SYQR 1: Quantum Optics and Quantum Information with Rigid Rotors 1

Time: Friday 11:00–13:00 Location: E415

Invited Talk SYQR 1.1 Fri 11:00 E415

Femtosecond timed imaging of rotation and vibration of alkali dimers on the surface of helium nanodroplets — •Henrik Stapelfeldt — Aarhus University, Aarhus, Denmark

Dimers of sodium or potassium, residing on the surface of helium nanodroplets, are set into rotation and vibration, through the dynamic Stark effect, by a moderately intense femtosecond pump pulse. Coulomb explosion of the dimers, induced by an intense, delayed femtosecond probe pulse, is used to record the time-dependent nuclear motion.

Concerning rotation, the measured alignment traces show a distinct, periodic structure that differs qualitatively from the well-known alignment dynamics of linear molecules in either the gas phase or dissolved in liquid helium. Instead, the observed alignment dynamics of Na2 and of K2 agree with that obtained from a 2D rigid rotor model, strongly indicating that the rotation of each dimer occurs in a plane, defined by the He droplet surface.

Concerning vibration, the Coulomb explosion probe method enables us to measure the distribution of internuclear distances as a function of time. For K2, we observe a distinct oscillatory pattern caused by a two-state vibrational wave packet in the initial electronic state of the dimer. The wave packet is imaged for more than 250 vibrational periods with a precision better than 0.1 Å on its central position and a resolution < 1 Å of its shape. Unlike the rotational motion, the vibration of the dimer is essentially unaffected by the presence of the He droplet.

Invited Talk SYQR 1.2 Fri 11:30 E415

Quantum toolbox for molecular state spaces — Eric Kubischta[1], Shubham Jain[1], Ian Teixeira[1], Eric R. Hudson[2], Wesley C. Campbell[2], Mikhail Lemeshko[3], and •Victor V. Albert[1] — [1]Joint Center for Quantum Information and Computer Science, NIST and University of Maryland, College Park, MD, USA — [2]UCLA Center for Quantum Science and Engineering & Department of Physics and Astronomy, Los Angeles, California, USA — [3]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria

Rotational states of symmetric- and asymmetric-top trapped molecules, modeled by infinite-dimensional Hilbert spaces of various quantized rigid bodies, present new opportunities for both the development of basic science and for the storage and processing of quantum information.

This work adapts basic quantum tools from established discrete- and continuous-variable systems to symmetric rigid bodies, developing a set of "position-state" labels for molecular orientations and a Pauli-type group of unitary operations. Our approach builds on the conjugate relationship between states of fixed angular momentum and fixed orientation and can be extended to incorporate nuclear spin.

We also study different types of noise present in molecular systems. We show that some noise can be highly non-local in the molecule's orientation-momentum "phase" space, characterizing instances where conventional (i.e., exact) error-correction can fail. We comment on the different strategies that can circumvent this no-go result.

Invited Talk SYQR 1.3 Fri 12:00 E415

Coherent rotational state control of chiral molecules — •Sandra Eibenberger-Arias — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany

Chiral molecules are ubiquitous in nature and they are of great importance in many biological and chemical processes. They are also at the center of some interesting fundamental physics questions, for example whether there is parity violation in chiral molecules, which has been long predicted but never experimentally observed.

I will present important recent experimental developments targeted at the understanding and the control of cold, chiral molecules in the gas phase. I will discuss enantiomer-specific state transfer (ESST) [1], an all-coherent method to populate a chosen rotational state preferentially with one enantiomer, providing a way of quantum-controlled chiral separation. In recent experiments [2,3], we realize increased control of chiral molecules. We employ a quantitative comparison between experiment and theory for the transfer efficiency of ESST. Straightforward extensions to our scheme will allow to create a molecular beam with an enantiomer-pure rotational level, holding great prospects for future spectroscopic and scattering studies.

[1] S. Eibenberger, J. Doyle, D. Patterson, Phys. Rev. Lett. 118, 123002 (2017) [2] A. O. Hernandez-Castillo, J. Bischoff, J. H. Lee, J. Langenhan, M. Karra, G. Meijer, and S. Eibenberger-Arias, Phys. Chem. Chem. Phys. 23, 7048-7056 (2021) [3] J. H. Lee, J. Bischoff, A. O. Hernandez-Castillo, B. Sartakov, G. Meijer, and S. Eibenberger-Arias, Phys. Rev. Lett. 128, 173001 (2022)

Invited Talk SYQR 1.4 Fri 12:30 E415

Optically levitated rotors: potential control and optimal measurement — •Martin Frimmer — Photonics Laboratory, ETH Zürich, Switzerland

Optically levitated nanoparticles have attracted significant attention recently and especially their rotational degrees of freedom offer exciting opportunities for sensing and quantum physics. The quantum control recently achieved for the center-of-mass motion of a levitated scatterer is to be extended to the orientational degrees of freedom of anisotropic scatterers. In this talk, we address the problem of optimally detecting the librational degrees of freedom of an anisotropic dielectric scatterer. Furthermore, we discuss a method to tune the conservative potential governing the librational degrees of freedom in an optical focus while keeping the center-of-mass motion trapped.