Colloquium
Physics Department
Temple University

X-ray Coherent Diffraction Imaging of Superfluid Helium Nanodroplets

Prof. Andrey Vilesov

University of Southern California, LA

Abstract

Helium nanodroplets have long been considered ideal model systems to explore quantum hydrodynamics in self-contained, isolated superfluids. However, the dynamic properties of individual droplets, such as vorticity, remained beyond the reach of experimentalists. Here, we investigate the rotation of single, superfluid ^{4}He droplets (D=200-2000 nm) via single-shot femtosecond X-ray coherent diffractive imaging. The angular velocities, ω, of the droplets span a range from vanishing to those close to the disintegration limit. The droplets exhibit large centrifugal deformations but retain axially symmetric shapes at ω well beyond the stability range of viscous classical droplets. The formation of quantum vortex lattices inside the droplets is confirmed by observing characteristic Bragg patterns from Xe clusters trapped in the vortex cores. The vortex densities are up to five orders of magnitude larger than observed in bulk liquid He, accessing a previously unattainable regime of quantum rotation. The images of the vortex filaments in the droplets with small vorticity were obtained from the diffraction images via phase retrieval techniques. This collaborative work was performed at Linac Coherent Light Source, the free electron laser within SLAC National Accelerator Laboratory.

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