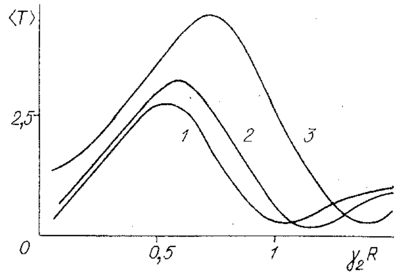

Fig. 2

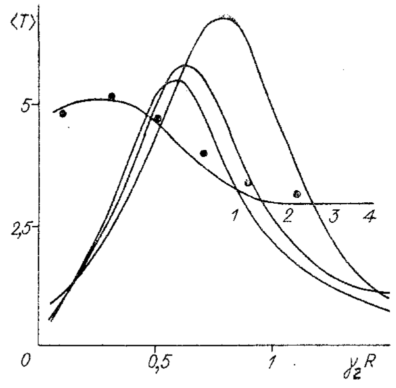

Fig. 3

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TRANSMISSION OF A PRESSURE PULSE TO METALLIC AND DIELECTRIC TARGETS IRRADIATED BY A NEODYMIUM LASER IN THE FREE GENERATION REGIME

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Pressure oscillations which are measured by a piezotransducer on the back side of targets are observed when concentrated energy fluxes, e.g., from laser radiation, interact with a material [1]. Zhiryakov et al. [1] observed pressure oscillations on a lead target for $J \simeq 2$ MW/cm^2, which disappeared rapidly when J was increased. Possible mechanisms for creating the oscillations due to an autovibration regime of self-screening or spurts of absorption in the plasma of light-eroding flares in the unstable evaporation regime have been analyzed in detail [2, 3].

Experiments were conducted in the VIKA vacuum chamber for a detailed investigation of pressure oscillations in targets [4]. Pulsed laser radiation with a wavelength of 1.06 μm and a pulse width at half maximum of $3 \cdot 10^{-4}$ sec acted on metallic and dielectric targets in a chamber whose pressure could be varied from 10^5 to 10^{-2} Pa. The diameter of the radiation spot in most cases was 6 mm; the target diameter was 20 mm.

The target 1 was mounted on a piezotransducer (Fig. 1), which operated as a voltage source. Its main feature was a long wave guide behind the piezoelement 2, which gave a read time up to 1.5 msec for both the initial and the reflected signal. The transducer was well shielded from electric and acoustic fields. A wideband amplifier 6, designed with an RC input on the order of 1-100 sec, was connected directly to the transducer in the vacuum chamber, which provided a very small charge loss from the piezoelement during the read time.

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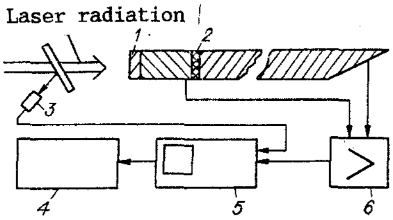

Fig. 1

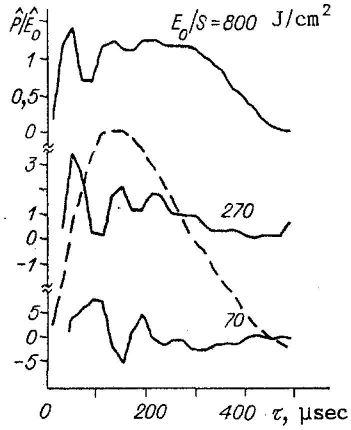

Fig. 2

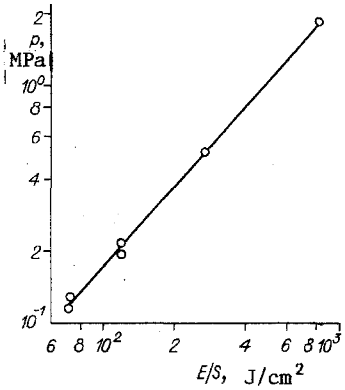

Fig. 3

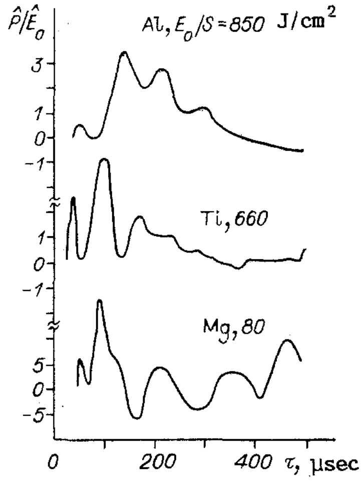

Fig. 4

The signal from the amplifier went to a S9-8 digital recording oscillograph 5 with a fast analog to digital converter and a buffer memory. The signal from an FK-19 coaxial photoelement 3, which recorded the time-resolved intensity of the laser radiation, was fed to the input of the other oscillograph channel. Information on the experiment control parameters and data from the oscillograph and other auxiliary instruments were fed to an IVK-6 computer complex 4 and processed.

The signals from the piezotransducer and the photoelement were processed by dividing their oscillograms into 10 μsec intervals and doubly normalizing them by $\Delta P_i/\Sigma P_i/\Delta E_i/\Sigma E_i = \hat{P}/\hat{E}_0$ (ΔP_i and ΔE_i are the areas of the elementary sections, and ΣP_i and ΣE_i are the total areas under these curves). These measures allowed features of the pressure dynamics to be distinguished independent of the shape of the laser radiation and the signal magnitude in a frequency range <100 kHz and to remove the high-frequency component of the signals related to the peak characteristics of the laser radiation in the free-generation regime.

Figure 2 presents normalized pressure measurements on an ebonite target for various laser radiation densities E_0/S and an ambient pressure $p_\infty = 10^5$ Pa. The dashed curve shows the shape of the diffracted laser pulse, which was held constant. Energy variations were obtained by placing attenuators (semitransparent mirrors) at the output of the laser system.

For $E_0/S < 10$ J/cm², an unstable evaporation regime was observed and several unordered peaks were recorded. As E_0/S increased, there was a clearly oscillating pressure configuration with a change in sign of the pressure vector. These oscillations were clearly observed in both the oscillograms and on the curves of normalized pressure, at $E_0/S = 70$ J/cm², for example. As E_0/S was increased further, the value of the oscillation amplitude above the background of the overall pressure in the radiation spot fell and the oscillations became undetectable. Only with appropriate scaling on the curves could it be seen that they still remained.

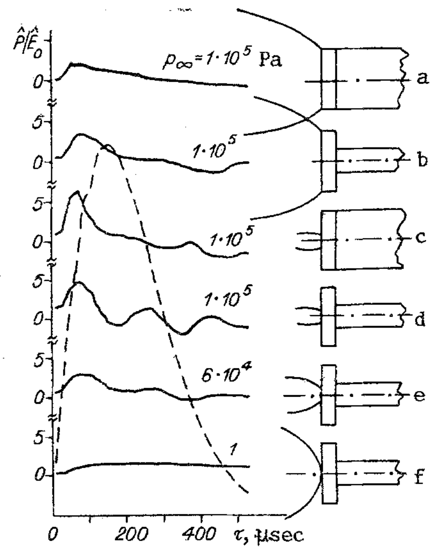

Fig. 5

Figure 3 shows the dependence of the maximum pressure p, recorded by the piezotransducer, as a function of the laser radiation flux $[E_0/S]$ in the irradiation spot for $p_\infty = 10^5$ Pa. As can be seen from the figure, p increases roughly by a factor of 15 as E_0/S increases from 70 to 800 J/cm² and can be represented by the empirical function

$$p = a(E_0/S)^n. \tag{1}$$

For dielectrics n ≈ 1-1.5.

We now return to Fig. 2, on which the scale on the ordinate for E_0/S = 70 and 800 J/cm² differs by a factor of 15, that is, close to the growth in the piezotransducer signal. The absolute values of the oscillation amplitudes follow the increases in E_0/S. As can be seen from Fig. 3, the amplitude of these oscillations for E_0/S = 70 J/cm², where the oscillations are more clearly expressed and can easily be seen directly on the oscillograms, is of the order p_∞ = 0.1 MPa.

An analogous picture is also observed for metallic targets, for example Al, Mg, and Ti (Fig. 4), where the pressure oscillation region, which can easily be seen on the oscilloscope, corresponds to pressures p_∞ in the radiation spot, as in the case of the dielectrics; as E_0/S is increased, the pulsations become difficult to distinguish rather rapidly without computer processing and scaling. This is explained by the fact that for metals n = 2-4 in Eq. (1), and the range of E_0/S in which $p \approx p_\infty$ is very small.

The oscillation amplitudes decrease with a decrease in the pressure of the ambient medium, and in a vacuum, one obtains a smooth convex curve without negative pressures. The normalized pressure curves d-f in Fig. 5 are plotted for a dielectric target at different p_∞, a fixed value E_0/S = 80 J/cm², and a fixed irradiation geometry.

The data obtained (such as the change in the sign of the pressure vector and conservation of the oscillation amplitude with increasing laser radiation intensity) are inconsistent with the conclusions from models based on an auto-oscillatory process of self-screening [2] and a spike of absorption in the plasma of the photoerosion jet in an unstable vaporization regime [3]. The research results given here rather indicate the influence of gas-dynamic processes in the space near the jet on the generation of pressure oscillations at the target.

These processes, such as ejection, can explain the negative pressures produced in the action of a beam on the "non-working" part of a target located outside the radiation spot and on the transducer mounting, as well as conservation of the oscillation amplitude with increasing E_0/S. The disappearance of oscillations when the jet escapes into a vacuum and the change in the oscillation amplitude with different gases in the ambient space fit logically into this mechanism. Finally, measurements of the pressure at targets for fixed $p_\infty = 10^5$ Pa and E_0/S = 80 J/cm² and variation of the "non-working" part of the target revealed a change in oscillation amplitudes. This transformation of the pressure oscillograms is shown in curves a-d of Fig. 5. For a large "non-working" part of the target (curve d), the pressure oscillations are clearly expressed. When the "non-working" part of the target is decreased due to the increase in spot size (curve b) to the target diameter or the diameter of the transducer is increased (curve c), then these oscillations are less clearly expressed. If there is almost no "non-working" part of the target (curve a), the pressure oscillations disappear and the pressure oscillogram becomes similar to curve f, obtained in a vacuum for a large "non-working" target surface.

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