Pulsed Second Sound in Liquid Helium II*

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PULSE methods previously employed[1] for investigating first sound in liquid helium II have been modified to to measure the velocity and attenuation of second sound, and observe various coupling effects between ordinary sound and second sound. Piezoelectric transducers have been replaced by thermal elements, and video pulses utilized. A paper giving more details will be submitted shortly to the Physical Review. This technique has already been described in the latest M. I. T. Research Laboratory of Electronics Quarterly Progress Report[2] where block diagrams, sectional drawings of apparatus, and a condensed version of the results are given.

The oscillogram of Fig. 1 represents the time sequence involved in this pulsing process. The d.c. generating pulse appears at the extreme left, triggered simultaneously with the start of the oscilloscope time-sweep. Arrival of the second sound pulses at the temperature sensitive element (carbon resistance strip[3]) is recorded by signal pips to the right. Individual markers appearing at 61.1-μsec. intervals provide the time scale. Elapsed time delay yields velocity directly, the transmitter-receiver separation being known; for the accompanying sample this distance was 7.57 centimeters. Absence of measurable time delay during pulse formation was established with gear having variable path length.

Advantages of the pulse method acrue mainly from the fundamental directness, no recourse to resonant systems[4,5] being involved. Consequent rapid readings simplify temperature control, and the low average power inherent in pulsed signals promises ultimate lower temperature measurements. Using path lengths of a few millimeters, and motion picture recording, velocities below two meters per second have been observed as the λ-point is approached. Immediately below the λ-point, temperature control to within 0.0002°K may be realized by holding the signal position fixed on the screen for constant transmitter-receiver position.

A great number of measurements of the velocity of second sound as a function of temperature have been made in the range from the λ-point to 1.0°K and the results appear to agree generally with the results obtained by previous investigations[4,5] employing standing waves.

Attenuation measurements of video second sound pulses have been observed for the first time by means of apparatus having variable path length. Motion pictures record showing the decreased signal strength with increased path length (ambient temperature constant) provide a measure of the "exponential temperature attenuation coefficient" α.

$$\Delta T = \Delta T_0 e^{-\alpha x},$$

where ΔT is the amplitude of the temperature wave. For the pulses employed (88 per second, and 150-μsec. duration) the attenuation is small, α increasing steadily with temperature from a value of about 0.01 cm^{-1} at 1.65°K to about 0.1 cm^{-1} at 2.06°K. At still higher temperatures α increases much more rapidly, rising sharply, apparently to infinity, in the immediate vicinity of the λ-point (see plot in reference 2).

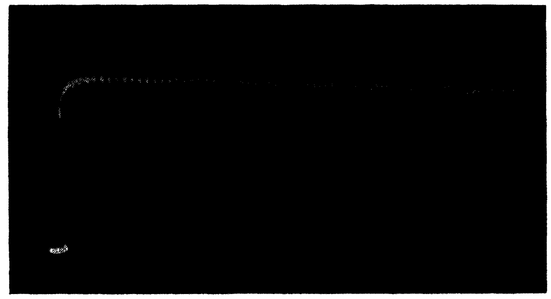

FIG. 1. Photograph of second sound pulse at 1.653°K (path length of 7.57 cm). See reference 2 for complete series.

The pulse method is particularly suitable for observing conversion phenomena between various types of sound, since the obscuring effects of system resonances are avoided. Thus quantitative data on the previously observed coupling[5] at the liquid surface has been obtained, plus evidence of two new forms of conversion for second sound. The surface coupling is observed by pulsing second sound from beneath and noting the drop in signal strength as the receiver is lifted vertically out of the liquid. The ratio of temperature fluctuations above and below the surface indicates that at 2.0°K about 5 percent of incident sound intensity is converted to vapor sound intensity (with no measurable time delay).

Substituting a classical (vibration) receiver for the temperature element reveals presence of first sound, also originating at the second sound generator, and unmistakable because of its higher wave velocity (possibly generated by internal breakdown of second sound). An even more subtle conversion is manifest in the faint signals following the original second sound signal of Fig. 1. The additional time delay corresponds to first sound transit time, though the events and their sequence are not clear.

After most of the data for the present research were obtained, word was received that similar experiments are in progress at the Royal Mond Laboratory in Cambridge, England. It is understood their results in the velocity of second sound are in general agreement with the present measurements.

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[1] J. R. Pellam and C. F. Squire, Phys. Rev. **72**, 1245 (1947).
[2] J. R. Pellam, "Investigations of second sound in liquid helium II," M. I. T. Research Laboratory of Electronics Quarterly Progress Report, July 15, 1948, p. 16.
[3] H. Fairbanks and C. T. Lane, Rev. Sci. Inst. **18**, 525 (1947).
[4] V. Peshkov, J. Phys. **10**, 389 (1946).
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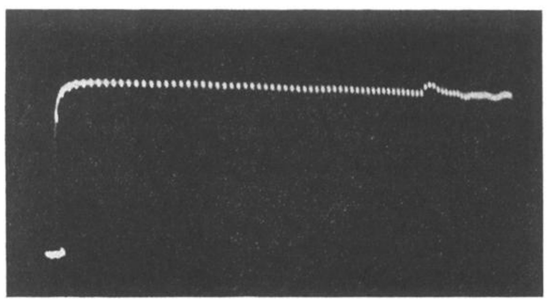

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