Certain singularities of the absorption of high-power laser radiation heating a LiD target

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We observed a dependence of the reflection coefficient on the energy of the preceding background when crystalline targets of LiD were exposed to radiation from a neodymium laser with intensity $10^{15} \leq I \leq 3\times10^{16}$ W/cm². The connection between the reflection coefficient and the intensity of the incident radiation is determined.

One of the most important problems of plasma heating to thermonuclear temperatures by laser radiation is the influence of the parameters of the radiation on the characteristics of the produced plasma. To this end, we performed experiments aimed at clarifying the physical singularities of the initial stage of plasma heating when a subnanosecond neodymium-glass laser pulse interacts with an LiD target under conditions when the intensity of the light flux exceeds 10^{16} W/cm². We investigated the influence of the background radiation on the reflection coefficient of the laser plasma and the profile of the electron density near the target surface.

1. The laser setup[1] could deliver to the target up to 100 J in a time 9×10^{-11} sec at a main pulse divergence ~10^{-3} rad. The radiation was focused on the polished surface of the target with a lens having $f=6$ cm and relative aperture $f/0.9$. The uncertainty in the position of the target surface relative to the focal plane did not exceed 2 μ. The principal radiation pulse with energy E_L was preceded by background radiation due to superradiance and the enhanced radiation of the pump lamps E_s, and also to the generator noise E_n incident on the input of the amplifying system when the Pockels shutters were opened at the instant of pulse shaping. The value of E_s was measured with calorimeters, while E_n was monitored in each flash with the aid of an FÉK-15 vacuum coaxial photocell and an I2-7 oscilloscope. Interferometry of the plume was carried out simultaneously in the light of the second harmonic of the principal radiation, for 1 nsec prior to the arrival of the laser pulse at the target. The contrast δ of the working flash was determined as the ratio of the total energy in the flash to the background energy $E_b = E_s + E_n$

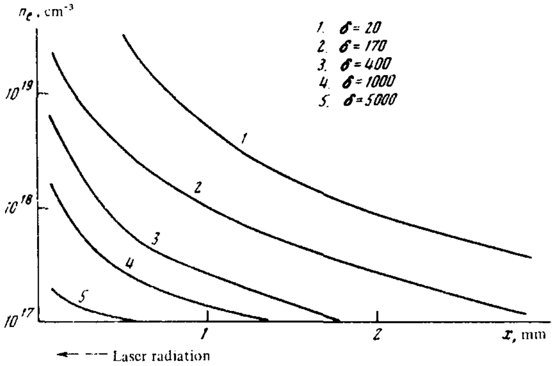

FIG. 1.

$$\delta = \frac{E_L + E_b}{E_b} \tag{1}$$

and could range from 10 to 5×10^4.

2. We observed a dependence of the plume dimensions and amount of the evaporated target material on the value of the contrast δ. Computer reduction of the interference patterns yielded the profile of the electron density along the optical axis x. The results are shown in Fig. 1. It is seen from the figure that both $n_{e\,\max}$, and the total number of the particles $n=\int n_e(z)\,dZ$ evaporated from the surface increased with decreasing δ. The density profile agrees satisfactorily with the results of self-similar solutions of the equation of motion for the matter evaporated by the laser radiation.[2] In addition, an investigation of the influence of the contrast on the reflection coefficient has shown that at laser radiation intensities $\gtrsim 10^{16}$ W/cm^2, the reflection coefficient retains its tendency to decrease with increasing intensity of the light flux incident on the target.[3] A dependence of the reflection coefficient R on the value of the contrast δ was observed (Fig. 2). This figure shows also the dependence of the maximum electron density $n_{e\,\max}$ on the contrast of the radiation pulse.

The reflection coefficient was determined with the aid of calorimeters, as the ratio of the energy reflected to the aperture of the focusing optics to the energy reaching the target surface (with allowance for the attenuation and reflection by all the surfaces of the lenses and of the beam-splitting plates). In comparison with the data of [3], where a focusing optical system with solid angle 0.12 sr was used, an increase was observed in the absolute value of R. However, inasmuch as the angular distribution of the reflected radiation has a rather gently sloping maximum at $\phi=180°$, it was possible to reduce the reflection coefficient measured in the solid angle 0.67 sr to the value for the 0.12 sr angle. Figure 3 shows a dependence of the reflection coefficient $R(I)$ in a wide range of intensities I, as observed with the setup of[1]. All the values of the reflection coefficients were obtained in flashes with contrast $\sim10^4$. The squares in the figure mark the values of R for 0.12 sr, and the circles the results of a recalculation of the values of R measured at 0.67 sr to this angle.

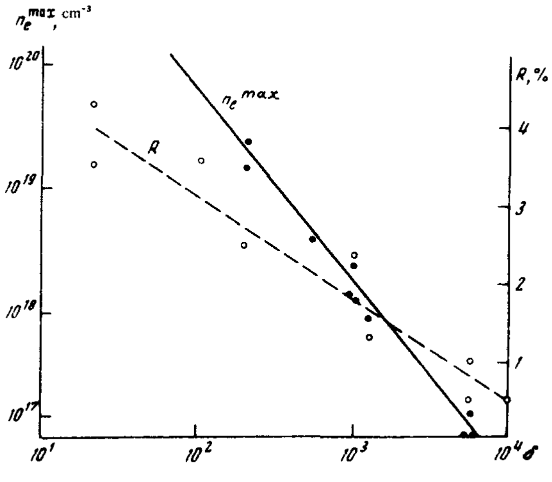

FIG. 2.

3. The dependence of the reflection coefficient on the contrast can be due to two factors.

First, in the case of exact focusing on the surface, the intensity of the incident radiation can change with increasing background energy as a result of evaporation of the surface, formation of a crater, and consequently an increase in the dimensions of the focal spot. The $R(\delta)$ dependence then takes the form

$$R(\delta) = R_\infty\left[1+\frac{E_L D}{\pi r_0^3 f\,\Omega}\,\frac{1}{(\delta-1)}\right]^{-\xi}, \tag{2}$$

where R_∞ is the reflection coefficient as $\delta\to\infty$, E_L is the energy of the main pulse, D and f are the diameter and focal length of the gathering lens, Ω is the specific evaporation energy per unit volume of matter, r_0 is the radius of the focal spot, and ξ is the exponent in the relation $R(I)\sim I^{\xi}$. In our experiments $\xi\approx-1/3$; the $R(\delta)$ dependence is well approximated by the relation $R(\delta)\sim\delta^{-1/4}$ (Fig. 2).

Second, a change in contrast changes the profile of the electron density (Fig. 1), and this should lead to a change of the gradients in the region of the anomalous absorption and to an influence on the fraction of the laser-pulse energy reflected from the regions with n_e

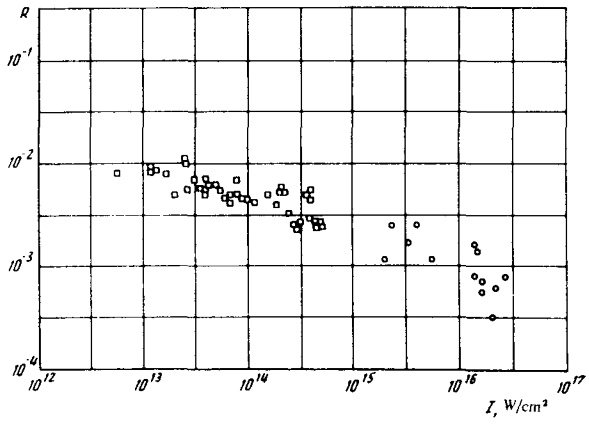

FIG. 3.

$< n_{e\,\mathrm{crit}}$. Obviously, there should exist here an optimal contrast that ensures the most complete absorption of the laser energy by the plasma.

We have thus shown that the reflection coefficient depends on the radiation contrast, and this dependence can be attributed to defocusing produced when the surface is evaporated. It has been observed in addition that in the intensity range $10^{15} \leqslant I \leqslant 3 \times 10^{16}$ W/cm^2 the reflection coefficient decreases monotonically with increasing radiation intensity.

[1] L. V. Dubovoĭ, V. D. Dyatlov, V. I. Kryzhanovskiĭ, A. A. Mak, R. N. Medvedev, A. N. Popytaev, V. A. Serebryakov, V. N. Sizov, and A. D. Starikov, Zh. Tekh. Fiz. **44**, No. 11 (1974) [Sov. Phys.-Tech. Phys. **19**, No. 11 (1975)].

[2] Yu. V. Afanas'ev and O. N. Krokhin, Trudy FIAN **52**, 118 (1970).

[3] V. D. Dyatlov, R. N. Medvedev, V. N. Sizov, and A. D. Starikov, ZhETF Pis. Red. **19**, 124 (1974) [JETP Lett. **19**, 76 (1974)].