TT 36: Nanotubes, BEC, Cryocoolers: Poster

Time: Wednesday 15:00–18:00 Location: P3

TT 36.1 Wed 15:00 P3

Quantum Dot Spectroscopy in Suspended MoS_2 Nanotubes — •Stefan B. Obloh[1], Robin T. K. Schock[1], Jonathan Neuwald[1], Matthias Kronseder[1], Matjaž Malok[2], Maja Remškar[2], and Andreas K. Hüttel[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Solid State Physics Department, Institute Jožef Stefan,1000 Ljubljana, Slovenia

MoS_2 as a semiconductor has attracted a lot of attention due to its 2D nature, strong spin-orbin coupling, broken inversion symmetry, and spin-split bands. By tuning the carrier density in MoS_2 with ionic liquid gating, intrinsic superconuctivity has been achieved [1]. Recent works were able to demonstrate single level transport in planar [2,3] and nanotube-based [4] devices. A remaining challenge lies in reducing the effects of substrate inhomogenity and surface charges, resulting in disordered quantum dots. To mitigate this, one can suspend the tubes above the substrate or shield them from the amorphous SiO_2. We show quantum dot transport measurements of suspended nanotubes as well as insights into fabrication challenges regarding this approach.

[1] J. T. Ye *et al.*, Science **338**, 1193 (2012).
[2] R. Krishnan *et al.*, Nano Lett. **23**, 6171 (2023).
[3] P.Kumar *et al.*, Nanoscale **15**, 18023 (2023).
[4] R. T. K. Schock *et al.*, Adv. Mat. **35**, 13 (2023).

TT 36.2 Wed 15:00 P3

MoS_2 Nanotubes as 1D Superconductors? — •Konstantin D. Schneider[1], Robin T. K. Schock[1], Stefan Obloh[1], Matthias Kronseder[1], Matjaz Malok[2], Maja Remskar[2], and Andreas K. Hüttel[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Solid State Physics Department, Institute Jožef Stefan, 1000 Ljubljana, Slovenia

Due to its intrinsic two dimensional nature, planar MoS_2 is at the center of manifold research efforts. Previous work has shown that MoS_2 exhibits superconducting properties in single and multi layer flakes when increasing its charge density by heavily doping the MoS_2 surface using a liquid-ion gate [1-3].

Clean and defect-free MoS_2 nanotubes, as grown via chemical transport reaction [4,5], should provide an even better test bed for the interplay of a tubular geometry and Ising superconductivity. In addition, with ionic doping mostly affecting the outermost shell of a multi-wall nanotube, the material system lends itself intrinsically for core-shell semiconductor/superconductor hybrid structures at strong spin-orbin interaction. Here, we present our ongoing work towards this objective [6,7].

[1] T. Ye *et al.*, Science 338, 1193 (2012).
[2] Costanzo *et al.*, Nat. Nano. 11, 339 (2016).
[3] C. Shen *et al.*, Nature 593, 211.
[4] M. Remskar *et al.*, Appl. Phys. Lett. 69, 351 (1996).
[5] M. Remskar *et al.*, Isr. J. Chemistry 62, e202100100 (2022).
[6] T. K. Schock *et al.*, Advanced Materials 35(13) (2023).
[7] Reinhardt *et al.*, pssRRL 13, 1900251 (2019).

TT 36.3 Wed 15:00 P3

Simulations to enhance the conductivity of graphene-based macromaterials — •Florian Fuchs[1,2,3], Fabian Teichert[1,2,3], and Jörg Schuster[1,2,3] — [1]Fraunhofer Institute for Electronic Nanosystems (ENAS), Chemnitz, Germany — [2]Center for Microtechnologies,Chemnitz University of Technology, Chemnitz, Germany — [3]Center for Materials, Architecture and Integration of Nanomembranes (MAIN), TU Chemnitz, Germany

Our aim is to enhance the conductivity of graphene-based macromaterials. These materials consist of many graphene flakes, which are arranged layerwise. A twofold strategy is pursued to improve the material: 1) optimizing the flake properties and the size of the macromaterial, and 2) intercalating molecules in-between the graphene layers.

A network model enables us to estimate the conductivity of the macromaterial for large model systems consisting of thousands of flakes. Particular emphasis will be given in our contribution on the variation of the layer numbers, which is of relevance for printed graphene paths.

To study the impact of intercalants, we perform density functional theory calculations. We concentrate on different fluorides and chlorides, where we vary the cation type and the anion number. The charge carrier density after intercalation is studied and related to more fundamental physical properties such as orbital overlaps and charge transfer.

TT 36.4 Wed 15:00 P3

Quantum Solvation of Flexible Molecules at Low Temperatures from Path Integral Simulations — •Katharina Leitmann[1], Harald Forbert[1,2], and Dominik Marx[1] — [1]Lehrstuhl für Theoretische Chemie, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Center for Solvation Science ZEMOS, Ruhr-Universität Bochum, 44780 Bochum, Germany

Protonated methane (CH_5^+) is a fluxional molecule whose sensitivity to its environment makes it an excellent probe for studying molecular interactions at low temperatures. We investigated CH_5^+ microsolvation in *para*-hydrogen clusters $(pH_2)_n$ subject to bosonic exchange at 1 K using a hybrid simulation approach that combines Path Integral Molecular Dynamics (PIMD) for CH_5^+ and bosonic Path Integral Monte Carlo (PIMC) to establish Bose-Einstein statistics of the $(pH_2)_n$ quantum solvation environment.

Our simulations, based on highly accurate High-dimensional Neural Network Potentials parametrised using coupled cluster theory (CCSD(T)), demonstrate stable solvation of CH_5^+ at least up to $n = 12$ pH_2 molecules, which we found to build the first solvation shell. We revealed, that the structure of CH_5^+ is not significantly perturbed by the solvation with pH_2. But we revealed significant fluctuations in the large amplitude motion of CH_5^+ associated to the phenomenon of partial hydrogen scrambling as a function of cluster size n. Further, we investigated the superfluid properties of pH_2 clusters. Analysing the superfluid fraction and bosonic permutation patterns, indicates the manifestation of superfluidity.

TT 36.5 Wed 15:00 P3

Generating a photonic Bose-Einstein condensate in a waveguide — •Lukas Schamriss[1,2,3], Louis Garbe[1,2,3], and Peter Rabl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

We aim to propose a superconducting device designed to generate a photonic Bose-Einstein condensate (BEC). The core component is a coupler that induces a pure three-wave mixing interaction linking a waveguide which hosts the condensate to a LC-mode for dissipating energy from the waveguide. This interaction induces an incoherent photon-number conserving thermalization process in the waveguide. Generally, this system is a minimal example for generating a thermalization mechanism for microwave photons which is a key ingredient for the preparation of finite-temperature equilibrium states on superconducting hardware for analog quantum simulations.

TT 36.6 Wed 15:00 P3

Loop current states and their stability in small fractal lattices of Bose-Einstein condensates — •Georg Koch and Anna Posazhennikova — Institut für Physik, Universität Greifswald, 17487 Greifswald , Germany

We consider a model of interacting Bose-Einstein condensates on small Sierpinski gaskets. We study eigenstates which are characterised by cyclic supercurrents per each triangular plaquette ("loop" states). For noninteracting systems we find at least three classes of loop eigenmodes: standard; chaotic and periodic. Standard modes are those inherited from the basic three-site ring of condensates with phase differences locked to $2\pi/3$. Standard modes become unstable in the interacting system but only when the interaction exceeds a certain critical value u_c. Chaotic modes are characterised by very different circular currents per plaquette, so that the usual symmetry of loop currents is broken. Circular supercurrents associated with chaotic modes become chaotic for any finite interaction, signalling the loss of coherence between the condensates. Periodic modes are described by alternating populations and two different phase differences. The modes are self-similar and are present in all generations of Sierpinski gasket. When the interaction is included, the circular current of such a mode becomes periodic in time with the amplitude growing linearly with the interaction. Above a critical interaction the amplitude saturates signalling a transition to a macroscopic self-trapping state originally known from a usual Bose Josephson junction. We perform a systematic analysis of this rich physics.

TT 36.7 Wed 15:00 P3

Sub-50 mK Adiabatic Demagnetization Refrigeration with Frustrated Yb-Oxide Magnets in the PPMS — •Anna Klinger, Jorginho Villar Guerrero, Marvin Klinger, Tim Treu, Anton Jesche, and Philipp Gegenwart — Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg

Accessing temperatures in the millikelvin (mK) regime is a prerequisite for quantum-matter research and quantum technologies. Adiabatic demagnetization refrigeration (ADR) is a simple and sustainable alternative to $^3He/^4He$ dilution refrigeration. We have shown recently, that geometrically frustrated Yb-oxides feature important advantages compared to the traditionally utilized hydrated paramagnetic salts for mK-ADR [1,2]. We report the development of Yb-oxide-based customized ADR cooling platforms for the use in the Quantum Design Physical Property Measurement System (PPMS) ®. Temperatures below 50 mK and hold times of several hours are demonstrated. Our ADR insert offers multiple experimental capabilities, including electrical transport, stress/strain and heat capacity measurements.

[1] Y. Tokiwa et al., Commun. Mater. 2 (2021) 42.
[2] T. Treu et al., J. Phys. Condens. Matter 37, 013001 (2025).

TT 36.8 Wed 15:00 P3

Experimental and Numerical Investigations of the Temperature and Mass Flow Behaviour in the Cold Heat Exchanger of a Single Stage GM-type Puls Tube Cooler — •Elias Eisenschmidt[1,3], Jack-Andre Schmidt[2,3], Bernd Schmidt[2,3], Hardy Weisweiler[1,3], and Andre Schirmeisen[2,3] — [1]Technische Hochschule Mittelhessen, Giessen, Germany — [2]Justus-Liebig-University, Giessen, Germany — [3]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany

GM-type PTCs play an important role in cooling sensitive electronics. Especially due to the recent developments in quantum computing, low vibration regenerative cooling is needed more than ever. [1]

The refrigeration power is usually calculated using a sinusoidal approximation of the mass flow, temperature and pressure of the working fluid inside a pulse tube cooler. However, several measurements have been carried out to gain insight into the actual time-dependent gas properties. It has been shown that the temperature and pressure curve differ significantly from a sinusoidal assumption. [2]

The goal of this work is to measure the time dependent mass flow and temperature behaviour of the helium gas in the cold end of the cooler, using a RTD and a CTA probe.

[1] Y. Zhai et al., IEEE Trans. Appl. Supercond. 34, May 2024
[2] P. P. Steijaert, Thermodynamical aspects of pulse-tube refrigerators, Technische Universiteit Eindhoven, 1999

TT 36.9 Wed 15:00 P3

Optimisation of Rotary Valve Size and Timing for High Massflow GM-Type Pulse Tube Cryocoolers — •Xaver Herrmann[1], Jack-André Schmidt[1,2], Bernd Schmidt[1,2], Jens Falter[2], and André Schirmeisen[1,2] — [1]Instiute of Applied Physics, Justus-Liebig University, Giessen, Germany — [2]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany

Closed-cycle cryocoolers have become a reliable and important tool for low temperature scientific research, such as IR astronomy, SNSPDs or surface science[1]. Here we focus on Gifford-McMahon (GM) type pulse tube cryocoolers (PTC), which offer low maintenance and long measurement periods[2]. A crucial component of a GM type PTC is the rotary valve. Losses in the rotary valve are a sizable fraction of overall losses in a GM type PTC [3,4]. This poster will focus on the effects of valve size and timing for a two stage high input power system(11 kW). Both valve size and timing show a strong effect on cooling performance of the first cooling stage. An increase of up to 90

[1] R. Güsten et al., Nature 568 (2019) 357.
[2] R. Radebaugh, J. Phys.: Condens. Matter 21 (2009) 164219.
[3] D. Liu et al., Cryogenics 81 (2017) 100.
[4] L.M. Qiu et al., Cryogenics 42 (2002) 327.