Superfluid Helium

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Abstract

I. INTRODUCTION

When cooled below 2.17 K, ^{4}He undergoes a phase transition from a typical liquid, Helium I, to the superfluid, Helium II. This "superfluidity" is characterized by the fluid's vanishingly low viscosity, which also gives rise to a number of other interesting phenomena. This superfluidity is thought to arise from Bose-Einstein Condensation. [2]

One of the unique properties of Helium II is its so-called "second sound" behavior. These waves are traveling temperature pulses, which observe many typical behaviors characteristic of waves, such as resonance and reflection characteristics.

We measure the temperature-dependence of the second sound waves in helium as well as helium's heat capacity.

II. BACKGROUND

A. Second Sound

Outline the two-fluid model (normal and superfluid components. Different densities, superfluid has none of the viscosity or entropy. Allows temperature waves to propagate and velocity is

$$u_2 = 26\sqrt{\frac{T}{T_\lambda}\left[1-\left(\frac{T}{T_\lambda}\right)^{5.5}\right]}$$

[1]

III. EXPERIMENTAL METHODS

A. Cryostat

Explain the process of cooling down

B. Second Sound Measurement

1. Cooling down
2. Pressure stable, take multiple measurements at each one
3. Measure length beforehand and then have relative thing after
4. Pulse generator to generate pulse, measure the wave later in the scope

C. Heat Capacity

1. Calculation of theoretical heat capacity of copper cell based on geometric parameters
2. Measure this heat capacity with pulses
3. Calibrate germanium thermometer
4. Measure heat changes in system as a function of time in Labview using calibration, subtract off addendum

IV. RESULTS AND DISCUSSION

A. Second Sound

B. Heat Capacity

[1] Russell J. Donnelly. The two-fluid theory and second sound in liquid helium. *Physics Today*, 62(10):34–39, October 2009. Publisher: AIP Publishing.

[2] D. R. Tilley. *Superfluidity and Superconductivity*. Routledge, July 2019. Google-Books-ID: pwuWDwAAQBAJ.

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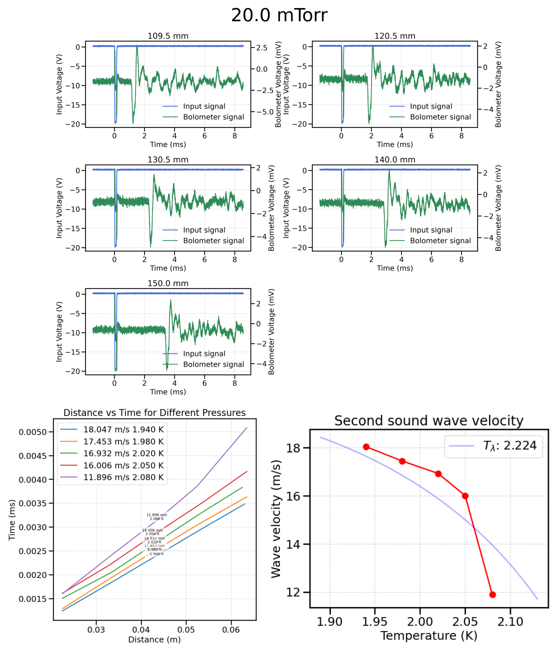

FIG. 1. Temperature dependence of second sound velocity in superfluid helium. We plot the time for our applied heat pulses to reach the bolometer for various distances from the heating plate at constant temperature (as determined by helium vapor pressure). From these distance vs. time lines, we extract the velocity of the second sound waves at each temperature, seen in the bottom plot (blue line). We fitted this to the theoretical form (see background) and compared to the theoretical curve with $T_\lambda = 2.17$ K.

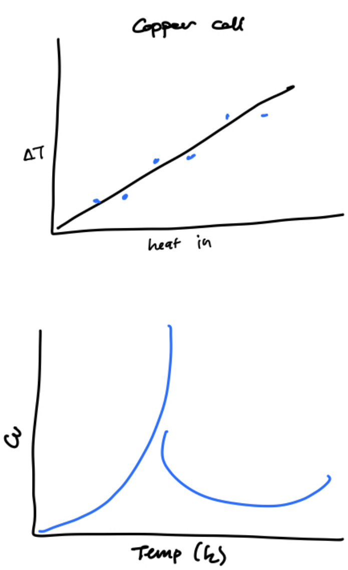

FIG. 2. Temperature dependence of heat capacity for Helium II