The measurement results shown in the figure indicate that we have observed oscillations from the closed part of the Fermi surface of MoO_2. The experimental oscillation frequencies are 1.11×10^7 and 1.71×10^7 Hz, respectively.

The temperature dependence of the oscillation amplitude was measured for the magnetic field direction [101] in the temperature interval 1.3 - 2.35°K. The effective mass calculated from these data is 0.97 ± 0.2.

MoO_2 should be a compensated metal, so that its unit cell contains two Mo^{+4} ions, each of which can give up to the conduction band two electrons from the unfilled 4d shell. Thus, other sections of the Fermi surface of MoO_2 should also exist.

In conclusion, the authors are deeply grateful to A.N. Zhukov and R.K. Nikolaev for supplying the MoO_2 single crystals, to V.Sh. Shekhtman and V.I. Kozlova for an x-ray diffraction determination of the crystal orientation, and to S.F. Kosterov and S.N. Nikonov for help with the experiments.

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EXCITATION OF SOUND WHEN A SURFACE LAYER OF A LIQUID ABSORBS A LASER PULSE

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We report in this article the first observation of the excitation of sound when radiation pulses from a CO_2 laser are absorbed in the surface layer of a liquid. We have observed that sound pulses consisting of compression and rarefaction pulses following each other at distances equal to the light-pulse duration are excited when water is exposed to focused powerful radiation from a pulsed CO_2 laser. Their growth time is determined by the time necessary to establish the quasistationary process of evaporation of the liquid from the surface. The sound excitation was due to the recoil pulse produced upon evaporation of the liquid.

Excitation of acoustic waves by absorption of CO_2-laser radiation in gases was observed in [1, 2]. Liquids have a much higher absorption coefficient in the infrared region. For water, according to our measurements, the coefficient of absorption of CO_2-laser radiation is $\alpha > 10^2$ cm^{-1}. Therefore, at sufficiently high incident-light intensity, a thin surface layer of the liquid is strongly heated. When the density of the absorbed energy αW ($W = I\tau$, where I is the intensity of the laser pulse and τ is its duration) exceeds the value $\lambda\rho$ (λ is the specific heat of evaporation and ρ the density of the liquid), forced evaporation of the liquid takes place. For water, the threshold value $W_{ft} = \lambda\rho/\alpha$ does not exceed 25 J/cm^2. The experiments were performed way above threshold. Under these conditions there is apparently no phase equilibrium.

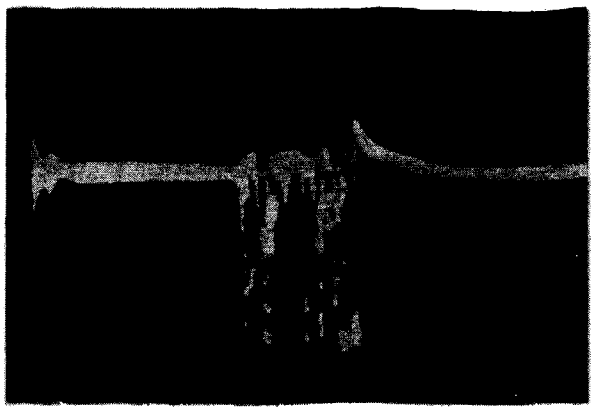

Fig. 1

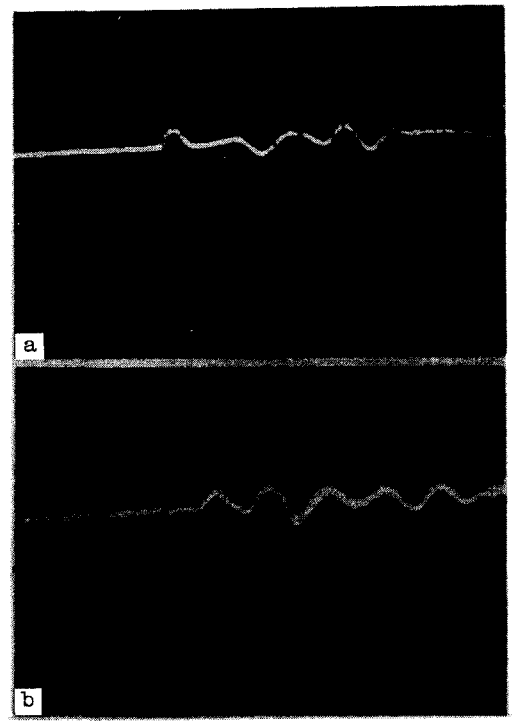

Fig. 2

We used a CO_2 laser with transverse feed-through and with a discharge in which the rapid replenishment of the working mixture, at a pressure up to 200 Torr, excluded the influence of mixture heating and dissociation on the value of the gain. This laser system has made it possible to obtain, at a length of 1.5 m, pulses with energy up to several Joules and duration of 10 μsec. When double modulation was used [3], it was possible to obtain pulses of duration from 1 to 30 μsec by introducing diaphragms into the resonator. The radiation pulses were focused on the surface of a liquid into a spot measuring 0.1 × 0.1 cm. Figure 1 shows a characteristic radiation pulse, consisting of a large number of short spikes with duration of about 100 nsec each. Figures 2a and 2b show the pressure oscillograms obtained by irradiating the surface of water with laser pulses of duration 20 μsec (a) and 5 μsec (b). In all the figures, one large division in the horizontal direction equals 20 μsec. The liquid compression and rarefaction pulses are clearly seen. The perturbations arising after the end of the rarefaction pulse can apparently be attributed to cavitation noise, since the amplitude and duration of the rarefaction wave exceed the threshold values for a non-degassed and unpurified tap water, which was used in the experiment.

The pressure pickup was a spherical receiver with sensitivity ∿0.5 - 1 μV/bar and with a bandwidth 80 kHz.

When the liquid is irradiated, a small crater is produced on its surface, from which the vapor flows out in a direction almost normal to the surface. The surface is then acted upon by a recoil momentum equal to the momentum of the escaping vapor. This differs from the ordinary optical hydraulic effect [4] that arises when light is absorbed inside a liquid, wherein the vapor released in the focal region becomes heated, expands, and excites a shock wave in the liquid.

For a quantitative description of the effect, we can introduce the force F(t) concentrated in the center of the focal spot on the unperturbed surface of the liquid. The order of magnitude of the time of action of the force F(t) equals the duration τ of the laser pulse, and the growth and decay times of the order of $t_1 \simeq \lambda\rho/\alpha I$ and $t_2 \simeq \alpha V^{-1}$, respectively, where V is the rate of vapor outflow. The maximum value of the force is $F_m = mV/\tau$, where m is the

mass of the evaporated matter. The values of m and V can be estimated from the formula $m = (1 - \delta)(WS/\lambda)$ and $V = \sqrt{2\delta WS/m} = \sqrt{2\delta\lambda/(1 - \delta)}$, where S is the area of the focal spot and δ is the coefficient that determines the fraction of the energy converted into kinetic energy of the vapor. Assuming $\delta = 0.05$, which agrees with known data [5] on metal evaporation, we obtain for our experimental conditions at $S = 10^{-2}$ cm^2 the values $t_1 \simeq 10^{-6}$ sec, $t_2 \simeq 3 \times 10^{-7}$ sec, and $F \simeq 10^6$ dynes.

The alternating force applied to the surface excites a sound wave in the liquid. The pressure in it is determined by the formula

$$p(F, t) = \frac{1}{2\pi}\left[\frac{F(t - r/a)}{r^2} + \frac{1}{ra}\frac{\partial F}{\partial t}(t - r/a)\right]\cos\theta, \qquad (1)$$

where a is the speed of sound, r the distance from the point of application of the force to the point of observation, and θ the angle between the normal to the surface and the direction to the observation point. At our pressures, the excitation of the sound can be considered in the linear approximation.

Thus, the radiation has a dipole character. At a sufficiently large distance from the surface, the second term of (1) is the decisive one. The described picture of excitation of the sound is in qualitatively good agreement with experiment (see Fig. 2). It can be assumed that the quantitative agreement is also satisfactory, if it is recognized that the reception bandwidth is narrower by approximately two orders of magntidue than the spectral bandwidth of the signal. Calculation yields at a distance r = 2 - 3 cm a peak pressure on the order of 10^6 bar, whereas the experiment yielded $p \simeq 10^4$ bar. Estimates of the transient time were apparently also correct, since the sound pressure does not follow the spike structure of the laser pulse.

We note that when $W < W_{thr}$, when there is no evaporation from the surface, sound can be excited by the expansion of a rapidly heated surface layer of the liquid with thickness α^{-1}. This mechanism of excitation, however, is less effective.

Thus, irradiation of the surface of water by a powerful pulse of radiation at a wavelength 10.6 μ has made it possible to observe excitation of acoustic waves in a liquid. Within the framework of the proposed explanation, this makes it possible to investigate the kinetics of the evaporation of liquids with a strongly superheated surface layer. In addition, pulsed laser irradiation of the surface of the liquid can be used to generate ultrasonic pulses.

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