Superfluid Helium Experiment Summary

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1 Experimental Goals

Our goal is to gain familiarity with the behavior and properties of liquid helium.

1. Observe "second sound" waves (temperature waves) in superfluid liquid helium
2. Observe the "fountain effect" and cessation of boiling in superfluid helium
3. Measure heat capacity of liquid helium and speed of sound as a function of temperature
4. Learn techniques of low-temperature physics and be able to safely handle cryogens

2 Safety

1. Personal safety
   (a) Be safe when handling cryogens (i.e. wear gloves and prevent contact of cryogens with skin). Ask for assistance from a staff member for first cooldown and read procedures for subsequent experiments.
2. Instrument safety
   (a) Do not let air enter the cryostat and do not let the cryostat over pressurize. Pump slowly to accomplish this.

3 Tentative Experimental Plan

Cooldown: Super important to watch the transfer video and read Appendinx 4.
WEAR GLOVES AND PROTECTIVE GOGGLES

1. Transfer procedure
   (a) Locate the transfer line and check pressure is below 60 microns (otherwise ask staff for help to pump it down)
   (b) Remove the liquid nitrogen through "blow-out tube" which can rest near the bottom of experimental area of cryostat. Place a storage vessel on the end of the tube and pump liquid nitrogen into the cryostat to push the liquid nitrogen into the vessel. Pump the Dewar to remove all liquid.
   (c) Check helium level in storage dewar with the "thumper" (by noting the Taconis effect). It is important to measure the level in the storage dewar before and after and to record it in the clipboard.
   (d) Insert transfer tube into storage dewar and wait for white plume to start forming. Then quickly insert the transfer tube as far as possible into the FILL tube in the cryostat. Storage tube should be 3-4mm above the bottom of the storage dewar to avoid blockages.
   (e) Slowly transfer at ≈ 0.25 psi pushing pressure into the storage dewar for about a minute to precool. (If not too much liquid will boil before the system is cooled below 4.2 K)

(f) Raise pressure to $\approx$ 1 psi. Good rule of thumb: At this pressure, the number of liters transfered will be approximately equal to the number of minutes elapsed. Check the level monitor to know when cryostat is full.

(g) Remove the transfer tube.

(h) Warm any frozen O-rings with a heat gun.

2. Observing second sound waves in helium: For this experiment, we will use the cryostat with windows to observe second sound waves and see the fountain effect.

   (a) Use the pulse generator to issue pulses to the heating element. Parameters were determined last time–we will use 100µm on and have roughly a second of rest between. We will then run for a number of samples to average and will measure via the bolometer how long it takes for the generated second sound waves to reach the bolometer.

   (b) While we are cooling down, we can observe the fountain effect in this cryostat. The superfluid helium will be able to flow through the porous plug at the bottom of the tube and spurt out the top, creating a "fountain."

3. Heat capacity: For this experiment, we will use the second cryostat without a viewing port (to isolate our temperature measurements from unnecessary photons). The experiment consists of filling a small metal cell (mostly copper) with helium, which is itself isolated from a bath of helium. The cell plus the tubes and have an approximate volume of 7.4 cm^3 and a mass of 14.8 grams. At first, the system will have a known amount of helium gas.

   (a) First, the cell must be thermally connected to the helium bath so it reaches a temperature below the λ point and the helium can condense inside it. This is done by introduce a small amount of helium gas into the pump-out tube to allow for thermal exchange.

   (b) Using the Wavetek 191 pulse/function generator, we will issue single pulses to cell. IMPORTANT: determine the value of heater resistance to estimate the appropriate amplitude and duration of the pulses.

   (c) the Heater resistance will measure the heat capacity of the helium plus the cell. To estimate the heat capacity of the helium, we will have to measure the heat capacity of the cell (known as the "addendum" first and adjust our measurements accordingly).

4 Questions

1. What is the difference between a Dewar and a Cryostat?

2. What is the expected behavior of the heat capacity of a metal as a function of temperature? Do we need to worry about this?

3. Do we need to worry about the heat we are running through the helium affecting the overall temperature in the second sound experiment?

References

[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.