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Imaging of quantum vortices in superfluid helium droplets

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Helium nanodroplets are especially promising for exploring quantum hydrodynamics in self-contained, isolated superfluids. However, until very recently, the dynamic properties of individual droplets, such as vorticity, could not be assessed experimentally. Here we investigate the rotation of single superfluid 4-He droplets ranging from 200 to 2000 nm in diameter at T = 0.4 K via single-shot femtosecond X-ray coherent diffractive imaging. The droplets were produced by free jet expansion of liquid helium into vacuum. The angular velocities of the droplets were estimated from the centrifugal distortion and span a range from vanishing to those close to the disintegration limit. For visualization of vortices, Xe atoms were added to the droplets where they gather in cores forming nm-thin filaments. A newly developed phase retrieval technique enables the reconstruction of the instantaneous positions and shapes of the vortices from the diffraction images with about 20 nm resolution. The vorticity attainable in the nano-droplets was found to be about six orders of magnitude larger than achieved in previous experiments in the bulk. Stationary configurations of vortices are represented by triangular lattice in large (2 μm) droplets and symmetric arrangements of few vortices in smaller (200 nm) droplets. Evidence for non-stationary vortex dynamics comes from observation of asymmetric formations of vortices in some droplets. This collaborative work was performed at Linac Coherent Light Source, the free electron laser within SLAC National Accelerator Laboratory. The experiments and the full list of collaborators are reported in: L. F. Gomez et. al. Science, 345 (2014) 906.