TT 16: Transport: Quantum Dots, Wires, Point Contacts 2 (jointly with HL)

Time: Monday 15:00–17:30 Location: H18

TT 16.1 Mon 15:00 H18

Bound States in a Carbon Nanotube Quantum Dot Coupled to Superconducting Leads — •Amit Kumar[1], Martin Gaim[1], Daniel Steininger[1], Andreas K. Hüttel[1], Christoph Strunk[1], Alfredo Levy Yeyati[2], and Alvaro Martín-Rodero[2] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Department of Theoretical Condensed Matter Physics, Universidad Autónoma de Madrid, 28049 Madrid, Spain

We report on tunnelling spectroscopy measurements on a carbon nanotube quantum dot device strongly coupled with niobium superconducting leads at two ends and weakly coupled to a tunnel probe (aluminium) in the middle. Gate dependent differential conductance measurements at low temperature down to 25mK reveal the formation of bound states (Andreev / Yu-Shiba Rusinov) inside the superconducting gap. By virtue of the larger superconducting gap of the niobium, we observe several such states. Odd Coulomb valleys show negative differential conductance features, which are characteristics for bound states with localized spins. These localized spins (odd number of electrons on the quantum dot) are known to generate localized Yu-Shiba Rusinov bound states inside the superconducting gap and are expected to dominate in asymmetrically coupled quantum dot devices. More detailed experimental investigations and theoretical calculations are in progress to understand these experimental findings.

TT 16.2 Mon 15:15 H18

Kondo Physics in Clean Carbon Nanotubes — •Daniel Schmid, Alois Dirnaichner, Peter Stiller, Andreas K. Hüttel, and Christoph Strunk — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Clean carbon nanotube quantum dots provide ideal model systems with orbitally degenerate quantum levels to probe novel Kondo physics. Transport measurements on single quantum dots were done down to a base temperature of $T \simeq 20\,\mathrm{mK}$ in the $10 \leq N_{\mathrm{el}} \leq 50$ electron regime, showing the typical signatures of the Kondo effect, as well as co-tunneling features at finite bias.
We focus on a specific charge state with $N_{\mathrm{el}} = 21$ electrons in the intermediate coupling regime $G_{\max} \simeq 0.9(2e^2/h)$. Besides the usual Kondo peak around zero bias voltage ($V_{\mathrm{SD}} = 0$) the differential conductance displays interesting satellites at finite V_{SD}. These satellites depend only weakly on magnetic field and temperature for the range $B < 8\mathrm{T}$ and $T < 1\mathrm{K}$.

TT 16.3 Mon 15:30 H18

Thermal quasiparticle spectroscopy of a carbon nanotube quantum dot coupled to superconducting leads: part I, experiment — •Markus Gaass, Andreas K. Hüttel, Tom Geiger, Sebastian Pfaller, Andrea Donarini, Milena Grifoni, and Christoph Strunk — University of Regensburg, 93040 Regensburg, Germany

We present electronic transport measurements of a single wall carbon nanotube quantum dot contacted with Niobium electrodes. At elevated temperatures, within the superconductor energy gap and the Coulomb blockade region additional transport resonances arise, which we attribute to thermally generated quasiparticles in the Nb leads. A detailed comparison of the temperature dependence with model calculations leads to excellent agreement for zero as well as finite applied bias.

TT 16.4 Mon 15:45 H18

Thermal quasiparticle spectroscopy of a carbon nanotube quantum dot coupled to superconducting leads: part II, theory — •Sebastian Pfaller, Markus Gaass, Andreas K. Hüttel, Tom Geiger, Andrea Donarini, Christoph Strunk, and Milena Grifoni — University of Regensburg, 93040 Regensburg, Germany

We present in this study a transport theory for a carbon nanotube quantum dot coupled to superconducting leads to lowest order in the tunneling. A generalized master equation is used to model the dynamics. For high enough temperatures, quasiparticles in the superconducting lead get thermally excited across the gap, leading to conductance in the Coulomb blockade including the subgap region. Around zero bias conductance peaks are observed. A comparison of the temperature dependence of these thermally induced conductance peaks with experimental data shows excellent agreement.

TT 16.5 Mon 16:00 H18

Mapping out the band structure of carbon nanotubes in a magnetic field: part I, experiment — •Alois Dirnaichner, Daniel Schmid, Magdalena Marganska, Milena Grifoni, Andreas K. Hüttel, and Christoph Strunk — University of Regensburg, 93040 Regensburg, Germany

We report on electronic transport spectroscopy measurements on an ultra-clean carbon nanotube as a quantum dot at low temperature and finite magnetic field. The direction of the magnetic field can be adjusted both parallel and perpendicular to the nanotube axis with flux densities of up to $B = 17\,\mathrm{T}$. Data focusses on the few-electron spectrum, highly regular down to $N_{\mathrm{el}} = 1$, where sharp Coulomb blockade oscillations enable tracing of multiple excited quantum states. We discuss spin-orbit coupling and KK'-mixing in our sample. The data is compared to state-of-the art CNT modeling.

15 min. break

TT 16.6 Mon 16:30 H18

Mapping out the band structure of carbon nanotubes in a magnetic field: part II, theory — •Magdalena Marganska, Alois Dirnaichner, Daniel Schmid, Andreas K. Hüttel, Christoph Strunk, and Milena Grifoni — University of Regensburg, Germany

We report here an analysis of transport measurements of ultraclean carbon nanotubes in parallel magnetic field. Employing the magnetic field dependence of the energies of ground and excited states of a single excess electron in the CNT-quantum dot we can assign a diameter and chirality to the nanotube present in the device. The data obtained in low fields allow us to extract several of the nanotube parameters, and to refine the minimal Hamiltonian commonly used for CNT quantum dots in parallel magnetic fields. With an additional asymmetry term appearing in the Hamiltonian, we can match the experimental data with high accuracy. Using the results from high magnetic fields we can further refine our analysis and identify the term responsible for electron-hole asymmetry in the spin-orbit splitting.

TT 16.7 Mon 16:45 H18

Tunable electron-vibron coupling in suspended carbon nanotube quantum dots — •Christoph Stampfer[1,2], Peter Weber[1,2], Carola Meyer[2], and Stefan Trellenkamp[2] — [1]JARA-FIT and II. Institute of Physics B, RWTH Aachen, 52074 Aachen, Germany — [2]Peter-Grünberg-Institut (PGI-6/8/9), Forschungszentrum Jülich, 52425 Jülich, Germany

Measurements through nano electromechanical systems and single-molecule junctions have shown that electronic transport is strongly influenced by the mechanical motion, leading to transport assisted by emission of vibrons. Furthermore, a strong electron-vibron coupling is expected to lead to a suppression of transport through the vibronic ground state, known as Franck-Condon blockade. Here we report on transport in a quantum dot formed in a partly suspended carbon nanotube devices. The data show Coulomb diamonds with a clear fourfold degeneracy and an experimental confirmation of Franck-Condon blockade mechanism. More interestingly, we show that our four-terminal quantum device allows us to tune the electron-vibron coupling. In particular, we focus on the investigation of spin states and the tunability of electron-phonon coupling in the suspended carbon nanotube quantum dot.

TT 16.8 Mon 17:00 H18

Spin-dependent coupling to vibrations in suspended carbon nanotube quantum dots — •Hernán L. Calvo[1,2], Julian Bohle[1,2,3], Christoph Stampfer[2,3,4], and Maarten R. Wegewijs[1,2,3] — [1]Institut für Theorie der Statistischen Physik, RWTH Aachen University, Germany — [2]JARA - Fundamentals of Future Information Technology — [3]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [4]II. Institute of Physics B, RWTH Aachen University, Germany

Recent transport experiments in a semi-suspended carbon nanotube

(CNT) quantum dot have shown an electron-vibration coupling that is markedly different for spin singlet and triplet states. In this talk, we show that such an apparent spin-vibration coupling can be understood in terms of a coupling of the electronic valley degree of freedom of the CNT to the observed longitudinal vibration. Strikingly, this Peierls-type coupling in the valley space leads to Franck-Condon sidebands that mostly develop for the triplet excited state. A vibrational modulation of the exchange interaction on the CNT is shown to result in a similar, but weaker effect. The effect can be understood qualitatively from polaronic shifts obtained in the Born-Oppenheimer approximation. In the regimes of interest, however, this approximation breaks down and we present transport calculations accounting for the full pseudo-Jahn-Teller mixing of the vibronic states that show satisfactory agreement with the experiment.

TT 16.9 Mon 17:15 H18

Graphene quantum dots on hexagonal boron nitride — •Alexander Epping[1,2], Stephan Engels[1,2], Christian Volk[1,2], Jan Dauber[1,2], Bernat Terres[1,2], Matthias Goldsche[1,2], Kenji Watanbe[3], Takashi Taniguchi[3], and Christoph Stampfer[1,2] — [1]JARA-FIT and II. Institute of Physics B, RWTH Aachen, 52074 Aachen, Germany — [2]Peter-Grünberg-Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]Advanced Materials Laboratory, National Institute for Materials Science, 1-1 Namiki, Tsukuba, 305-0044, Japan

Graphene exhibits unique electronic and mechanical properties making it a promising material for future quantum-electronic applications. However, state of the art graphene quantum dots fabricated on SiO_2 substrates suffer from their poor quality due to a large disorder potential. Recently, it has been shown that placing graphene on hexagonal boron nitride (hBN) substantially reduces the disorder potential because of its atomically-flat graphene-like hexagonal structure. Here, we present the fabrication and characterization of single-layer graphene quantum dots on hBN substrates. In particular we show low-temperature transport measurements showing Coulomb diamonds with charging energies between 9 meV and 11 meV.