A computer calculation was also made of the dependence of the thermal conductivity on the electron concentration. It shows that in both limiting cases $\ell_{el} \ll \lambda$ and $\ell_{el} \gg \lambda$ the thermal conductivity can change by hundreds of times with changing free-carrier density, the minimum being attained at $N \simeq 5\times10^{16}$. In the former case, however, the minimum is somewhat wider and deeper than in the second. All the remaining crystal parameters also influence only the width and the depth of the minimum. The two limiting curves abtained as a result of the calculation are shown dashed in Fig. 1. All the experimental results, as seen from the figure, lie in the band bounded by the limiting curves.

The fact that the thermal conductivity does not depend on the temperature (Fig. 2) can apparently be attributed to the fact that the increase of the carrier density due to heating hinders the thermal-conductivity growth usually observed in dielectrics at "helium" temperatures [5].

The observed phenomenon gives grounds for assuming that the thermal conductivity at helium temperatures is determined by the scattering by the carriers even at electron densities 10^{13} - 10^{14}.

It should be noted that the observed influence of the photoconductivity on the thermal conductivity makes it possible in principle to control thermal processes inside a semiconductor, and the characteristic time of the thermal conductivity is determined by the time needed for the photoconductivity to become established.

[1] The decrease in the thermal conductivity can be qualitatively explained also with the aid of other mechanisms (see, e.g., [2, 3]). Quantitatively, however, only the effect of the free carriers can be accounted for at present.

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EXPERIMENTAL VERIFICATION OF THE DYNAMIC SCALE THEORY OF THE CRITICAL POINT

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The frequency and temperature dependences of the absorption and velocity of sound were investigated in the region of the critical point. The existence of a characteristic critical frequency uniquely determined by the equilibrium correlation radius is demonstrated.

Concepts based on the assumed existence of a characteristic frequency ω_c uniquely determined by the equilibrium correlation radius r_c have recently gained currency as applied to kinetic phenomena near the critical point [1 - 4].

Thus, the ratio of the "order parameter" relaxation frequency to ω_c, with allowance for the spatial dispersion, is a universal function of $y = kr_c$ (k is the wave number)

$$\omega(k, r_c)/\omega_c = F(y), \tag{1}$$

where

$$\omega_c = 2Dr_c^{-2} \equiv k_B T/3\pi\eta(y)r_c^3, \tag{2}$$

(y) is the "high-frequency" shear viscosity [5].

The anomalous part of the complex bulk viscosity θ_c is determined by a universal function of $\omega^* = \omega/\omega_c$ (ω is the external frequency) [4]

$$\omega\theta_c(\omega,\omega_c) = G(T)J(\omega^*). \quad (3)$$

The validity of (1) and (2) is confirmed by the latest rather thorough measurements of the width of the unshifted Rayleigh scattering line [6, 7]. Equation (3) can be verified by investigating the frequency and temperature dependences of the absorption and velocity-dispersion of sound. We have verified experimentally the main conclusion of the dynamic scaling theory in the following sequence: 1) We proved the validity of the static scaling theory for the chosen object (binary nitroethanisooctane solution), determined the "critical exponents," and calculated the critical frequency ω_c from the experimental data. 2) We demonstrated the validity of (3) in the entire range of variation of ω and T ($10^{-2} < \omega^* < 10^5$). 3) We compared the experimental data on the absorption and velocity dispersion of sound with the explicit form obtained in [4] for the function $J(\omega^*)$.

1. Verification of static scaling theory [8].

We determined the critical exponents of the specific heat (α), of the co-existence curve (β), and of the "susceptibility" (γ). The dependence of the concentration of the dense phase on the temperature (at $T < T_c$) was obtained by measuring the speed of sound (ω = 10 MHz) [9]. We obtained $x - x_c \sim t^\beta$, where $t = |(T - T_c)/T_c|$, $\beta = 0.34 \pm 0.01$, $T_c = 304.51°K$, and $x_c = 0.6$ mol. parts of nitroethane. The specific heat $C_{P,x}$ was measured at $x = x_c$ by an aidabatic method [10]. The best fit of the experimental data to the formula

$$C_{P,x}/T = A^\pm t^{-\alpha^\pm} + B^\pm \quad (4)$$

in the interval $t = 10^{-2} - 10^{-4}$ is obtained with the following values of the parameters: $\alpha^+ = 0.12 \pm 0.16$, $A^+ = 0.055$, $\alpha^- = 0.12 \pm 0.04$, $A^- = 0.113$, $B^+ = B^- = 0.53$. We als measured the isochoric specific heat $C_{V,x}$ at $t > 10^{-2}$. The temperature dependence of the "susceptibility" was determined by us jointly with Aref'ev, Fabelinskii, and Kiyachenko [1] by measuring the Landau-Placzek ratio of the Rayleigh scattering spectrum. $\gamma = 1.22 \pm 0.06$ in the interval $t = 10^{-2} - 10^{-4}$. The static scaling theory relation [8] $\alpha + 2\beta + \gamma = 2$ is satisfied accurate to ~1%.

The critical frequency was determined from formula (2), using the relations $r_c = r_0 t^{-\nu}$ and $3\nu = 2 - \alpha$ [8]. The value $\nu = (2 - \alpha)/3 = 0.63$ corresponds to the value $r_0 = 2.6 \pm 0.4$ Å obtained in [11].

We used also the experimental values of the shear viscosity $\eta(T)$ [12], since $\eta(y)$ differs from $\eta(T)$ at small k by not more than 5 - 6% [5]. We wish to emphasize that, unlike in the earlier studies [13, 14], no fitting parameters were used anywhere. Only in the comparison of the experimental results with the explicit form of the function $J(\omega^*)$ [4] did we have to vary

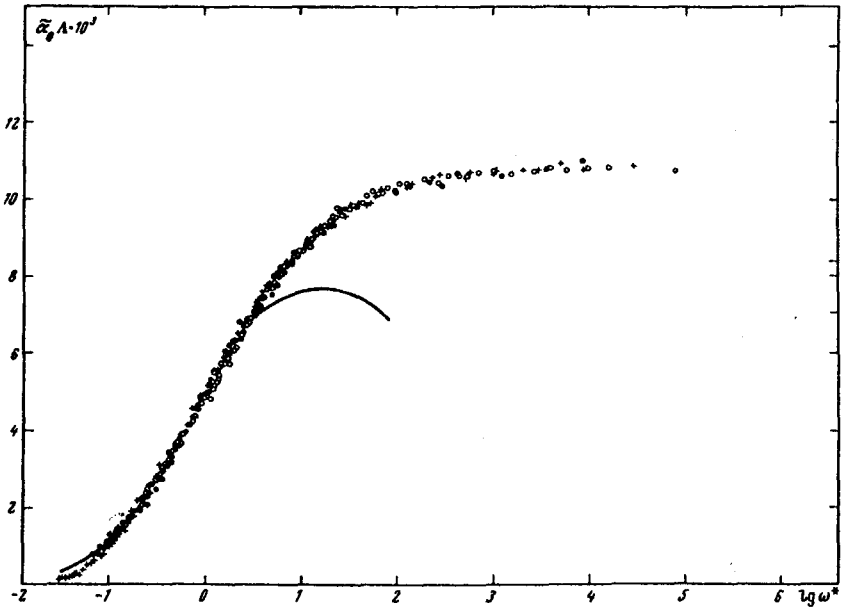

Fig. 1. Product of excess absorption coefficient and wavelength vs. relative frequency $\omega^* = \omega/\omega_c$ (● - ω = 4.2 MHz, × - 10.1 MHz, o - 15.9 MHz). Solid line - calculation from formula (5).

r_0 within the range of its error.

2. Verification of dynamic scaling theory.

We measured the sound absorption coefficient ($\tilde{\alpha}$) at the frequencies 4.2, 10.1, and 15.9 MHz by a pulse method, and the sound velocity (u) at 2, 9.3, and 27.7 MHz by the acoustic-interferometer method [15]. The random errors in the determination of the absorption times the wavelength ($\tilde{\alpha}\Lambda$) near T_c, where $\tilde{\alpha}\Lambda \sim 10^{-2}$, is 1 - 2%, and far from T_c, where $\tilde{\alpha}\Lambda \sim 10^{-4}$, it reaches 10 - 15%. The mean error of the sound velocity is ~0.05%. The temperature was maintained accurate to $\pm 10^{-3}$ deg.

Figure 1 shows a plot of the absorption coefficient times wavelength, with the absorption due to shear viscosity subtracted, as a function of $\omega^* = \omega/\omega_c$. Practically all the excess absorption is connected with the bulk viscosity ($\tilde{\alpha}_\theta\Lambda = (\omega/\ ^2)\mathrm{Re}\theta$), since the absorption connected with the thermal conductivity and with the mutual diffusion is negligibly small at $t > 10^{-4}$ [11]. We have also neglected the possible regular part of the bulk viscosity, since extrapolation of $\tilde{\alpha}\Lambda$ to $\omega^* = 0$ yields a value close to $\tilde{\alpha}_{\eta\Lambda}$ ($\sim 10^{-4}$). It is easy to see that $\tilde{\alpha}_\theta\Lambda$ is a function of one argument $\omega^* = \omega/\omega_c$ in a tremendous range of variation of ω^*, from 10^{-2} to 10^5. The asymptotic behavior of $\tilde{\alpha}_\theta\Lambda$ (at $\omega^* \ll 1$ and $\omega^* \gg 1$), and consequently of $J(\omega^*)$, can be predicted on the basis of the general ideas of dynamic scaling theory. As $\omega^* \to 0$, the kinetic coefficients should not depend on ω, and are determined only by r_c. Then, in accordance with (3), $\mathrm{Re}J \sim \omega^*$ and $\mathrm{Re}\theta_c \sim \omega_c^-$ [2, 4]. As $\omega^* \to \infty$, to the contrary, the kinetic coefficients should not depend on the proximity to the critical point (i.e., on r_c). Then $\mathrm{Re}J = \mathrm{const}$ and $\mathrm{Re}\ \theta_c \sim \omega^{-1}$. Our experiment confirms convincingly these principal conclusions of the theory. We note also the complete analogy between the behavior of the bulk viscosity in solutions and in one-component liquids [12] (the isomorphism of the kinetic coefficients, which was predicted in [16, 17]).

3. Explicit form of the function $J(\omega^*)$.

Kawasaki [4] obtained the following dependence of the absorption and velocity dispersion of sound on ω and T:

$$\tilde{\alpha}_\theta\Lambda = \frac{k_B T^2 \nu^2}{\pi \rho T_c^2 r_0^3}\, g(T)\, t^{-\alpha}\, \mathrm{Re}\, J(\omega^*), \tag{5}$$

$$\frac{v(\omega) - v(0)}{v(0)} = \frac{1}{2\pi}\, \tilde{\alpha}_\theta\Lambda\, \frac{\mathrm{Im}\, J(\omega^*)}{\mathrm{Re}\, J(\omega^*)}, \tag{6}$$

where

$$J(\omega^*) = \int_0^\infty \frac{y^2\, dy}{(1+y^2)^2}\ \frac{\omega^*}{F(y) - i\omega^*}. \tag{7}$$

It can be shown [9, 10] that for "incompressible" binary solutions, in the interval of t where the singular parts of $C_{P,x}$ and $(\partial V/\partial P)_{T,x}$ are smaller than the regular ones we have

$$g(T) = (1/C_{P,x})\left[(a\, C_{P,x}/A\, C_{V,x}) - (C_{P,x}/T)(\partial P/\partial V)_{T,x}(dT_c/dP)^2 - 1\right]$$

(a is the coefficient of the anomalous part of $C_{V,x}$). This differs greatly from the result of [18], $g(T) = \{C_{P,x}[(C_{P,x}/C_{V,x}) - 1]\}^{-1}$, which is connected with the incorrect assumption (for the entire experimentally attainable region of t; see [10, 17]) that $C_{V,x}$ has no anomaly. The thermodynamic quantities were taken or calculated from measurement data on $C_{P,x}$, $C_{V,x}$, and the speed of sound. The form of the function $F(y)$ was obtained in [3, 4]. The integral (7) was calculated with a BESM-6 computer. The result of the calculation of $\tilde{\alpha}_\theta\Lambda$ by formula (5) is shown in Fig. 1 by the solid curve. The calculation and experiment agree at $\omega^* < 2$ if one chooses $r_0 = 2.2$ Å, which is somewhat lower than the value $r_0 = 2.6 \pm 0.4$ Å obtained in an experiment on light scattering [11]. Some disparity at $\omega < 0.1$ may be due to an unaccounted-for systematic error, since the absorption is very small here. A qualitative discrepancy between experiment and calculation at $\omega^* > 2$ was predicted in [4] and is connected with the use of the Ornstein-

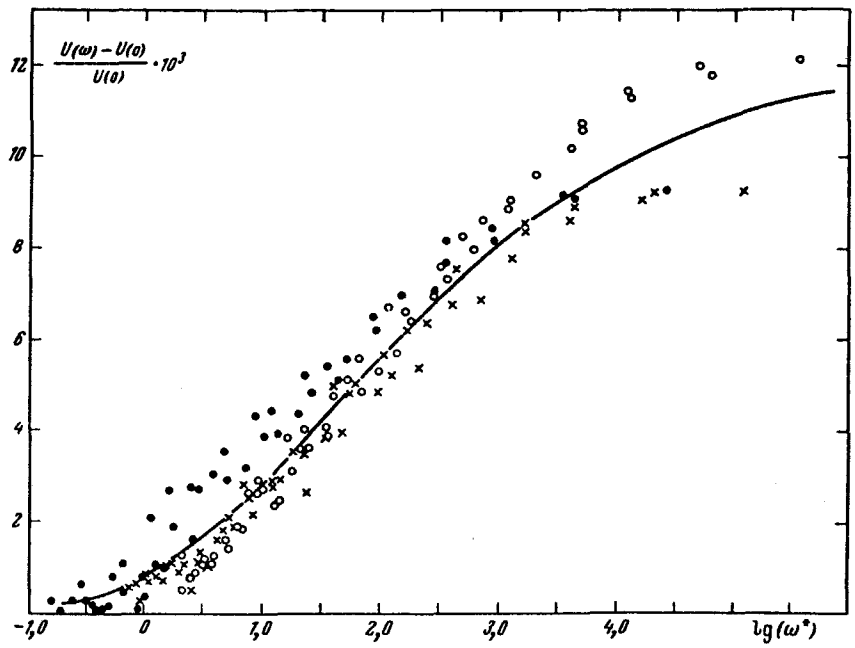

Fig. 2. Dispersion of sound velocity vs relative frequency (● - ω = 2. MHz, × - 9.3 MHz, o - 27.7 MHz). Solid curve - calculation from formula (6).

Zernike-Fisher correlation function, which does not hold for large K, to derive (7).

The results of the experiment and the calculation of the dispersion are shown in Fig. 2. Although the scatter of the points is larger here than in Fig. 1, by approximately one order of magnitude (the maximum variance does not exceed 1%), the agreement between experiment and calculation is satisfactory. It is of interest that the dependence of $\Delta u/u$ on ω^* (at $\omega^* \gg 1$), unlike $\tilde{\alpha}\Lambda$, is apparently not very sensitive to the form of the correlation function. We plan to investigate this question in detail in the future.

In conclusion we can state that the main conclusions of the dynamic scaling theory are valid. For an alternate approach to kinetics near critical points of liquids (independent kinetic "critical exponent" [19]) there are at present apparently no experimental grounds.

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ENERGY ATTENUATION OF ULTRASHORT OPTICAL PULSES BY SCATTERING MEDIA

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We report preliminary results of direct measurements of one of the main characteristics of a scattering medium (the attenuation coefficient) interacting with an ultrashort pulse of optical radiation. Experiment revealed a decrease in the attenuation of an ultrashort pulse compared with the case of continuous illumination.

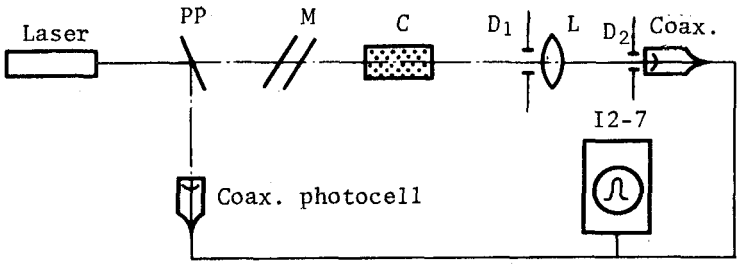
To describe the transport of optical radiation in scattering media, it is necessary to know their optical characteristics. These are pretty well known by now for the stationary scattering process, both from the theory of scattering of a plane monochromatic wave by a particle (the Love-Mie theory [1, 2]) and from experiment [3]. There are no such data, however, for nonstationary conditions, when an important role is assumed by the finite character of time of interaction between the photon flux and the scatterer.

The purpose of the present paper is to report preliminary results of direct measurements of one of the main characteristics of a scattering medium, the attenuation coefficient, in interaction with an ultrashort pulse of optical radiation.

The measurement setup is shown in the figure. A laser system generated an optical pulse of duration 50 μsec at a wavelength 0.69 μ [4]. The laser beam passing through the scattering medium was collimated with a long-focus lens (f = 1000 mm) and registered with a coaxial photocell FEK-15 and an oscilloscope I2-7. To prevent back-scattered laser light from entering the recording system, we placed at the focus of the lens a diaphragm D_2 with a diameter corresponding to the divergence of the incident laser radiation (0.003 rad). Part of the entering laser radiation was diverted with a beam-splitting plate to another FEK-15 photocell, the signal from which was also registered with the I2-7 oscilloscope. Such a scheme made it possible to compare the laser pulse passing through the scattering medium with a reference laser pulse in each measurement. To calibrate both channels, the scattering medium was replaced by dielectric mirrors that attenuated the beam in the investigated channel in such a way that when the mirrors were replaced by the scattering medium the amplitudes of the registered laser pulses were approximately the same in the two channels. This made it possible to extend the dynamic range of the recording system and to measure the attenuation coefficients of rather dense media.

The transmission of continuous illumination through a scattering layer was measured by a similar optical system. The light source was an incandescent lamp (KIM-75) in conjunction with an interference filter with a transmission bandwidth 20 Å at a wavelength 0.69 μ. The radiation passing through the scattering medium was registered with an FEU-28 photomultiplier.

The concentration of the scatterers in the investigated media did not exceed 10^8 cm^{-3} for small particles and 10^5 cm^{-3} for large ones (as a result, the distance between scatterers was not less than ten scatterer diameters). This excluded a possible influence of interference



PP - plane-parallel plate, M - attenuating mirror system, C - cell with scattering medium, D_1, D_2 - diaphragms blocking the laterally scattered radiation, L - lens.