TT 12: New Experimental Techniques

Time: Wednesday 10:00–11:00 Location: H7

TT 12.1 Wed 10:00 H7

Chip-based magnetic levitation of superconducting microparticles for macroscopic quantum experiments — •Marti Gutierrez[1], Achintya Paradkar[1], Gerard Higgins[1,2], and Witlef Wieczorek[1] — [1]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, Kemivagen 9, SE-412 96 Gothenburg, Sweden — [2]Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, Boltzmanngasse 5, Vienna, A-1090, Austria

In this work, we demonstrate chip-based magnetic levitation of superconducting microparticles. Magnetic levitation has been proposed as a platform to decouple the center-of-mass (COM) motion of a levitated mechanical resonators from the environment. As a result, this platform enables the development of novel, ultra-sensitive force and acceleration sensors, as well as performing quantum experiments with macroscopic objects of 10^13 atomic mass units. Our approach is based on an integrated magnetic trap consisting of a two-chip stack with microfabricated niobium superconducting coils. We further fabricate near spherical lead spheres of sub-100um diameter. A pair of integrated coils is used to generate the magnetic trapping field, while additional coils are used for SQUID-based detection and, independently, for feedback-based manipulation of the COM motion of the levitated particle. We show first trapping experiments, where we observe the motion of the levitated particle optically and via SQUID-based read-out. In future experiments, we aim to couple the levitated particle to superconducting circuits, in order to perform quantum control over its COM motion.

TT 12.2 Wed 10:15 H7

Reaching the ultimate energy resolution of a quantum detector — •Bayan Karimi[1], Fredrik Brange[1,2], Danilo Nikolic[3], Joonas T. Peltonen[1], Peter Samuelsson[2], Wolfgang Belzig[3], and Jukka P. Pekola[1] — [1]QuESTech and QTF Centre of Excellence, Department of Applied Physics, Aalto University, Finland — [2]Department of Physics and NanoLund, Lund University, Sweden — [3]QuESTech and Fachbereich Physik, Universität Konstanz, Germany

We demonstrate experimentally detection of equilibrium fluctuations of temperature in a system of about 10^8 electrons exchanging energy with phonon bath at a fixed temperature [1]. In this experiment, we employ a radio-frequency thermometer, connected to a nanocalorimeter, based on a zero-bias anomaly of a tunnel junction between a superconductor and proximitized normal metal [2,3]. It features noninvasive detection and essentially uncompromised sensitivity down to the lowest temperatures of below 20 mK. We show theoretically that this detector is capable of observing single microwave photons in a continuous manner [4,5].

[1] B. Karimi, F. Brange, P. Samuelsson, J. P. Pekola, Nat. Commun. **11**, 367 (2020)
[2] B. Karimi and J. P. Pekola, Phys. Rev. Appl. **10**, 054048 (2018)
[3] B. Karimi, D. Nikolić, T. Tuukkanen, J. T. Peltonen, W. Belzig, J. P. Pekola, Phys. Rev. Applied **13**, 054001 (2020)
[4] B. Karimi and J. P. Pekola, Phys. Rev. Lett. **124**, 170601 (2020)
[5] J. P. Pekola and B. Karimi, arXiv:2010.11122 (2020)

TT 12.3 Wed 10:30 H7

Towards time domain phase diagram of metastable charge-ordered states — •Yaroslav Gerasimenko[1,2], Jan Ravnik[1,3], Jaka Vodeb[1], Michele Diego[1], Yevhenii Vaskivskyi[1], Viktor Kabanov[1], Igor Vaskivskyi[1], Tomaz Mertelj[1], and Dragan Mihailovic[1] — [1]Jozef Stefan Institute, Ljubljana, Slovenia — [2]University of Regensburg, Regensburg, Germany — [3]PSI, Villigen, Switzerland

Metastable self-organized electronic states in quantum materials are emergent states of matter[1] typically formed through phase transitions under non-equilibrium conditions. It is of fundamental importance to understand the process of their formation that can involve multiple mechanisms[1,2] spanning a large range of timescales.

Here we combine multiple techniques to map the evolution of metastable states in 1T-TaS_2, a prototypical charge-ordered quantum material, using the photon density and temperature as control parameters on timescales ranging from 10^{-12} to 10^3 s. The combination of STM and in situ ultrafast excitation allows us to observe explicitly both parametric stability and nanoscale relaxation of the light-induced metastable states on the scale of seconds, while time-resolved optical techniques and electrical measurements allow us to study the ordering and relaxation processes down to a few picoseconds. [3]

[1] Ya. A. Gerasimenko et al., Nat. Mater. 18, 1078-1083 (2019)
[2] Ya. A. Gerasimenko et al., npj Quantum Materials 4, 1-9 (2019)
[3] J. Ravnik et al., Nat. Comm. 12, 2323 (2021)

TT 12.4 Wed 10:45 H7

Advanced technique for probing critical elasticity in strongly coupled electron-phonon systems — •Yassine Agarmani, Jan Zimmermann, Steffi Hartmann, Bernd Wolf, and Michael Lang — Institute of Physics, Goethe University Frankfurt, Germany

The recently proposed phenomena of critical elasticity arises from a non-perturbative coupling between lattice and critical electronic degrees of freedom. As demonstrated for the Mott insulator κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl, tuning to the critical endpoint of the first order Mott transition cause a vanishing elastic modulus and a violation of Hooke's law of elasticity [1, 2]. Similar effects are expected to surround the critical region of the valence transition in $EuPd_2Si_2$. Measurements of relative length changes under control of temperature and pressure have proven a most sensitive tool for investigating this phenomenon of critical elasticity. In order to develope a deeper understanding of critical elasticity, an expansion of the setup used in Ref. [2] has been designed and realized. It consists of two identical capacitive dilatometer systems, the temperature of which can be controlled individually, and which are connected to a He-gas pressure reservoir. We discuss the new possibilities this system offers for performing high-resolution measurements of relative length changes over wide ranges of temperature and pressure.

[1] Zacharias *et al.*, Eur. Phys. J. Spec. Top. 224, 1021-1040 (2015)
[2] Gati *et al.*, Sci. Adv. 2, e1601646 (2016)