution relative to the normal at a fixed angle of incidence of the laser radiation. Ten measurements were made for each value of the angle. The standard deviation of the ion-current amplitude was 20%.

The angular distributions of the ions were investigated with several materials for different charge multiplicities, energies of the registered ions, and laser radiation flux densities. Some of them (for Al^{13}_{27})

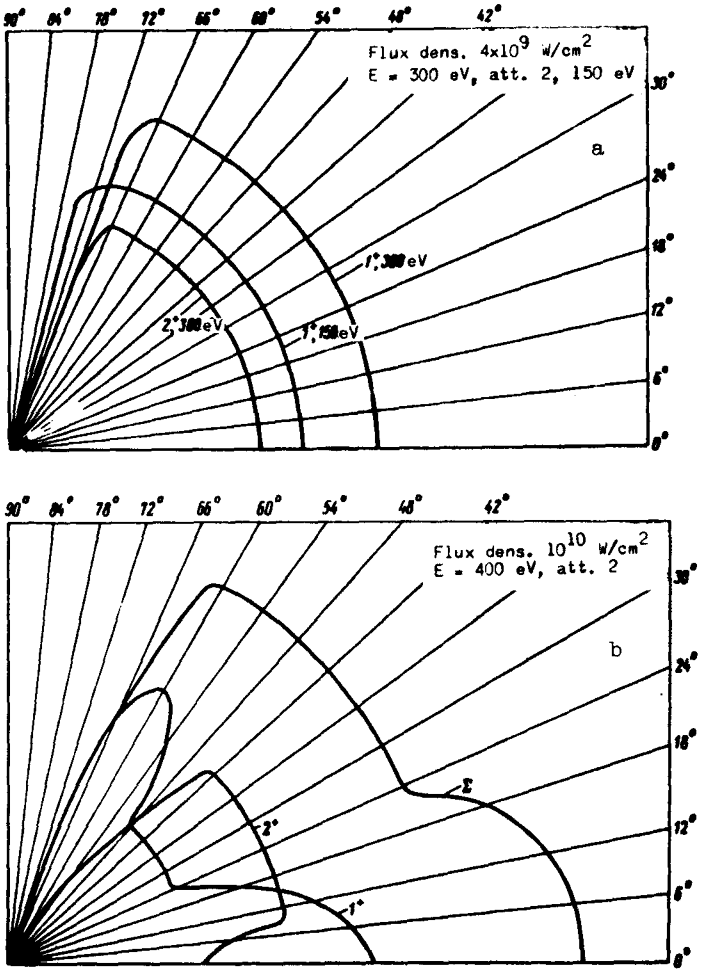

Fig. 1. Angular distribution of Al^{13}_{27} ions: a - q = 4×10^9 W/cm^2, att. 2, energies 150 and 300 eV. b - q = 10^{10} W/cm^2, att. 2, energy 400 eV.

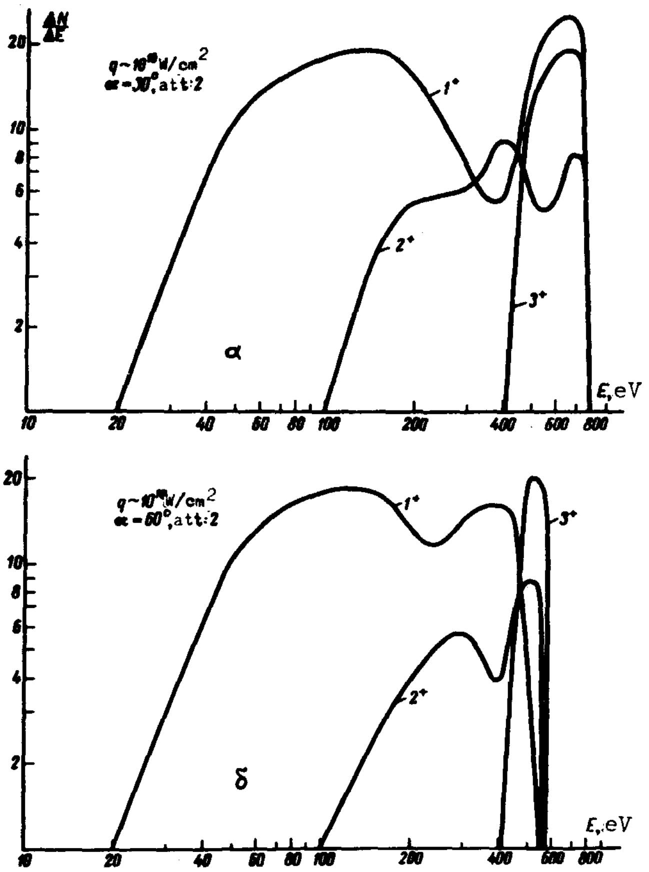

Fig. 2. Energy distribution of Al_{27} ions at $q = 10^{10}$ W/cm²; a – α = 30°, b – 60°.

are shown in Fig. 1 (a and b). Figure 2 shows the energy distribution of the ions for different angles at a radiation flux density $q \sim 10^{10}$ W/cm².

II. The experiments point to certain regularities in the angular distributions:

1. The angular distributions of ions with energies from 50 to 250 or 300 eV are isotropic within the range of angles in which ions are registered at all used values of q. For example, at $q = 4 \times 10^9$ W/cm², when ions with z = 1 and 2 and energies up to 400 eV are observed.

2. At $q = 10^{10}$ W/cm² and 10^{11} W/cm² the ions with energy larger than 250 - 300 eV have an isotropic angular distribution, and for ions with z = 1 and z = 2 there are observed characteristic spikes in directions other than perpendicular. The angular distributions of ions with maximum charge ($z_{max} = 4$ at $q = 10^{10}$ W/cm² and $z_{max} = 5$ at 10^{11} W/cm²) have the form of a narrow lobe elongated in the perpendicular direction. The larger the ion charge, the smaller the solid angle in which the expansion takes place.

3. For any value of the angle, the registration of the energy distribution begins with an energy on the order of 20 eV.

4. At all values of the radiation flux density q, charge z, and ion energy E, and at a fixed angle of incidence of the laser beam on the target, the angular distribution is symmetrical with respect to the direction perpendicular to the sample.

5. In plotting the energy distributions at angles 0, 30, and 60° to the normal, the presence of several maxima has been observed on the distribution of the singly- and doubly-charged ions (Figs. 2a and 2b). The maximum energy decreases with increasing registration angle.

III. The obtained ion angular distribution can be interpreted on the basis of the model developed in [4] to explain the energy spectrum. According to [4], the energy distributions of ions of different charges are formed as a result of the acceleration of the ions in the electric field produced on the boundary of the expanding plasma and recombination. In addition, it must be recognized that the expansion of the ions takes place in a definite solid angle which decreases with increasing charge (see Item 2 above and [4]). Consequently, the recombination of ions with charge z contributes to the angular distributions of the ions with smaller charge at the energies and angles characteristic of the z ions. The angular and energy distributions of the ions with charge z then contain contributions from the distributions of the ions with charge from z + 1 to z_{max} (z_{max} is the maximum ionization multiplicity at the given laser-emission parameters).

Let us consider the concrete case corresponding to Fig. 1a, where ions with z = 1 and energy 150 eV expand in an angle ∿78°, and ions with energy 300 eV in a smaller angle ∿72°, exactly equal to the angle of expansion of the doubly-charged ions. This is explained by the fact that the singly-charged ions with E = 300 eV are produced by recombination from the more strongly accelerated doubly-charged ones, and have the same energy and angular distribution as the latter.

Figure 1b also demonstrates the formation of the angular distribution of the spectrum of the singly-charged ions as a result of the described process. For example, the maximum number of singly-charged ions is registered in the direction along which the minimum number of doubly-charged ions is observed. If we sum the number of particles moving in a given direction (curve Σ on Figs. 1a and 1b), then the angular distribution becomes smoothed out, as it should. The anisotropy of the curve Σ is due to the preferred expansion of the ions with larger charges along the normal to the target. This is confirmed by the form of the curves Σ corresponding to the larger densities of the radiation flux q. Other experimental results on the angular distributions are explained similarly.

The important role of recombination is manifest also in the fact that the slow ions are not registered at all observation angles (Fig. 2), and the energy spectrum corresponding to each value of the charge begins with a certain minimal value $E_{min}(z)$. On the other hand, recombination of the accelerated ions leads to the appearance of several maxima on the energy spectra (Fig. 2 and [4]).

Thus, the character of the angular and energy distributions of the ions of a laser plasma is well explained as being due to processes of acceleration and recombination.

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FEATURES OF THE RESONANCE OF DOMAIN-BOUNDARY DISPLACEMENT IN A DISK

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Theoretical and experimental investigations [1, 2] of magnetic resonances in spherical single-crystal ferrites in the presence of a domain structure have shown the demagnetizing fields are among the main factors determining the resonant frequencies and the coupling of various oscillation modes.

From this point of view, interest attaches to investigations of ferromagnetic resonance (FMR) and domain-boundary displacement resonance in samples in the form of disks, in which the demagnetizing fields have a sharply pronounced anisotropy. In the calculation of the conditions for FMR and domain-boundary oscillations, we consider an ellipsoidal sample (Fig. 1) of a single crystal with cubic symmetry and negative anisotropy, the principal axis of which