Superfluid Flow and Critical Velocity of Liquid Helium in a Single Nanohole

M. Savard, G. Dauphinais, and G. Gervais

Department of Physics, McGill University, Montreal, Canada, H3A 2T8

We present the first measurements of the normal and superfluid flow of liquid helium through a single nanohole of radius R<25 nm. Our experimental scheme [1] has the sensitivity required for direct measurement of mass flow through a single nanohole. In liquid helium I, it is shown experimentally that there is a classical mass flow that is not clamped in our nanohole of aspect ratio $L/D \simeq 1$. The helium mass flow above T_λ is successfully described/quantified using a viscous flow model in a cylindrical short-pipe. In the helium II region, the normal contribution to the flow can be subtracted from the total mass flow in order to extract the superfluid contribution. From this superflow, superfluid velocities through the single nanohole are obtained for various densities above saturated vapor pressure and for temperatures down to 1.5 K. These velocities compare well with the intrinsic critical velocities previously observed in larger micro-apertures, and from the vortex half-ring nucleation theory. Finally, we discuss our plan to use helium flow in a $\sim$ 1 nm diameter nanohole to study one-dimensional behavior in helium where a Luttinger liquid is predicted to occur [2].

(1) M. Savard, C. Tremblay-Darveau, and G. Gervais, Phys. Rev. Lett. **103**, 104502 (2009); *ibid* to be published.
(2) A. Del Maestro, M. Boninsegni, and I. Affleck, Phys. Rev. Lett. **106**, 105303 (2011).