TT 29: Nanotubes and Nanoribbons

Time: Tuesday 14:00–16:00 Location: H2

Invited Talk TT 29.1 Tue 14:00 H2

Mesoscopic quantum electrodynamics with carbon nanotubes — •Takis Kontos — CNRS/ENS, Paris, France

Cavity quantum electrodynamics techniques have turned out to be instrumental to probe or manipulate the electronic states of nanoscale circuits. Recently, cavity QED architectures have been extended to quantum dot circuits. These circuits are appealing since other degrees of freedom than the traditional ones (e.g. those of superconducting circuits) can be investigated. I will show how one can use carbon nanotube based quantum dots in that context. In particular, I will focus on how to engineer a coherent spin/photon coupling in a double quantum dot spin-valve and to use this interface to manipulate the electronic spin with cavity photons. Quantum dots also exhibit a wide variety of many body phenomena. The cQED architecture could also be instrumental for understanding them. One of the most paradigmatic phenomenon is the Kondo effect which is at the heart of many electron correlation effects. I will show that a cQED architecture has allowed us to observe the decoupling of spin and charge excitations.

Invited Talk TT 29.2 Tue 14:30 H2

Nanomechanical characterization of the Kondo charge dynamics in a carbon nanotube — Karl J. G. Götz, Daniel R. Schmid, Felix J. Schupp, Peter L. Stiller, Christoph Strunk, and •Andreas K. Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Suspended single wall carbon nanotubes are at cryogenic temperatures both extraordinary nanomechanical systems and prototypical clean and defect-free single electron devices. This allows for many interesting studies. In particular, by measuring the gate voltage dependence of the transversal vibration frequency, the evolution of the charge on a quantum dot embedded in the nanotube can be precisely evaluated.

We apply this technique to the case of strong Kondo correlations between a quantum dot and its contacts. The current through the nanotube displays a clear odd-even pattern, with a zero-bias conductance anomaly at odd electron number. The time-averaged charge on the quantum dot, however, shows no odd-even pattern, and can be well modelled via sequential tunneling only. We conclude that the Kondo current is carried via virtual occupation of the quantum dot alone.

In addition, the simultaneous detection of charge and current signal allows us to compare the gate potentials where on one hand the current is maximal and on the other hand the charge in the quantum dot increases. Here, a distinct relative shift is observed, decreasing logarithmically with temperature. Our observations agree very well with models for Kondo-correlated quantum dots.

[1] K. J. G. Götz *et al.*, PRL **120**, 246802 (2018)

TT 29.3 Tue 15:00 H2

Oscillator induced phase transition in a quantum dot Josephson junction — •Robert Hussein, Daniel Reger, and Wolfgang Belzig — Fachbereich Physik, Universität Konstanz, Germany

We investigate the Josephson transport through a suspended carbon nanotube quantum dot—acting likewise as a mechanical resonator—in the presence of an external magnetic field. At sufficiently low temperatures, the transport properties are characterized by the ground state of the electronic subsystem being either in a singlet, doublet, or current suppressing triplet state. We show that the triplet blockade can be lifted by the coupling to the resonator and study the emergence of a triple point, where all three ground states coexist. Furthermore, we demonstrate that this oscillator induced phase transition also manifests in the critical current.

TT 29.4 Tue 15:15 H2

Quantum transport through carbon nanotube $NbSe_2$ hybrid devices for Majorana Fermion detection — •Christian Bäuml[1], Michaela Eichinger[1], Brecht Simon[1,2], Maria-Teresa Handschuh[1], Lorenz Bauriedl[1], Anh-Tuan Nguyen[1], Nicola Paradiso[1], and Christoph Strunk[1] — [1]University of Regensburg, Regensburg, Germany — [2]Delft University of Technology, Delft, Netherlands

The initial proposals for the realization of Majorana fermions (MFs) were based on one-dimensional semiconductors proximitized by a superconductor (SC) in the presence of spin-orbit interaction and of perpendicular magnetic field. More recently, it was suggested that MFs can also occur in carbon nanotubes (CNTs) in proximity to an ultrathin superconductor in large parallel fields [1,2].

In this work, we demonstrate first building blocks of the device proposed by Marganska et al. As a SC we chose a bilayer $NbSe_2$ crystal, which is so thin that its electron density and chemical potential can be tuned by a gate. Such tunability is crucial to enter the topological phase of the proximitized CNT. We show that the $NbSe_2$-CNT contact transparency can be drastically improved by exfoliating and stamping the flake in N_2 atmosphere. Finally, we present a first proof-of-principle device, whose transport characteristics are measured as a function of temperature and magnetic field.

[1] R. Egger et al. Phys. Rev. B **85**, 235462 (2012)
[2] M. Marganska et al. Phys. Rev. B **97**, 075141 (2018)

TT 29.5 Tue 15:30 H2

Transport properties of MoS_2 and WS_2 nanotubes — •Simon Reinhardt[1], Luka Pirker[2], Christian Bäuml[1], Maja Remškar[2], and Andreas K. Hüttel[1] — [1]Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany — [2]Solid State Physics Department, Institute Jožef Stefan, Ljubljana, Slovenia

While synthesis procedures for nanotubes based on layered materials other than graphene are well-known [1, 2, 3], their transport properties are so far largely unexplored [4]. Here, we introduce transition metal dichalcogenide (TMDC) nanotubes as a new material platform for transport spectroscopy. We present results on optimized nanotube synthesis, first device fabrication, and electrical characterization. MoS_2 and WS_2 nanotubes are synthesized using a chemical transport reaction. Optimized growth parameters lead to thin nanotubes with diameters down to 7nm, lengths up to several millimeters, and an extremely low number of structural defects. Field effect devices based on individual nanotubes are characterized in low temperature transport measurements.

[1] R. Tenne *et al.*, Nature **360**, 444 (1992)
[2] M. Remškar *et al.*, Appl. Phys. Lett. **69**, 351 (1996)
[3] M. Remškar *et al.*, Advanced Materials **10**, 246 (1998)
[4] F. Qin *et al.*, Nature Communications **8**, 14465 (2017)

TT 29.6 Tue 15:45 H2

Coexistence of superconductivity and quantum Hall states in InSb Nanosheets — •Ning Kang — Department of Electronics, Peking University, China

Hybrid superconducting devices based on high-mobility two-dimensional electron gases with strong spin-orbit coupling are considered to offer a flexible and scalable platform for topological quantum computation. Here, we report the realization and electrical characterization of hybrid devices based on high-quality InSb nanosheets and superconducting Nb electrodes. The high critical magnetic field of Nb combined with high-mobility InSb nanosheets allows us to exploit the transport properties in the exotic regime where the superconducting proximity effect coexists with quantum Hall effect. Transport spectroscopy measurements in such a regime reveal an enhancement of the conductance at the quantum Hall plateaus, accompanied by a pronounced zero-bias peak in the differential conductance. We discuss that these features originate from the formation of Andreev edge states at the superconductor-InSb nanosheet interface in the quantum Hall regime.