Investigation of reflection in the case of oblique incidence of the laser radiation on a plasma

O. G. Baĭkov, V. I. Bayanov, A. A. Mak, R. N. Medvedev, V. A. Serebryakov, and N. A. Solov'ev

S. I. Vavilov State Optical Institute

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Results are presented on the experimental study of reflection of laser radiation from a plasma at different flux densities, polarizations, and angles of incidence of radiation on a target. Effects of linear transformation and anomalous absorption in the region of one-quarter critical density are identified.

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Absorption of laser radiation in a plasma is one of the central problems of inertial confinement fusion (ICF). A number of works address this problem.[1-3] The experiment described in this article was designed to study reflection of laser radiation at different angles of incidence of the laser beam on a target, at different beam intensities and for different polarizations of the incident radiation.

In this experiment we used a neodymium glass laser with pulse duration of 200 picoseconds and pulse energy varying from 5 to 50 J, and beam divergence of 10^{-3} rad.

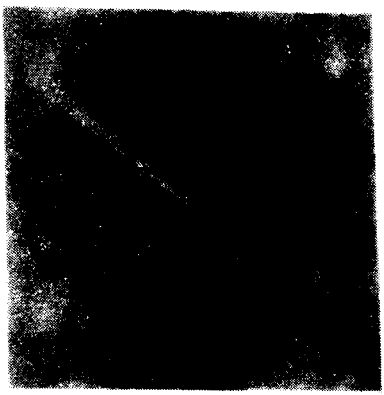

FIG. 1. Photograph of the specular component of reflected radiation.

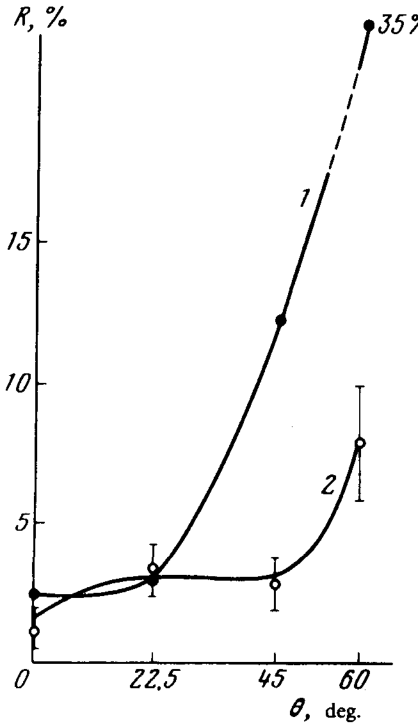

FIG. 2. Dependence of the coefficient of reflection on the angle of incidence of radiation on a target. R (%) $= E_{\text{spec.}}/E_{\text{inc}}$, where E_{spec} is the energy of specular reflected radiation, E_{inc} is the energy of incident radiation ≈ 5 J. Curve 1 corresponds to S-polarized radiation, curves 2, 3, 4—p-polarization. Curves 1, 2 were obtained at a prepulse energy $E_{pp} \approx 2\times10^{-2}$J, curve 3 at $E_{pp} \approx 2\times10^{-3}$ J, curve 4 at $E_{pp} \sim 7\times10^{-2}$ J.

The pulses were focused on a plane polyethylene target by means of $f = 100$-mm lens. The laser output was 95% polarized by a polarizer placed beyond the final stage. In the absence of the polarizer the output was fully depolarized.

We carried out a preliminary study of the directional pattern of reflected radiation by placing a film-loaded cartridge in the path of reflected energy. Figure 1 shows a chracteristic photograph. Processing of photographs showed that the mirror-reflected radiation propagates in the same solid angle as incident radiation beyond the focusing lens. This suggests that in our case we observed plane scattering of a plasma.

Figure 2 shows the results of measurements of the coefficient of reflection for the specular component as a function of the angle of incidence θ of radiation on a target, and prepulse energy E_{pp}, constrained by superluminescence of the amplifying cascades with $q \sim 10^{13}$ W/cm^2 (q is flux density at the target for a normal incidence). The electron temperature, measured by the absorption method for normal incidence, was 100 eV. A comparison of curves *1* and *2*, obtained for identical prepulse energies, leads to a conclusion concerning the occurrence of linear transformation in our case. In view of a large angle step in the measurement of reflection, we are unable to indicate accurately the position of a minimum of the coefficient of reflection for the p-polarization, which is associated with linear transformation, and to clearly determine from these measurements the characteristic scale of inhomogeneity near the critical density. However, if we assume that a minimum lies in the 20° region, the characteristic scale of inhomogeneity a may be roughly estimated. Such an estimate yields $a = 5$ μm. This

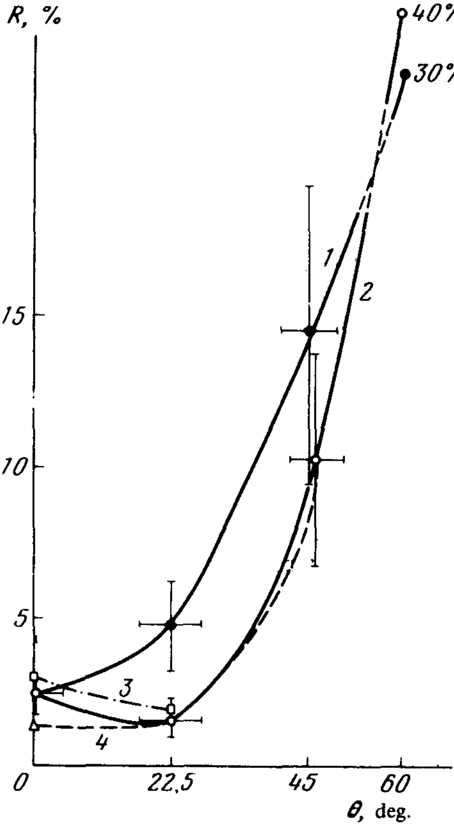

FIG. 3. Curve 1—$R(\theta)$ at $q \sim 10^{13}$ W/cm², 50% polarization, $E_{pp} \sim 2\times10^{-2}$ J. Curve 2—$R(\theta)$ at $q \sim 10^{14}$ W/cm², 50% polarization, $E_{pp} \approx 2\times10^{-2}$ J, $E_{inc} \approx 50$ J.

result is in an agreement with data in Ref. 4, where a resonant absorption maximum at $q \sim 10^{13}$ W/cm² is determined from the maximum of the electron temperature of the plasma and lies in the 18° region. Figure 2 shows such a dependence of the coefficient of reflection on the magnitude of prepulse energy. Reduction of the coefficient of reflection with increasing prepulse energy may be treated as an increase in the absorption due to increased length of the absorbing layer.

Figure 3 shows the results of measurement of the coefficient of reflection as a function of the angle of incidence for $q \sim 10^{14}$ W/cm². The electron temperature at this flux density and normal angle of incidence was 400 eV. Figure 3 also shows the function $R(\theta)$ for $q \sim 10^{13}$ W/cm², plotted for unpolarized radiation on the basis of the foregoing experimental results. A comparison of the two curves, obtained for $q \sim 10^{13}$ W/cm² and 10^{14} W/cm², indicates the presence of two different mechanisms of absorption of the laser radiation in a plasma. In the first case (10^{13} W/cm²) radiation is absorbed over the entire optical range due to the classical absorption and linear transformation, the greatest contribution in our case being due to bremsstrahlung absorption. At increased flux densities (10^{14} W/cm²) a considerable increase in the electron temperature occurs which may lead to reduced classical absorption. However, experimental data indicate that the absorption remains approximately the same as at $q \sim 2\times10^{13}$ W/cm² in the small θ angle region, and it increases at angles $\theta = 45$–60°.

This type of behavior of the coefficient of reflection may be explained, over the entire optical range, by "inclusion" of anomalous mechanisms of absorption at higher flux densities. As is known from a formula applicable to a plane plasma layer, $n/n_{cr} = \cos^2\theta$, where n is electron density of radiation incident on a plasma at an angle θ and n_{cr} is critical electron density; in our case, reflection for $q \sim 10^{14}$ W/cm^2 begins to increase sharply when the electron density attains a value $n = n_{cr}/4$. Thus, at flux densities of 10^{14} W/cm^2 we are dealing with anomalous absorption in the region $n_{cr}/4$ which may be attributed to disintegration of the transverse wave of the incident radiation into two Langmuir plasma oscillations.

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