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CORRELATION EFFECTS IN A LIQUID BINARY MIXTURE NEAR THE PLASMA TRANSITION TEMPERATURE

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Theoretical and experimental research on phase transitions follows the path of studying the correlation functions, i.e., studying the probabilities of the distributions of the relative coordinates and momenta of the moving particles.

The most valuable information on correlation functions is obtained from experiments on the scattering of neutrons and photons in the x-ray and optical bands. In experiments of this type one studies the angular and energy distributions of the individual scattered neutrons and photons, which are not connected with one another by any phase relations. However, with the development of lasers, whose emission consists of photons that coherently connected by definite phase relations, another formulation of the problem becomes possible, wherein one investigates the change of the coherent properties of the light passing through the sample. In this case one studies not the change of the spectral composition of the scattered light or the angular dependence of its intensity, but the change of the phase relations in the scattered field at two spatially separated points, as a function of the distance between them. Such an approach to the investigation of correlation functions is the most fruitful one for the study of second-order phase transitions. In this case the change of the coherence of the scattered light can be connected directly with the correlation radius or with the size of the fluctuations arising at the phase-transition point [1].

In this paper we demonstrate, for the first time, that correlation effects in small-angle scattering of coherent light in the liquid phase are sensitive to the change of the disperseness of the system under phase-transition conditions. We reveal the characteristic features of this phenomenon as

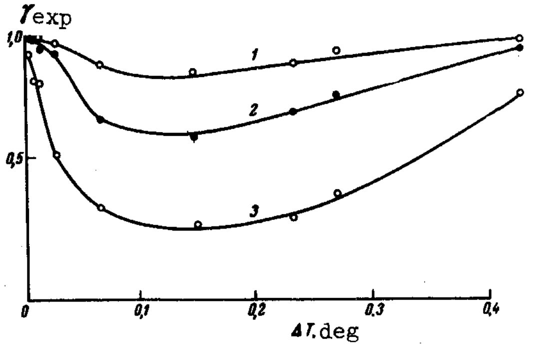

Fig. 1

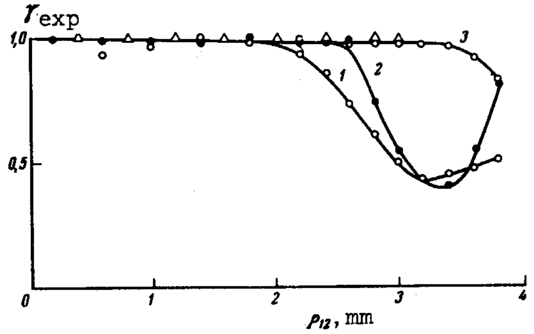

Fig. 2

compared with scattering by a system of uncorrelated centers.

We investigated a mixture of triethylamine with water at a concentration 42.2 wt.% of the triethylamine. The mixture had a lower critical lamination temperature $T_c = 17.85°C$. The lamination temperature was determined from the vanishing of the meniscus. The employed stabilization system has made it possible to vary the sample temperature in steps of 0.0025° and to maintain it with an accuracy ±0.02 for a long time. The relative temperature was measured accurate to ±0.0005°C. We measured the coherence of the field passing through a thin (2 mm) layer of opalescent mixture and scattered through small angles. The direct and scattered lights were superimposed on each other, and their relative intensity varied with the degree of approach to the critical temperature. To measure the modulus of the spatial coherence (γ_{12}) of the scattered light we constructed a Young interferometer with a laser as the light source [2]. The aperture resolution of the interferometer was 12 sec and the observation temperature ranged from 17 sec to 5 min. The aperture of the illuminated zone of the sample (as judged by the 0.1 level of the intensity distribution in the cross section of the beam in the region of the sample) relative to the screen with the openings was 4 min.

Figure 1 shows the dependence of the degree of spatial coherence on the temperature as the latter approaches the critical value. We see that with decreasing ΔT the spatial coherence first decreases smoothly and then increases sharply. With increasing distance between the apertures in Young's interferometer ρ_{12} (1 - ρ_{12} = 1.8 mm; 2 - ρ_{12} = 2.2 mm, 3 - ρ_{12} = 3.8 mm), which is equivalent also to large-angle scattering, this effect becomes stronger. Such a behavior of the γ_{exp} curves is attributed to the presence of exciting light with high coherence in the investigated field, owing to the fact that small-angle scattering is being investigated. At large ΔT the scattering is small, and the fraction of non-scattered light is large, and therefore the spatial coherence is high. Then, on approaching the critical temperature, the contribution of the scattered light to the investigated field increases, and since the coherence of the light scattering at large ΔT is low because of the weak correlation between the scattering centers, the degree of spatial coherence begins to decrease. On approaching the critical temperature, the intensity of the scattered light increases strongly, and the latter begins to predominate in the investigated field. At the same time, however, the correlation between the scattering centers increases and the fluctuation scattering processes slow down. This leads to a considerable increase of the degree of spatial coherence of the scattered light.

Figure 2 shows the dependence of the degree of spatial coherence γ_{exp} of the light interacting with the investigated liquid on the distance ρ_{12} for ΔT

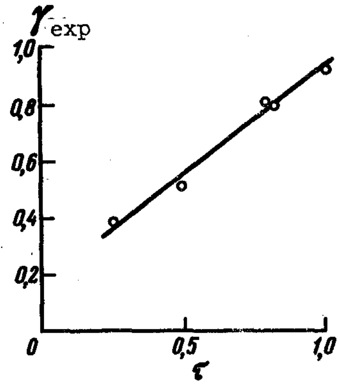

Fig. 3

values 0.027° (1), 0.013° (2), and 0.008° (3). We see that γ_{exp} increases with decreasing ΔT at fixed ρ_{12}, and the minimum of the curves shifts towards larger scattering angles (larger ρ_{12}). Such a behavior of γ_{exp} as a function of ρ_{12} coincides qualitatively with the predictions of [1], but calculations with allowance for the conditions of the given experiments are needed to obtain quantitative data.

Figure 3 demonstrates the increase of γ_{exp} with increasing optical thickness τ of the sample, at a fixed layer thickness, i.e., with increasing multiple scattering, for ρ_{12} = 3.8 mm. Such a dependence of γ_{exp} on τ can be attributed to the increase of the fluctuation correlation when the critical point is approached [1] and qualitatively contradicts the $\gamma(\tau)$ dependence in small-angle scattering of light by a system of independent scatterers [3].

In conclusion, we consider it our pleasant duty to thank D.M. Kaminker for support, V.A. Stepanov for a fruitful participation in the preparation of the last part of the investigation, G.V. Rozenberg, Yu.V. Petrov, and L.V. Popov for useful discussions, M.I. Trukhin for help and consultation on sensitometric measurements, and T.G. Braginskaya, A.D. Seledtsov, and T. Smirnov for help with the measurements and with the reduction of the experimental data.

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EFFECT OF IMPURITIES ON THE DAMPING OF HYPERSONIC WAVES IN CRYSTALS

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Point defects in crystals (impurities, vacancies, inclusions) cannot scatter hypersonic elastic waves directly, because the dimensions of such defects are smaller by several orders of magnitude than the wavelength of the elastic waves (the wavelength is about 10^{-4} cm at 1000 MHz). Point defects, nonetheless, can influence the damping of the elastic waves indirectly, via thermal phonons.

According to Akhiezer's theory [1], elastic-wave damping connected with their interaction with thermal phonons is given by [1 - 3]:

$$A = \gamma^2 \frac{CT\omega^2\tau}{2\rho v^3(1+\omega^2\tau^2)} \qquad (1)$$

Here γ is the anharmonicity constant, T the temperature, C the specific heat, ρ the density, v and ω the velocity and frequency of the elastic waves, and τ the relaxation time, proportional to the relaxation time τ_{ph} of the thermal