NEWSLETTER

CUI – Graduate School

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Editorial

In about one month the final outcome of the evaluation of the excellent cluster proposals of the third excellence initiative of the federal government will be announced. While looking forward to this event at September 27, 2018, we present you this summer a selection of high-quality research results by our CUI members. As usual, given the abundance, it was a very tough choice.

Antonio Negretti and Peter Schmelcher

Research highlights

Heterogeneous order in self-assembled nanostructures: In a CUI collaboration between the CUI scientists Dr. Felix Lehmkühler and Lara Frenzel from the group led by Prof. Gerhard Grübel at DESY with Dr. Florian Schulz from the group of Prof. Holger Lange at UHH and the former CUI scientist Dr. Martin Schroer, the local orientational order in thin films formed by gold nanoparticles was studied. For this purpose, the scientists performed coherent X-ray scattering experiments at the beamline P10 of DESY's synchrotron radiation source PETRA III. The particles were coated by a soft shell of poly(ethylene glycol) that dominates the interaction between the particles and in this way the formation of thin films by drop-casting.

Self-assembled nanoparticle superstructures are promising for many applications in research and technology. While self-assembly is the most common route of preparing nanoparticle assemblies, knowledge on structure formation on the nanoscale is scarce and thus represents a hot topic in current nanoscience. The samples were scanned in two dimensions using an X-ray beam of 400 nm x 400 nm size (see Fig 1 a). Using novel X-ray cross-correlation analysis approaches, the scientists found that structurally heterogeneous films are formed with dominating six- and four-fold local order in domains of few micrometers in size (see Fig 1 b). Depending on the initial particle concentrations, the films showed different degrees of structural heterogeneity.

Unlike conventionally used microscopy methods, where typically the structure of a two-dimensional film is accessed, the X-ray methods provide true 3D information of the films, as demonstrated in this study by the CUI scientists.

The work has been published in the International Union of Crystallography Journal **5**, 354 (2018).

Inducing chirality through rotations: Chiral molecules are ubiquitous throughout nature and exist in two structural forms known as enantiomers, which are the mirror image of each other and thus non-superimposable by translation and rotation. Less well known is that achiral molecules can be made chiral through extreme rotational excitation. Now, utilizing techniques from strong-field laser physics, the CUI postdoc Dr. Alec Owens with the Theory Team leader Dr. Andrey Yachmenev in the Controlled Molecule Imaging group of Prof.

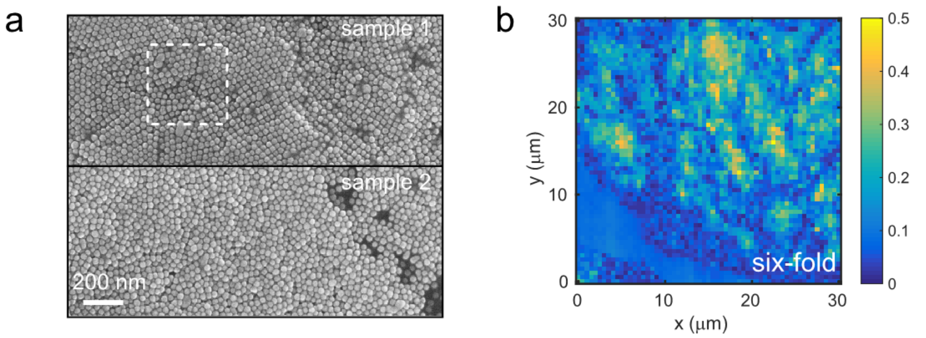

Fig. 1: (a) Transmission electron microscopy images of samples studied. The scale bar corresponds to 200 nm, the dashed square marks the beam dimensions of 400 nm x 400 nm. (b) Spatial map of the degree of local six-fold order of one sample studied.

Personalia

Malik M. Abdullah

Dr. Malik M. Abdullah has obtained the doctoral degree in Physics under the supervision of Prof. Robin Santra and Prof. Beata Ziaja Motyka. He has developed a theoretical method to study ionisation dynamics and the diffraction patterns of irradiated nanocrystals. The method has been used for analysing effective form factors at high intensities and in studies of high energy density plasma formation.

Christof Weitenberg

Dr. Christof Weitenberg has received a starting grant from the European Research Council with the goal of engineering and exploring anyonic quantum gases, which will be pursued with artificial quantum systems made of ultracold atoms. Anyonic particles have been predicted to appear in the fractional quantum Hall effect, but their exotic behaviour under particle exchange has been not clearly observed so far.

We congratulate them for their achievements!

Jochen Küpper have demonstrated a clear strategy for producing such dynamically chiral molecules.
Their approach employs an optical centrifuge, which is a corkscrew shaped laser pulse capable of spinning molecules into highly excited rotational states. Molecules can be made to rotate coherently in either a clockwise or anticlockwise direction, with clockwise rotations defining one rotating enantiomer, and anticlockwise rotations the other. Interestingly, by applying a strong dc electric field during the centrifuge pulse, they have shown that either one of the rotating enantiomers can be exclusively produced depending on the direction of the dc field, i.e. creating a chiral ensemble instead of the racemic mixture generated otherwise (see Fig. 2). This essential step towards characterizing rotationally-induced chirality should pave the way for future research to explore this novel physical effect, e.g., studying the interaction of dynamically chiral gases with other chiral entities such as light or chiral surfaces.
This work is published as a preprint at arXiv:1802.07803 (2018).

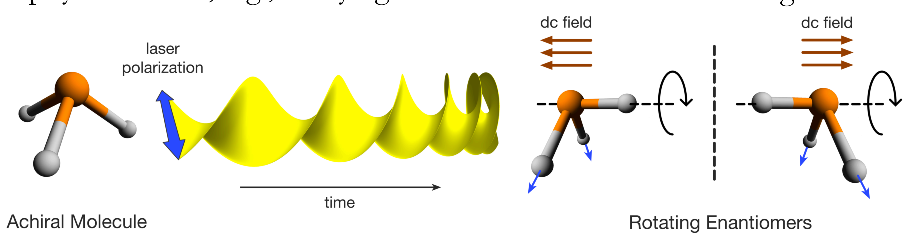

Fig. 2: Rotationally-induced chirality in the phosphine molecule using an optical centrifuge in conjunction with a static electric field. Reversing the direction of the field produces the other rotating enantiomer.

Two-dimensional homogeneous Fermi gases: What novel states of matter emerge when the dimensionality of a strongly interacting quantum system is reduced? Ultracold two-dimensional Fermi gases offer an ideal experimental platform to answer this question as they provide an unprecedented level of control over the preparation and characterization of quantum many-body states. Current experiments, however, were limited to 2D Fermi gases with an inhomogeneous density distribution, which complicated the detection of fundamental non-local quantities like its momentum distribution.
Now, in the group of Prof. Henning Moritz, the CUI PhD student Niclas Luick and colleagues realized the first 2D Fermi gas with a homogeneous density distribution (see Fig. 3). They implemented a setup of optical dipole traps to create a box-like potential with steep walls. In their search for characterizing signatures of many-body phases, they employed a matter wave focusing technique to directly image the momentum distribution of the system. In a first set of measurements, they prepared a non-interacting Fermi gas as a textbook example of statistical physics and directly observed Pauli blocking in the occupation of momentum states.

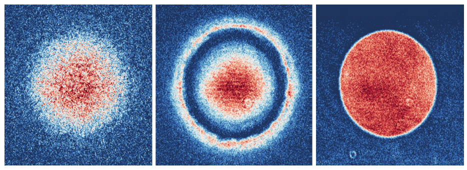

Fig. 3: Absorption images of the atomic density distribution showing the steps in the production of a strongly-interacting homogeneous 2D Fermi gas in a box potential. After evaporation in an elliptic dipole trap (left panel), the outer, high entropy region of the cloud is cut away by a repulsive ring potential (middle panel). After further evaporation, the radial magnetic confinement is ramped down to spill the atoms outside the ring and the atoms are transferred into a single antinode of an optical lattice to obtain the desired homogeneous 2D Fermi gas (right panel).

Building on this achievement, Niclas Luick and his colleagues are now preparing measurements to analyze spin correlations to find signatures of Cooper pairs and explore their stability in the presence of spin imbalance, where exotic types of superfluids are predicted to exist.
This work has been published in Phys. Rev. Lett. **120**, 060402 (2018) as Editors' suggestion.

Important dates

We draw your attention to the following CUI events: October 24-25, Matlab workshop for beginners; November 14-16, CUI Annual Meeting in the Hotel Hohe Wacht in Hohwacht.
Please, mark these important dates in your agenda!

You are welcome to: ... to suggest us topics, which you would like to be mentioned in the next newsletter. Just send an informal e-mail to Dr. Negretti (anegrett@physnet.uni-hamburg.de).