Imaging Superfluid Helium Droplets and Jets

Sean M. O. O'Connell[1], Rico Mayro P. Tanyag, Andrey F. Vilesov[2]

*Department of Chemistry, University of Southern California, Los Angeles, United States, 90089

Synopsis Helium jets and their resulting droplets were imaged by pulsed laser light. Both dark- and light-field approaches were used. Single droplets with diameters on the order of 500-8000 μm were resolved. Some different shapes of droplets can be seen.

Recent x-ray scattering experiments [1] revealed the instantaneous positions and shapes of quantum vortices in freely rotating droplets produced upon the breakup of free helium jets in vacuum. While the exact origins of vorticity remain to be understood, it is conceivable that vortices are generated during the turbulent free-jet expansion of pressurized liquid helium through a 5 μm diameter nozzle.

Here, we report an extension of our imaging experiments to optical microscopy of the jet close to the nozzle. Single helium droplets have previously been imaged in Ref. [2]. Although, optical microscopy cannot resolve quantum vortices in a droplet, the sizes and shapes of the droplets with diameters ranging from 500 nm to 8 μm and aspect ratios close to 2 are observed.

We also present different regimes of the jet breakup at varying nozzle temperatures and stagnation pressures of helium. These experiments will contribute to a better understanding of the formation mechanism and rotation of helium droplets, as well as the origins of their shape oscillations and quantum vortices.

Herein, several images are shown that exemplify those that will be presented. Figure 1 shows helium droplets illuminated by pulsed laser light against a black background. While the droplets, shown in green, are resolved, there are significant diffraction patterns that limit the effectiveness of this technique.

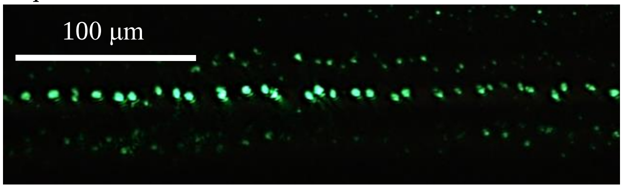

Figure 1. Droplets with diameters of 500-2000 nm are illuminated by a 7 ns pulse of 532 nm coherent light. The temperature of the nozzle was 3.5 K and the backing pressure of the helium line was 20 atm. The image was taken at 13X Zoom.

[1]E-mail: smoconne@usc.edu

[2]E-mail: vilesov@usc.edu

The diffraction patterns can be eliminated by using incoherent light. Figure 2 shows an image of helium droplets using a light-field method of photography. Helium droplets are imaged as bright blue spots ringed by a shadow.

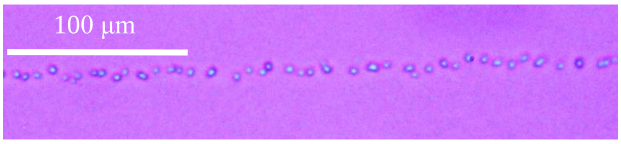

Figure 2. Helium droplets with diameters from 500 nm-2000 nm are irradiated with ~440 nm incoherent light. The temperature of the nozzle was 3.5 K and the backing pressure was 20 atm. The image was taken ~2 mm downstream from the nozzle at 13X zoom.

Images of a helium jet exiting the nozzle were taken using the light-field approach. The nozzle temperatures range from 3.5 to 5 K, and the backing pressure of the helium line ranges from 5 atm to 60 atm. Figure 3 shows the helium jet leaving the nozzle and forming droplets.

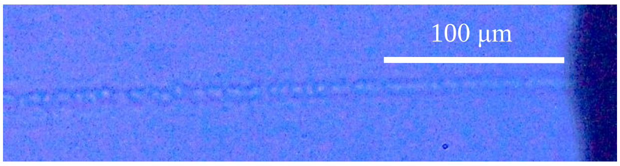

Figure 3. A helium jet exits a nozzle, shown as the dark object on the right. The temperature of the nozzle was 3.5 K and the backing pressure of the helium line was 20 atm. The image was taken at 13X Zoom.

Note that the jet appears to break into droplets ~100 μm (~500 ns) after exiting the nozzle, which is much shorter than the distance estimated by Rayleigh breakup. This, and other unique findings will be discussed.

References

[1] L.F. Gomez *et al.* 2014 *Science* **345** 6199
[2] M. Kühnel *et al.* 2009 *Nucl. Instrum. Meth. A* **602** 311