

IRTG-Seminar

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“The Study of Nanoscale Superfluidity with Molecular Superrotors”

An optical centrifuge is used to control the rotation and alignment of molecules embedded in Helium nanodroplets.¹ By combining two circularly polarized chirped laser pulses, a rotating field is created that can spin anisotropically polarizable molecules to extreme rotational frequencies on the order of 10 THz. At this state, the rotational energy is comparable to the bond strength and the molecules are known as superrotors.² The goal of this work is to establish a method of controlling and studying the rotational motion of a superrotor embedded within superfluid helium nanodroplets.

Helium nanodroplets are used to cryogenically isolate an impurity molecule, bringing it to the ground vibrational and low rotational states because of its internal temperature of ~ 0.4 K.³ In bulk helium, the liquid phase transitions to a superfluid regime below 2.17 K, where the properties of the system are governed by complex many-body dynamics. Superfluidity can break down at high velocities due to thermodynamic excitations that form, known as Landau’s critical velocity, and leads to the disappearance of frictionless motion of macroscopic objects in the bulk medium. Free rotation of embedded molecules in helium nanodroplets has been observed at low rotational frequencies, indicating superfluid dynamics at the nanoscale. However, a decrease in the rotational constant of some molecules has also been observed, suggesting a local non-superfluid layer.⁴

Rotational velocities of the molecule will be scanned near Landau’s critical velocity using the centrifuge to study the analogue of this break down in a quantum system. These studies will be analyzed using velocity map imaging (VMI) to resolve the angular distribution from the molecular rotation of doped droplets. The optical centrifuge and its ability to sample higher rotationally excited states offers the ability to further explore the complexities of nanoscale superfluidity.

1. J. Karczarek, et. al., “Optical Centrifuge for Molecules.” *Physical Review Letters*, 82(17) 3420-3423 (1999)
2. J. Li, et. al., “Scheme for state-selective formation of highly rotationally excited diatomic molecules.” *The Journal of Chemical Physics* 122, 6255 (2000)
3. J. Toennies & A. Vilesov, “Superfluid Helium Droplets: A Uniquely Cold Nanomatrix for Molecules and Molecular Complexes.” *Angewandte Chemie Int. Ed.* 43(20) 1521-3773 (2014)
4. Y. Kwon, et. al., “Quantum solvation and molecular rotations in superfluid helium clusters.” *The Journal of Chemical Physics* 113, 6469 (2000)

**Tuesday, November 14, 2017, 6:00 p.m., HS II,
Physics high rise, Hermann-Herder-Str. 3**

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