Vortices in Helium Droplets

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Synopsis Shapes of superfluid ^{4}He nano-droplets and imbedded quantum vortices studied by x-ray coherent diffractive imaging

Micrometer sized free helium jets and nano-droplets offer a unique platform for extending studies of superfluid hydrodynamics and turbulence to meso- and nano-scales. This talk will start with a review of the corresponding experimental techniques [1] and estimates of the attainable vorticity. Single droplets of 200 to 2000 nm in diameter resulting from the jet breakup in vacuum are visualized with diffraction of femtosecond x-ray pulses from a free electron laser.[2] The formation of strongly deformed droplets is evidenced by large anisotropies and intensity anomalies (streaks) in the diffraction images, as exemplified in Fig. 1. The analysis of the images shows that, in addition to previously described axially symmetric oblate shapes,[2] some droplets exhibit prolate shapes as shown in Fig. 1.[3] The angular velocities of the droplets were estimated from the centrifugal distortion and span a range of 10^5 - 10^7 rad/s.

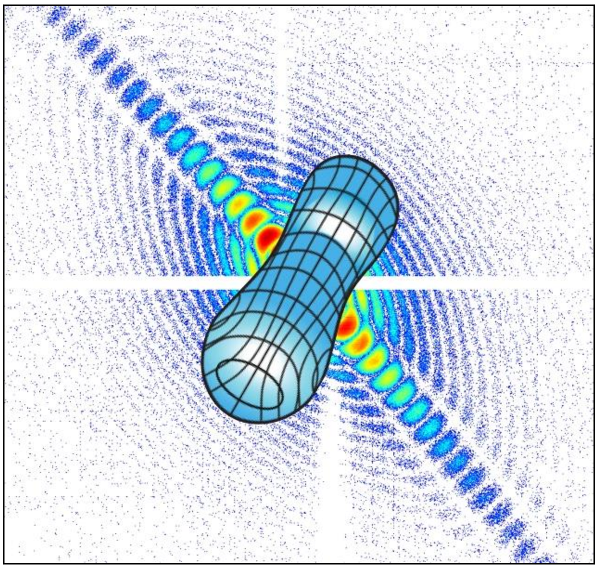

Figure 1. Diffraction from a prolate helium droplet. [3]

For visualization of vortices, Xe atoms were added to the droplets, where they gather in cores forming nanometer-thin filaments.[2,4,5] A newly developed phase retrieval technique enables the reconstruction of the instantaneous positions and shapes of the vortices with about 20 nm resolution as depicted in Fig. 2.[4]

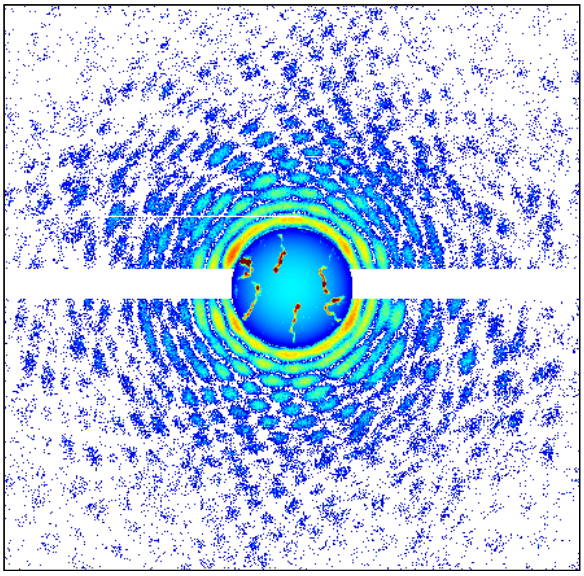

Figure 2. 600 nm diameter superfluid He droplet (blue) with six vortex filaments (red) obtained from the x-ray diffraction pattern shown in the background [4].

Stationary configurations of vortices are represented by triangular lattice in large (~2 μm) droplets and symmetric arrangements of few vortices in smaller (~500 nm) droplets as in Fig. 2. [2,4,5] 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 Refs. [2-5].

References

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