FIRST-SOUND DISPERSION PRODUCED IN He^4 BY DECELERATION OF THE NORMAL COMPONENT

B. N. Esel'son, N. E. Dyumin, E. Ya. Rudavskii, and I. A. Serbin
Physico-technical Institute of Low Temperatures, Ukrainian Academy of Sciences
Submitted 17 July 1967
ZhETF Pis'ma 6, No. 8, 783-787 (15 October 1967)

Two independent* types of oscillation, first and second sound, play an important role in an unbounded volume of HeII. In the first-sound wave the velocities of the normal and superfluid components are equal ($v_n = v_s$), whereas in the second-sound wave $\rho_s v_s + \rho_n v_n = 0$ (ρ_n and ρ_s are the densities of the normal and superfluid components). When the sound propagates in narrow channels filled with HeII, these relations cannot be satisfied because $v_n = 0$ on the boundary with the solid. Therefore the character of the acoustic oscillations in such a medium depends on the ratio of the channel dimension 2d and the depth of penetration of the viscous wave $\lambda_b = (2\eta_n/\omega\rho_n)^{1/2}$ (η_n - viscosity of normal component, ω - oscillation frequency). If the normal component is not clamped ($\delta = d/\lambda_b >> 1$), then both first and second sound can propagate, but if the first component is completely clamped ($\delta << 1$), then the first sound goes over into fourth sound [1-3] and the second sound into a damped thermal wave. This phenomenon can be referred to as the dispersion of the sound, and the parameter determining the dispersion is the quantity δ. The first to observe second-sound dispersion were Pollack and Pellam [4]. The most complete theoretical study of both first and second sound dispersion connected with partial deceleration of the normal component was made by Adamenko and Kaganov [5]. It is shown in [5], in particular, that in the case of considerable clamping, $\delta \sim 1$, propagation of two types of sound is also possible, but their velocity and absorption depend on δ. For example, the velocity of the first sound is

$$u_{1\delta}^2 = u_1^2 \left(1 - b\frac{\rho_n}{\rho}\right)\left[1 + \frac{3}{8}\left(\frac{a\rho_n}{\rho - b\rho_n}\right)^2\right]^2, \qquad (1)$$

and the absorption, if due only to the slippage of the normal component, is

$$d = \frac{1}{2}\frac{\omega}{u_{1\delta}}\frac{a\rho_n}{\rho - b\rho_n}.$$

In these formulas u_1 is the velocity of first sound as $\delta \to \infty$, and the coefficients a and b, given by

$$a = \frac{\mathrm{sh}\,2\delta - \sin 2\delta}{4\delta(\cos^2\delta + \mathrm{sh}^2\delta)}, \qquad b = \frac{\mathrm{sh}\,2\delta + \sin 2\delta}{4\delta(\cos^2\delta + \mathrm{sh}^2\delta)},$$

take into account the degree of clamping of the normal component as a result of the proximity of the walls.

The purpose of this investigation was to observe experimentally the first-sound dispersion that should occur, according to Adamenko and Kaganov [5], when $\delta \sim 1$. To this end we measured the temperature dependence of the velocity of first sound propagating in He^4 in

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a system of branched channel formed by corundum powder with average particle dimension 28 μ. We used a pulsed method of determining the velocity, and the procedure and apparatus were similar to those employed by us earlier [6] to determine the velocity of fourth sound in He^3-He^4 solutions. We note only that the greatest contribution to the sound pulse passing through such a "filter" with HeII was made by the frequency ∿25 kHz.

In determining the speed of the sound propagating in the system of irregular channels, the measured and true values u' and u do not coincide, owing to multiple scattering, which increases the path of the sound. This is usually taken into account by introducing a correction $n = u/u'$, which is constant for the given "filter." We were unable to determine this correction with sufficient accuracy for the "filter" used by us, and therefore determined n in such a way that the experimental and theoretical values coincided at 1.5°K. The true values of the speed of sound obtained in this manner are shown as a function of the temperature in Fig. 1 (curves 1 and 2 pertain to first and fourth sound, respectively). The values of $u_{1\delta}$ calculated** from formula (1) with d = 6.5 μ (curve 3) differ near the λ point from the experimental ones (for n = 1.31) by not more than ∿6%. By using the same plot it is easy to verify that no choice of a constant value of n will make it possible to reconcile the experimental points with the velocity of first sound in the entire temperature interval.

The fact that this sound can propagate in He I is not unexpected, and agrees with the fact that in any liquid the speed of sound is lower in narrow channels. The velocity and absorption of sound in He I can be calculated with the aid of the same formulas (1) and (2),

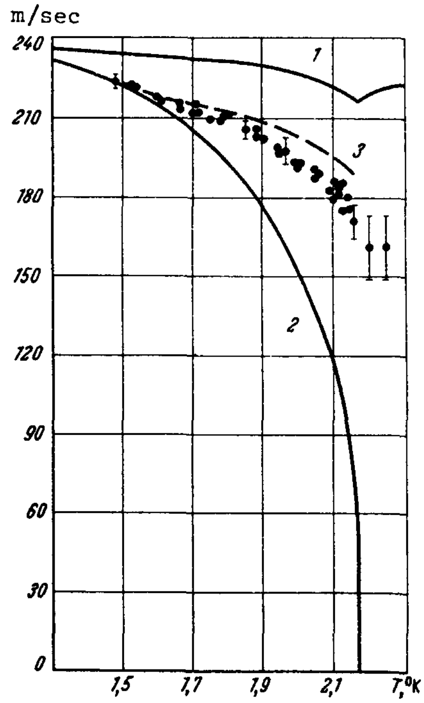

Fig. 1. Temperature dependence of speed of sound: 1 - first sound, 2 - fourth sound, 3 - theoretical dependence $u_{1\delta}(T)$. o - experimental results.

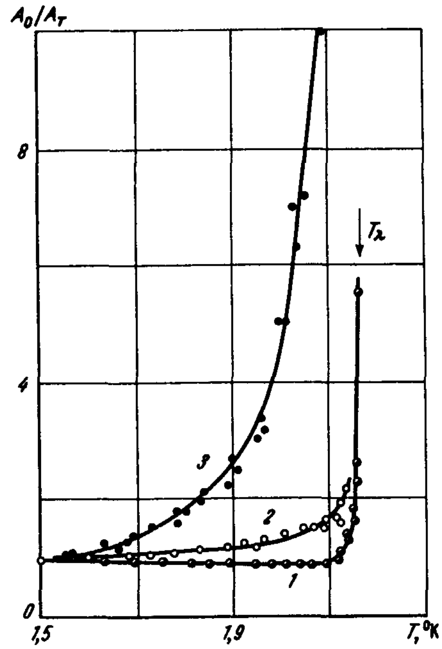

Fig. 2. Temperature dependence of A_0/A_T: 1 - fourth sound, 2 - first sound, 3 - sound under conditions of strong dispersion. (δ ∿ 1).

but substitute ρ for ρ_n. An exact experimental determination of these quantities for $\delta \sim 1$ is made difficult by the large absorption.

Figure 2 shows the temperature dependence of the ratio of the pulse amplitude at T = 1.5°K (A_0) to the amplitude at a temperature T (A_T). Curve 1 corresponds to fourth sound ($\delta \ll 1$), and curve 2 corresponds to first sound with very weak dispersion ($\delta \sim 2$, these conditions were realized in corundum powder with average particle size ~60 μ; in this case the speed of sound almost coincided with u_1); curve 3 corresponds to sound in the region of strong dispersion ($\delta \sim 1$). The quantity A_0/A_T represents the temperature dependence of the absorption coefficient, and it follows from the figure that the absorption has a stronger temperature dependence in the dispersion region. The ratio A_0/A_T does not depend on the amplitude up to ~2.0°K; the determination of this dependence at higher temperatures is hindered by the strong absorption, which leads to an unfavorable signal/noise ratio.

Thus, the described experiments confirm that when the normal component is substantially clamped (i.e., when the dimension of the channel is comparable with the depth of penetration of the viscous wave), dispersion of first sound sets in.

The authors are grateful to M. I. Kaganov and I. N. Adamenko for interesting discussions and for a preprint of their paper.

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*These types of oscillation are independent only if thermal expansion is neglected.

**To calculate λ_b, we used the values of ρ_n and η for He^4, given in [7, 8].

NONLINEAR INTERACTION OF OSCILLATIONS IN A PLASMA-BEAM SYSTEM

I. P. Shashurin
Kiev State University
Submitted 21 July 1967
ZhETF Pis'ma 6, No. 8, 787-790 (15 October 1967)

When an electron beam interacts with a transversely-bounded plasma in a magnetic field under conditions when $f_p > f_H$, simultaneous excitation of microwave oscillations in two frequency regions becomes possible [1]. The first of these regions lies close to f_p and is governed by the polarization interaction between the beam and the plasma, whereas the second is lower than f_H and is governed by the interaction between the slow space-charge wave and the direct plasma-waveguide wave. Both instabilities have a collective character and their amplitudes increases in the direction from the electron gun to the collector.

It is to be expected that when several oscillations are excited in a nonlinear medium such as a plasma, they interact. Our purpose was to observe and study the properties of such an interaction.