[1] B. D. Josephson, Phys. Lett. 1, 251 (1962).
[2] M. D. Fiske, Revs. Modern Phys. 36, 221 (1964).
[3] I. K. Yanson, V. M. Svistunov, and I. M. Dmitrienko, JETP 47, 2091 (1964), Soviet Phys. JETP 20, 1404 (1965).
[4] T. I. Smith, Phys. Rev. Lett. 15, 460 (1965).
[5] R. E. Eck, D. J. Scalapino, and B. N. Taylor, Phys. Rev. Lett. 13, 15 (1964).
[6] D. D. Coon and M. D. Fiske, Phys. Rev. A138, 744 (1965).
[7] I. M. Dmitrienko, I. K. Yanson, and V. M. Svistunov, JETP Letters 2, 17 (1965), transl. p. 10.
[8] I. O. Kulik, ibid. 2, 134 (1965), transl. p. 84.
[9] I. K. Yanson, V. M. Svistunov, and I. M. Dmitrienko, JETP 48, 976 (1965), Soviet Phys. JETP 21, 650 (1965).
[10] I. Giaever, Phys. Rev. Lett. 14, 904 (1965).
[11] D. N. Langenberg, D. J. Scalapino, B. N. Taylor, and R. E. Eck, Phys. Rev. Lett. 15, 294 (1965).
[12] I. M. Dmitrienko and I. K. Yanson, JETP Letters 2, 242 (1965), transl. p. 154.

*The chart speeds used to obtain the current-voltage characteristics (Fig. 1) differ somewhat from one another, which naturally affects the P-t diagram.

VISUAL OBSERVATION OF SECOND SOUND BY THE TOEPLER METHOD

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The fundamental experimental data on the mechanism of heat propagation in helium II, in Kapitza's experiments [1] with stationary heat flow, and also in subsequent investigations with second sound, were obtained with the aid of resistance thermometers. The use of such thermometers in the study of thermal pulses in helium II [3,4] does not present the complete picture of pulse propagation, owing to the local disposition of the thermometer and unavoidable distortions. It is possible to obtain information on the spatial structure of the thermal waves and on the character of their flow around obstacles by observing the instantaneous fields of the refractive index of helium II using optical methods, such as the here-employed Toepler method with short illumination flashes. The possibility of measuring the density gradient in helium II by this method changes little with temperature, whereas the conditions for observing the temperature gradients are connected with the coefficient of thermal expansion of helium II, and are therefore favorable near the λ-point ($T_{\lambda} = 2.173^{\circ}$K) and become worse with decrease in temperature.

Figure 1 shows a diagram of the setup. A cryostat with windows made of glass plane-parallel discs of 230 mm diameter is placed between collimator 1 and the sighting tube 6 of the Toepler instrument AIB-451 [5]. The light is produced by an electric discharge in a xenon lamp producing an intense glow for 1 - 2 μsec. Inside the housing of the cryostat (with windows 2) is placed, in vacuum, a chamber 5, closed by discs 4, between which the investigated layer of liquid helium is poured. The helium vapor is pumped off

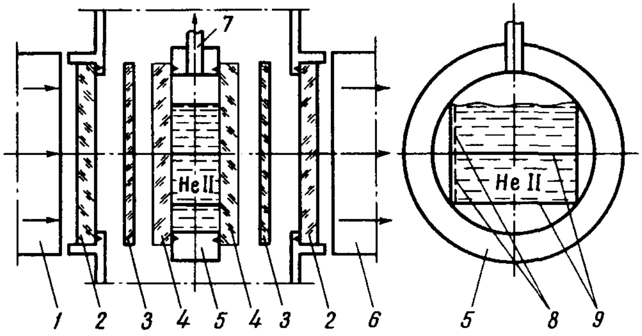

Fig.1. Experimental setup

with a vacuum pump through tube 7. The liquid-helium temperature was determined from the vapor pressure (1958 scale) with an error not exceeding ±0.001 deg. The chamber was surrounded with a cooling (liquid nitrogen) screen and discs in contact with it, the disc temperature being close to 80°K. Horizontal partitions 9 divided the chamber into two working volumes: a lower parallelepiped of square cross section, 58 x 58 x 157 mm, separated by a partition from the surface of the liquid (gaps $\leq$ 0.5 mm), and an upper volume, bounded from above by the free surface of the liquid (the liquid surface was sometimes strongly perturbed by thermoacoustic oscillations in tube 7). On the left vertical support are placed flat electric heaters 8 wound of constantan ribbon 35 μ thick, 0.5 mm wide (approximate resistance 110 ohm), arranged in zigzag fashion with 1 mm pitch. The ribbon is stretched on ribs of a glass plate, and polished projections on the edge of the plate support the ribbon in one plane at a distance 0.5 mm from the surface of the glass; deviations of individual ribbons from the plane do not exceed 0.1 mm.

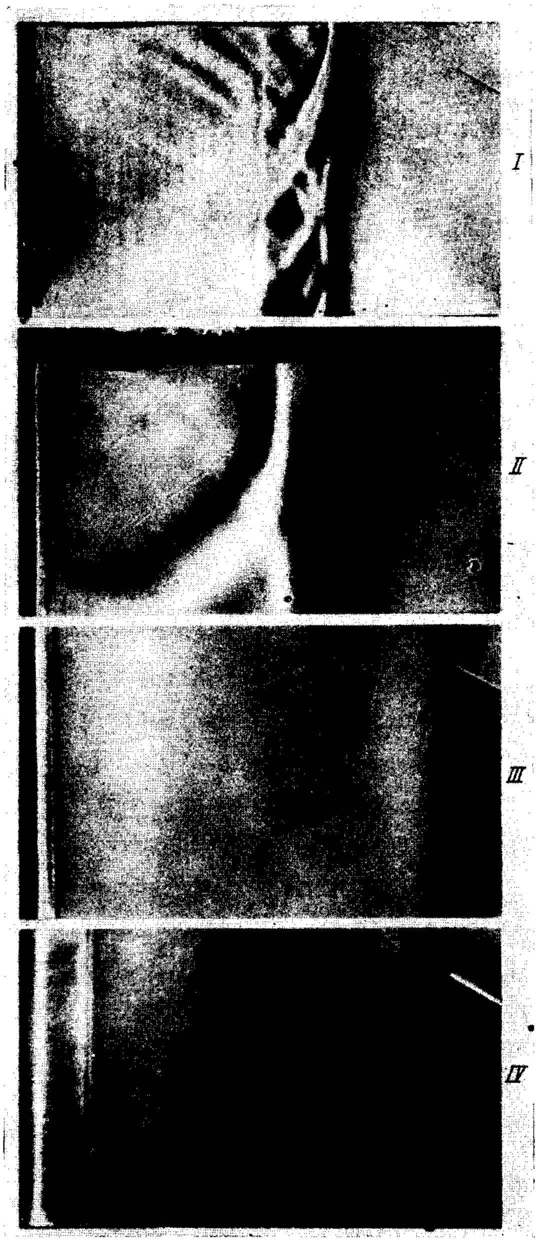

Fig. 2. Toepler pictures observed in HeII. I) T = 2.172°K, t_+ = 0.28 msec; II) T = 2.157°K, t_+ = 0.30 msec; III) T = 2.143°K, t_+ = 0.37 msec; IV) T = 2.138°K, t_+=1.10 msec.

A shifted-pulse generator was used for synchronization of the thermal pulses with the light flashes. The heater was fed by an amplified reference square pulse (amplitude up to 1.8 A, front rise time not longer than 0.3 μsec, inclination of "horizontal" part not larger than 2%), and the shifted generator pulse, after additional delay and amplification, initiated the discharge in the lamp. The delay system is calibrated my measuring the time interval t_+ between the leading front of the pulse in the heater and the start of the discharge in the lamp. The reading error, with smooth regulation of the interval t_+, did not exceed 5%. The generator could be triggered either once, whereby one thermal pulse and one flash synchronized with the camera shutter were produced, or periodically at a frequency up to 50 Hz. Figure 2 shows Toepler pictures observed in helium II at different temperatures after a time t_+ elapsed after applying to the flat heater (located to the left at the vertical wall) a square electric pulse of 100 μsec duration and of approximately 8 W/cm^2 power (total flux per unit cross section occupied by the heater, propagating first in both directions). The transverse dimension of the channel shown on the photographs is 58 mm. The slit in the Toepler instrument is vertical, and the Foucault knife edge is so placed that an increase in the illumination of a section of the image, compared with the "zero" (gray) background, corresponds to a positive direction (from left to right) of the density gradient of the liquid in this section. The reduction of about one hundred photographs has shown the following: When $T \geq T_\lambda$ the heating pulse excites a "sound packet" of perturbations (photo I, $T \simeq T_\lambda$), the front and rear boundaries of which occurred at the instants when the corresponding pulse fronts passed through the heater, and the propagation velocity of which is 220 m/sec (the speed of sound). Lowering the temperature leads to vanishing of the distinct front boundary of this packet (photo II, T = 2.157°K), with a visible front boundary of increased density (start of darkening) appearing 10 - 15 μsec after the leading front of the pulse. No delay in the distinct rear boundary of the packet is observed in this case. Photo II shows, after the departure of the spreading "sound packet," the separation of a second perturbation from the heater, in the form of a thin dark band parallel to the heater. At lower temperatures (photos III and IV, $T \simeq 2.141$°K), there was no "sound packet" produced at all (although the conditions for observing density gradients in the liquids were practically unchanged), and the second perturbation propagated already in the form of two bands separated by approximately 1 mm (twice the distance between the heater in the wall; the second band is reflected from the wall). The velocity of the second perturbation increases with decreasing temperature (7.5 m/sec on photo II and approximately 10 m/sec on photos III and IV) and coincides with the values of the second-sound velocity obtained in [2,3]. With increasing velocity, the width of the bands increases, and they become superimposed, forming a "second-sound packet" accompanied during the course of motion (see photo IV) by cylindrical "tails," in analogy with the "sound packet" on photos I and II. The tails are noticeable until the first reflection of the packet from the opposite wall, and an increase in the density gradients at the rear edge is observed in the structure of the packet itself after reflection. By increasing the power of the thermal pulse it is possible to excite a "sound packet" at a lower temperature, i.e., to increase somewhat the temperature at which it vanishes.

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[1] P. L. Kapitza, JETP 11, 1 (1941).
[2] V. P. Peshkov, JETP 16, 1000 (1946).
[3] J. R. Pellam, Phys. Rev. 75, 1183 (1949).
[4] D. V. Osborne, Proc. Phys. Soc. 64, 114 (1951).
[5] S. A. Abrukov, Tenevye i interferentsionnye metody issledovaniya opticheskikh neodnorodnostei (Shadow and Interference Methods of Investigating Optical Inhomogeneities) Kazan' University Press, 1962.