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CUI THE HAMBURG CENTRE FOR ULTRAFAST IMAGING

NEWSLETTER

CUI – Graduate School

No.12, August 2016

Main topics

Editorial

When looking for the research highlight material for this newsletter, we realised the impressive abundance of high-quality results attained by our graduate school members. Thereof we decided this time to give space essentially to the scientific results of our graduates only.
We hope this reflects your interests and we wish you a pleasant reading and a nice summer time.

Antonio Negretti and Peter Schmelcher

Research highlights

A: Superfluids have the surprising property that obstacles can move freely in them without experiencing friction. In contrast, when pulling a stick through water, one clearly feels a resistance.
Superfluids can be created by laser cooling atoms to a millionth of a degree above absolute zero: They then represent an ideal testing ground to investigate superfluid behaviour. For example, the Landau criterion states that the frictionless nature of the superfluid flow around the obstacle breaks down above a certain critical velocity. In the group of Henning Moritz at the Institute for Laser Physics, the superfluid behaviour of a Bose-Einstein condensate (BEC) of ^{6}Li molecules was probed by stirring it with a laser beam. A schematic diagram of the experiment, where a circularly moving, red-detuned laser beam stirs the condensate, is depicted in Fig. 1a. When the laser beam moves slower (faster) than certain velocity, (no) heating of the cloud was observed, allowing to measure the critical velocity.
The work was performed in close CUI collaboration with the theorists Vijay Singh and Ludwig Mathey. It provides a quantitative understanding of the superfluid response of a BEC. Using both analytical and simulation methods, they determined the critical velocity of the BEC, and compared it with the measured critical velocity. The comparison provides a systematic insight into the experiment: for a red-detuned laser superfluidity decays due to the creation of phonons (Fig. 1b), whereas for a blue-detuned laser it decays via vortex-antivortex pairs (Fig. 1c).
The work has been published in the Physical Review A **93**, 023634 (2016).

B: The CUI PhD student Sabrina Zinn and colleagues in the research group of Melanie Schnell have investigated the intermolecular interaction between small sugar molecules. Sugars are important building blocks in nature and interact with each other in a highly selective way, which is also known as molecular recognition. These molecular recognition processes are guided by interplay between different inter- and intra-molecular forces.
To understand these processes on a molecular level, the researchers studied the aggregation of glycolaldehyde, which is the smallest sugar existing. Interestingly, it is also the

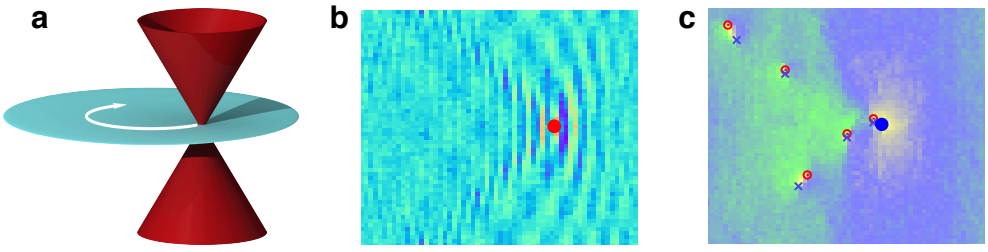

Fig. 1: a Schematic representation of the stirring experiment, where a circularly moving, red-detuned laser (small red beam) stirs the condensate (circular disk). **b** A linearly moving, red-detuned laser (red dot) causes dissipation due to the creation of phonons (density waves). **c** Dissipation also occurs via vortex-antivortex (circled-dot and cross) for a blue-detuned laser (blue dot).

Personalia

Dr. Sabrina Zinn is the second PhD student of CUI that has obtained on May 27, 2016, the doctoral degree in Chemistry with a thesis examining the conformational flexibility and complex formation of biologically relevant molecules by means of high-resolution broadband rotational spectroscopy.

Sabrina Zinn

Prof. R. J. Dwayne Miller (Max Plank Institute for the Structure and Dynamics of Matter) and CUI spokesperson has become a Fellow of the Royal Society of Chemistry for his significant contributions to the chemical sciences, particularly for his studies on femtosecond electron diffraction. Additionally, the Royal Society of Chemistry awarded him the Centenary Prize 2016 for his outstanding scientific achievements in Chemistry, but also for his exceptional communication skills, and invited him to give lectures in the United Kingdom.

R. J. Dwayne Miller

We congratulate both to their achievements and recognitions!

first and so far only sugar detected in the interstellar space and an important player in the discussion on the origin of life in space.
From a high-resolution rotationally resolved spectrum recorded with a broadband microwave spectrometer, the precise structure of molecules and molecular complexes can be determined. In the case of glycolaldehyde, two stable dimer structures were identified in the gas-phase spectrum, revealing two different binding motifs (see also Fig. 2). The precise experimentally determined structures allow to characterize the dominant interaction mechanism between the sugar molecules. It will now be interesting to see how these findings can be extended to larger sugar molecules. This work has been published in Angewandte Chemie International Edition **55**, 5975 (2016).

C: The diffusion through nanoscale membranes is important for catalytic processes, biomineralization and medical applications of polymer encapsulated nanomaterials. However, its direct observation is challenging, because it requires the accurate determination of the concentration of the analyte (i.e., a chemical constituent of the process) in confined space.
Dr. Jan-Philip Merkl, CUI postdoc of Holger Lange's group, developed a fluorescence quenching based assay to investigate Cu(II) diffusion through polymer membranes that surround fluorescent nanoparticles (e.g., quantum dots in quantum rods in Fig. 3). Such a method also allows the identification of ensemble inhomogeneities, which are essential for the basic understanding of encapsulated nanomaterials. Future investigations will focus on new methods for cross-linking of the polymer moieties and the reduction of the overall hybrid material size, while keeping the outstanding shielding capacity. Further information can be found in Nanoscale **8**, 7402 (2016).

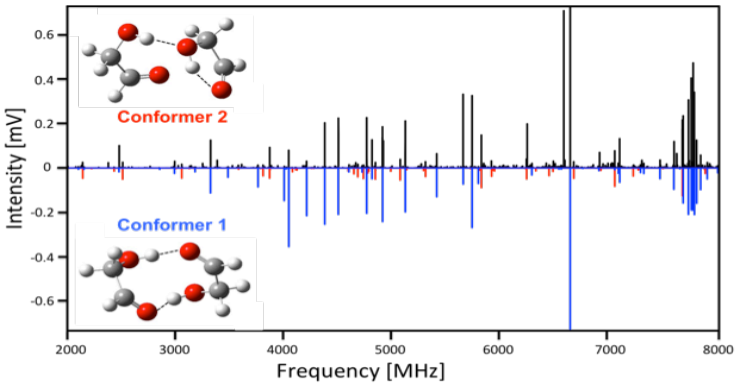

Fig.2: Broadband rotational spectrum of the glycolaldehyde dimer, exhibiting two conformers. The upper trace shows the experimental data. The lower trace shows the simulated spectrum based on fits employing an asymmetric rotor Hamiltonian for the two most stable conformers.

Mildred Dresselhaus Guest Professors 2016

We warmly welcome Prof. Cristiane Morais Smith (University of Utrecht) and Dr. Friederike Ernst (Stanford University) as CUI guest professors.
We wish them a very productive and successful research work during their stays at CUI.

Important dates in 2016-17

We draw your attention to the following CUI events: October 5-7 CUI Annual Meeting in the Hotel Hohe Wacht in Hohwacht; November 3-6 German Women in Physics Conference, November 10 CUI International Symposium in conjunction with the Hamburg Prize for Theoretical Physics, and November 17 Science on Tap (Wissen vom Fass). Finally, the next graduate days of CUI will take place during March 13-16, 2017.

You are welcome to: ... send us suggestions of topics, which you would like to be mentioned in the next newsletter (anegrett@physnet.uni-hamburg.de).

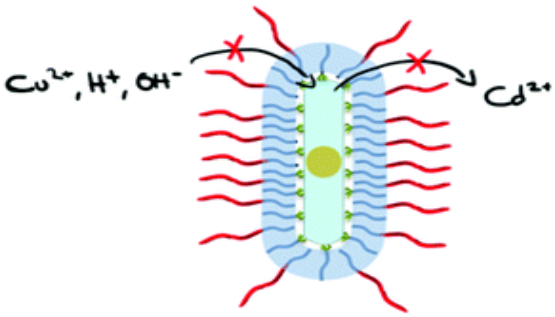

Fig.3: Schematic representation of encapsulated quantum dots in quantum rods using amphiphilic polymers. The hydrophobic region, essential for diffusion through this membrane, is shown in blue, while thy hydrophilic part is shown in red. The polymer shell can be adjusted, so that diffusion processes towards the particle can be fully suppressed.