Precisely Controlled Superconducting Levitating Sphere as a Tool for Studying Superfluid Hydrodynamics

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We present a recent development of magnetically levitated superconducting ball setup and its use for probing hydrodynamic properties of superfluid helium. The setup [1,2], built at Lancaster University, allows to magnetically levitate superconducting objects of various shapes and sizes and enables us to study superfluid flows around mechanical objects fully detached from the walls. In this topology, specific scenarios of remnant vorticity arrangement in 4He superfluid may be realized and studied. In addition, we can drive both steady and oscillatory motion of the levitating object at tunable frequency and probe the critical velocity development based on the geometry of such superfluid flows [3].

The vital part of the setup lies within the ability to accurately detect the object's position in a high range. For this purpose, we have developed and further optimized sensitive detection system, using inductive coupling, consisting of a single transmission coil and a set of high-quality sensing coils. I will report on recent systematic measurements of superfluid 4He flows describing the transition between laminar and turbulent regimes in various geometries. We have implemented this technique in the dilution refrigerator reaching millikelvin temperatures where pure superfluid hydrodynamics can be studied, e.g. answering questions relevant to remnant vortex dynamics in zero temperature limit [4] or a hydrodynamic lift force in a pure superfluid [5].

Finally, the measured ultra-low dissipation rates of this probe in vacuum combined with exceptional vibration isolation and ultracold environment open pathways to probing the classical-quantum interface, e.g. [6].

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