Morphology and Angular Momentum of Superfluid Helium Drops

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Introduction

A cryogenic fluid is a substance that exists in a liquid state at extremely low temperatures. Cryogenic fluids such as liquid helium, hydrogen, and oxygen have many implementations in space and ocean travel research. The morphology of rotating classic fluid droplets has been well explored [1] however, the rotation of superfluid droplets remains limited. When a superfluid droplet spins, it carries angular momentum in two ways: quantized vortex lines inside of it and surface traveling deformation. In order to investigate these two mechanisms we use a magneto-optical cryostat with a 14.75 T superconducting magnet. To properly test the superfluid helium the cryostat utilizes magnetic levitation through superconducting solenoid. This method allows us to analyze the relationship between morphology and angular momentum. This experiment is set up to levitate superfluid droplets and rotate them in an electric field, then we can investigate how morphology of a rotating classical drop is different from a superfluid droplet due to the two previously mentioned mechanisms. This approach will provide a deeper understanding of how a rotating superfluid droplet behaves and help clarify several questions in quantum turbulence research.

Motivation

- Unlike classical fluids, superfluid helium-4 (He II) carries angular momentum through quantized vortices and surface deformation modes, but how this partitioning affects droplet morphology and stability remains an open question.
- Previous studies lacked control over angular momentum injection, providing only static views of He II droplets [2]. This research overcomes these limitations by enabling real-time visualization of vortex dynamics in a wall-free environment, addressing key questions in vortex nucleation, reconnection, and quantum turbulence decay.
- Its findings will advance quantum fluid dynamics and have broader implications in fluid mechanics, astrophysics, and superconductivity.

Methods

1. Produce superfluid He droplet
2. Levitating the superfluid droplet by using superconducting magnet *(Fig. 2)*
3. Injecting angular momentum to levitated droplet *(Fig. 3)*
4. Visualization of rotating droplet
5. Measuring and Analyzing Droplet Behavior (Track droplet deformation and stability under varying angular momentum conditions.)

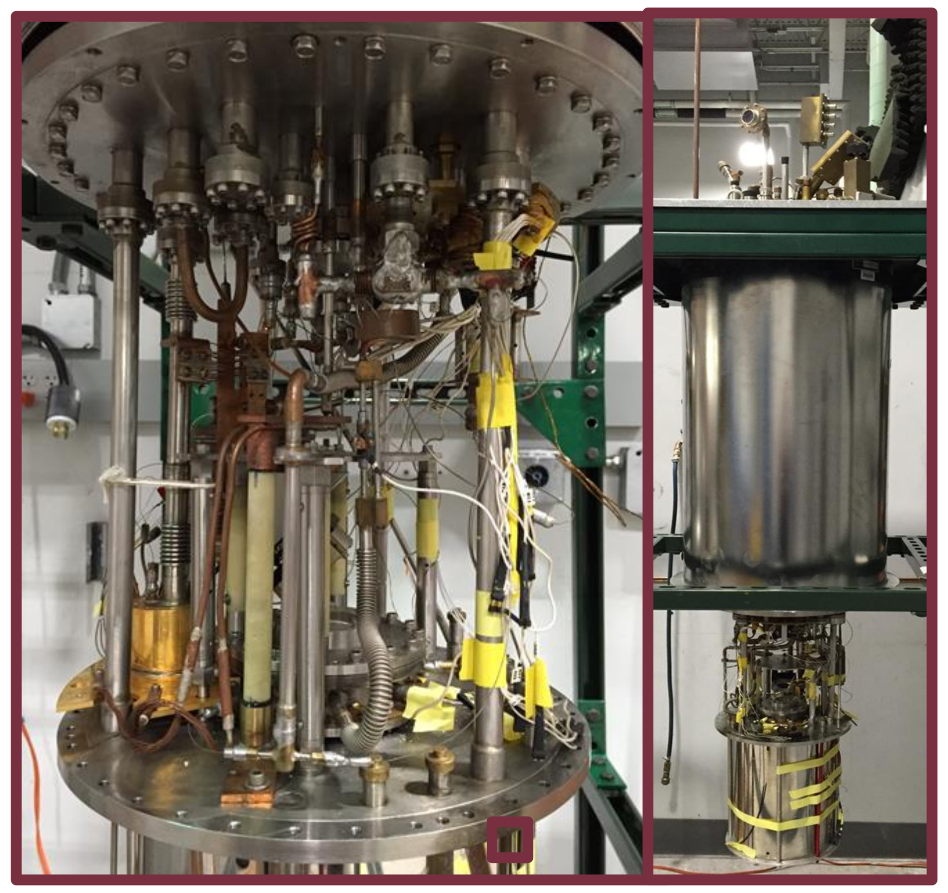

Figure 1. Levitation cryostat

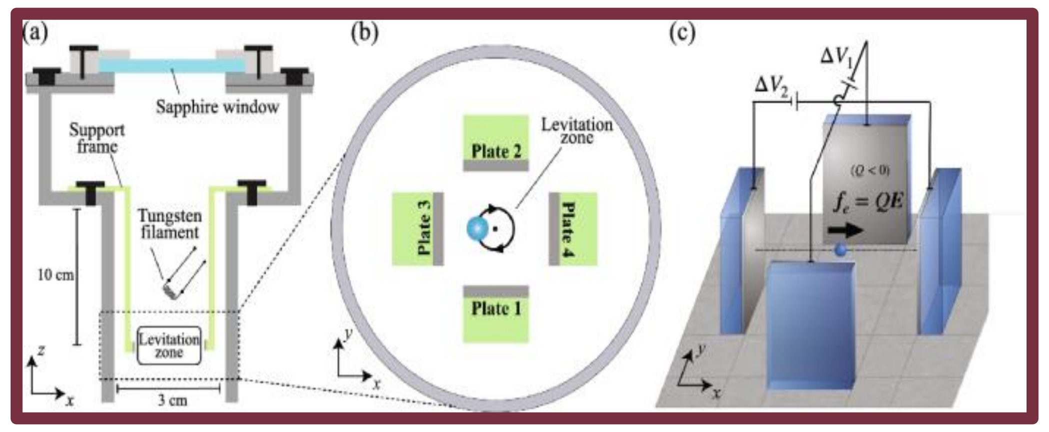

Figure 3. Simplified schematic of the levitation cell [3].

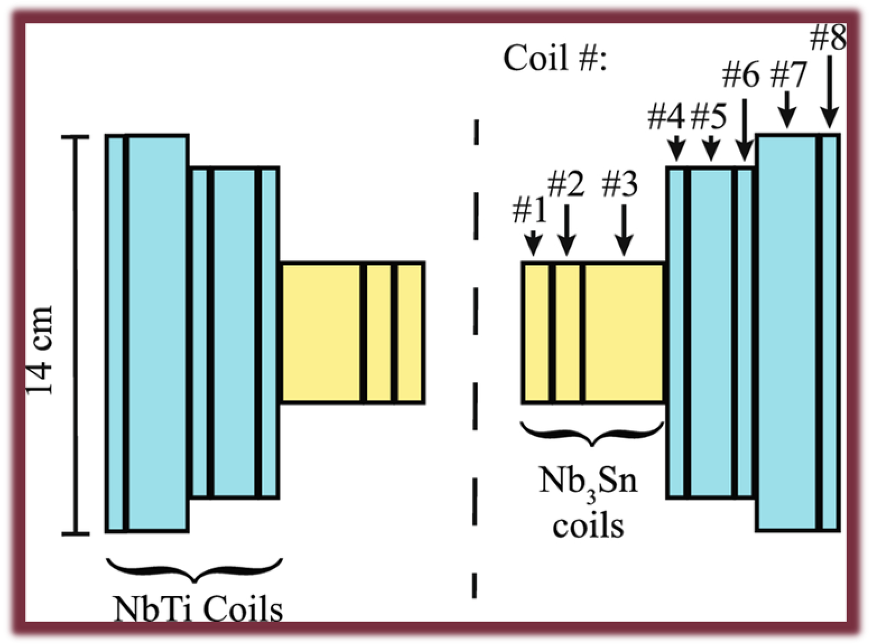

Figure 4. Schematic showing the cross-sectional view of the magnet, consisting of eight concentric super- conducting coils [3].

Liquid Helium Bath: Supplies Liquid helium continuously to **1K Pot** and **Magnet**.

1K Pot: Continuously filled with LHe by the helium bath and can be cooled down evaporatively. It is used to cool down GHe to condense before sending to **Cell**.

Cell: Inside which He II droplet levitation takes place. LHe is transferred to it through the capillary.

Magnet: Consists of superconducting coils. LHe sent from **Bath** is used to maintain the coil temperature below a threshold. More detail presented in the following section.

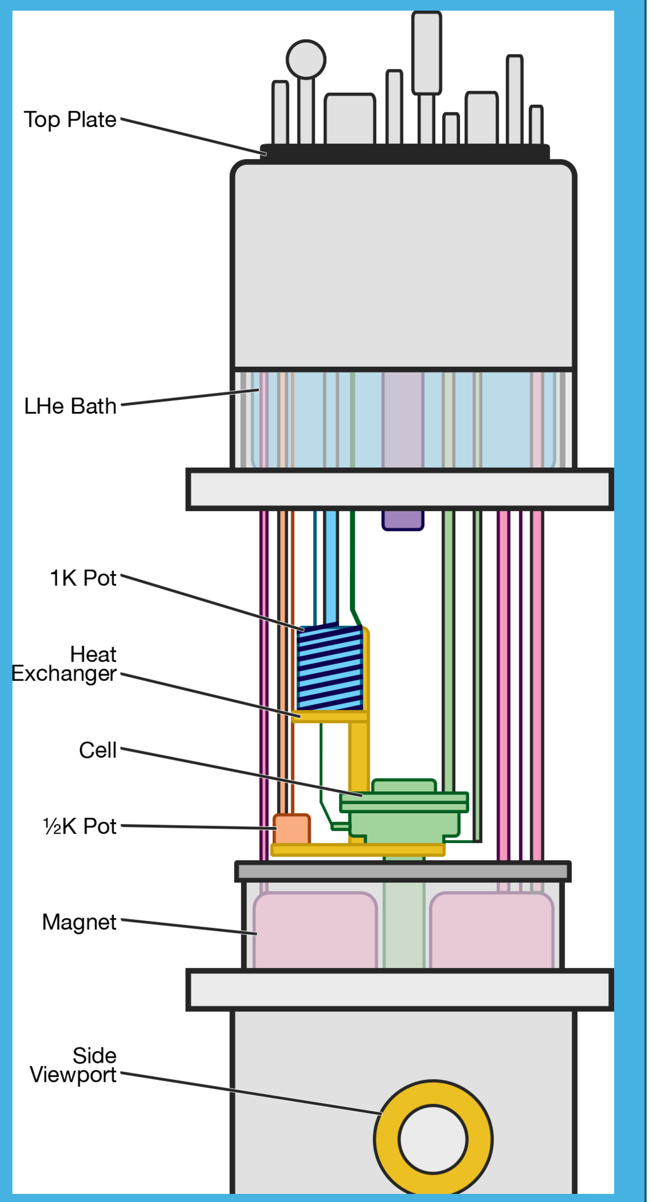

Figure 2. simplified schematics of the cryostat.

Results

•However, we found that our cryostat has the ability to levitate a large Helium droplet for an extended time using a 16.3 magnet

•We also found a new scheme for stabilizing the droplet motion and injecting the angular momentum with a magnetic field

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Resources

[1] R.J.A. Hill, L. Eaves, Nonaxisymmetric shapes of a magnetically levitated and spinning water droplet.
[2] S.M.O. O'Connell, R.M.P. Tanyag, D. Verma, C. Bernando, W. Pang, C. Bacellar, C.A. Saladrigas, J. Mahl, B.W. Toulson, Y. Kumagai, P. Walter, F. Ancilotto, M. Barranco, M. Pi, C. Bostedt, O. Gessner, A.F. Vilesov, Angular momentum in rotating superfluid droplets. Phys. Rev. Lett. 124, 215301 (2020).
[3] Inui, Sosuke, Faezeh Ahangar, and Wei Guo. "Controlled angular momentum injection in a magnetically levitated He II droplet." Journal of Low Temperature Physics (2025): 1-13.