FM 59: Enabling Technologies: Quantum Dots and Superconductivity-based Systems

Time: Wednesday 14:00–16:00 Location: 3043

FM 59.1 Wed 14:00 3043

Full Counting statistics of a driven single electron quantum dot — •Adrian Schmidt, Johannes C. Bayer, Timo Wagner, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Hanover, Germany

The AC driving of a single electron quantum dot shows as function of frequency and tunnelling rate clear signature of a quantum stochastic resonance. [1] We now analysed the tunnelling through such a single electron quantum dot in terms of full counting statistics.

For this we used a quantum dot formed by split gates in a GaAs/AlGaAs heterostructure with a nearby quantum point contact. The QPC allows to measure single electron tunnelling through the ac driven quantum dot in real time. From these data the full counting statistics for the driven tunnelling can be extracted. We analysed the collected data to identify the occurring transitions in the system and extracted the time dependend tunnelling rates for different modulations.

Reference

[1] T. Wagner, P. Talkner, J. C. Bayer, *et. al.*, Nat. Phys. **15**, 330-334 (2019).

FM 59.2 Wed 14:15 3043

Metallic magnetic calorimeters for photon sensing with sub-eV energy resolution — Matthäus Krantz, Andreas Fleischmann, Christian Enss, and •Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg, Germany

Energy-dispersive single photon detection with high quantum efficiency is a key technology for modern quantum science. But despite its great importance, there is a lack of detector concepts providing simultaneously an excellent energy resolution, a quantum efficiency close to 100 %, a fast timing as well as linear detector response.

During the last decade, metallic magnetic calorimeters (MMCs) have proven to fill this gap. MMCs are calorimetric single photon detectors typically operated at temperatures well below 50 mK. They use a paramagnetic temperature sensor strongly coupled to a photon absorber to convert the photon energy into a magnetic flux change that is measured using a current-sensing dc-SQUID via a superconducting flux transformer. The present record energy resolution is 1.6 eV (FWHM) for 6 keV photons. To challenge this limit we have started to develop next-generation MMCs combining temperature sensor and SQUID within a single device to grealty enhance the signal to noise ratio. Our most recent prototype comprises a gradiometric meander-shaped SQUID inductance and planar temperature sensors made of Ag:Er and gives strong reasons to expect that we can achieve sub-eV energy resolution for photon energies up to several keV. We describe the design, microfabrication and optimization of our prototype and discuss the presently achieved performance.

FM 59.3 Wed 14:30 3043

Sensing the quantum limit in scanning tunneling microscopy: tunneling between single quasiparticle levels at atomic scale — •Haonan Huang[1], Jacob Senkpiel[1], Robert Drost[1], Ciprian Padurariu[2], Simon Dambach[2], Björn Kubala[2], Juan Carlos Cuevas[3], Alfredo Levy Yeyati[3], Joachim Ankerhold[2], Christian R. Ast[1], and Klaus Kern[1,4] — [1]MPI für Festkörperforschung, Germany — [2]Institut für komplexe Quantensysteme, Universität Ulm, Germany — [3]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain — [4]EPFL, Switzerland

Tunneling processes between discrete electronic levels offer the possibility of the protection of coherence and entanglement, as well as the determination of lifetime and environmental effect. These processes have been studied extensively via quantum dots. However, to push these observations to the atomic scale remains challenging. Using a scanning tunneling microscope at 15mK, we can study the tunneling between tip and sample Yu-Shiba-Rusinov (YSR) states, the sharp in-gap states generated by magnetic atoms on a superconductor. We call these new tunneling processes Shiba-Shiba tunneling, which is a realization of tunneling between single levels at the atomic scale. Shiba-Shiba tunneling indeed inherits features of tunneling between discrete levels, and the dependency of the transport on the normal state conductance provides a direct measurement of quasiparticle lifetime with atomic precision, which shows great potential as a general tool of measuring the lifetime of an impurity or topological levels such as Majorana bound states.

FM 59.4 Wed 14:45 3043

Practical guide to simple characterization of superconducting quantum dots — •Martin Žonda[1], Alžběta Kadlecová[2], Vladislav Pokorný[2], and Tomáš Novotný[2] — [1]Albert Ludwig University of Freiburg, Institute of Physics, Freiburg, Germany — [2]Department of Condensed Matter Physics, Charles University, Prague, Czech Republic

Quantum dots attached to superconducting leads can be viewed as tunable Josephson junctions. Their qualitative properties, including the point of $0-\pi$ impurity quantum phase transition, can be externally controlled by the gate voltage or the superconducting phase difference of the leads. This makes them a promising candidate for future components of superconducting circuit computers. However, quantitative characterization of these devices, which is necessary for their future implementation, often requires broad scans throughout the parameter space of their theoretical models. This turned to be challenging if precise numerical methods, like NRG or QMC, are used. These methods are especially inconvenient for the initial data analysis.

We offer some inexpensive, fast and reliable alternatives to these procedures. We present analytical formuleas which allow for a very good estimation of the position of the $0-\pi$ phase boundary in the complementary weakly interacting and strongly correlated (Kondo) regimes. We also suggest an approach for efficient determination of the quantum phase boundary from measured finite-temperature data.

[1] A. Kadlecová et al., Phys. Rev. B 95, 195114 (2017)
[2] A. Kadlecová et al., Phys. Rev. Applied 11, 044094 (2019)

FM 59.5 Wed 15:00 3043

Towards semiconductor-superconductor hybrid qubits based on core/shell nanowires — •Patrick Zellekens[1,2], Russell Deacon[3,4], Pujitha Perla[1,2], Steffen Schlör[5], Mihail Ion Lepsa[1,2], Martin Weides[5], Koji Ishibashi[3,4], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institute, Forschungszentrum Jülich, 52428 Jülich, Germany — [2]JARA-FIT, Fundamentals of Future Information Technology — [3]RIKEN Center for Emergent Matter Science, 351-0198 Saitama, Japan — [4]Advanced Device Laboratory, RIKEN, 351-0198 Saitama, Japan — [5]Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

State-of-the-art qubits are typically tuned in frequency by a magnetic field. Our goal is to fabricate and characterize electrically tunable qubits, i.e. Gatemon and Andreev qubits, using a semiconductor nanowire Josephson junction as nonlinear element.

The main limitation for the qubit performance is the semiconductor-superconductor interface. We present a detailed analysis of the DC- and AC-properties of InAs/Al and InAs/Nb nanowire Josephson junctions with epitaxially grown superconductor shells based on Shapiro, emission and gate-dependent VI measurements.

Additionally, we present flux- and gate-dependent measurements of Andreev qubits as well as the spectroscopy of individual Andreev bound states by means of pump-probe experiments. The latter one reveals a Rashba- induced lifting of the spin degeneracy, which is one of the prerequisites for the realization of Majorana fermions.

FM 59.6 Wed 15:15 3043

Quantum phases and quantum phase transitions in frustrated networks of Josephson junctions — •Mikhail Fistul[1,2] and Alexei Andreanov[1] — [1]Center for Theoretical Physics of Complex Systems, Institute for Basic Science (IBS), Daejeon, Republic of Korea — [2]National University of Science and Technology MISiS, Russian Quantum Center, Moscow, Russia

We present a theoretical study of spatial correlations of Josephson phases in *frustrated quantum networks* of Josephson junctions. We focus on one-dimensional sawtooth chains where frustration arises due to the Josephson couplings having alternating signs in a single lattice cell of our model. The classical nonlinear dynamics of such system [1] shows the crossover from non-frustrated to frustrated regimes at the critical value of frustration, f_c. Such crossover is characterized by the thermodynamic spatial correlation functions of phases on vertices, φ_n, i.e. $C(n-m) = \langle \cos(\varphi_n - \varphi_m) \rangle$ displaying the transition from long- to short-range spatial correlations.

In the quantum regime using a direct mapping to the classical one- or two-dimensional lattices of spins with alternating sign long-range interactions, we obtain the zero temperature phase diagram ($\sqrt{E_c/E_J}$)-f, where E_c and E_J are the charge and Josephson coupling energies, respectively. The various macroscopic quantum phases, e.g. quantum vortices/antivortices, quantum vortex-antivortex pairs, quantum superposition states, quantum strip phases, are discussed.

[1] A. Andreanov and M. V. Fistul, J. Phys. A: Math. Theor. **52**, 105101 (2019).

FM 59.7 Wed 15:30 3043

Interaction of Skyrmions and Pearl Vortices in Superconductor-Chiral Ferromagnet Heterostructures — •Samme M. Dahir, Anatoly F. Volkov, and lya M. Eremin — Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany

We investigate a hybrid heterostructure with magnetic skyrmions (Sk) inside a chiral ferromagnet interfaced by a thin superconducting film via an insulating barrier. The barrier prevents electronic transport between the superconductor and the chiral magnet, such that the coupling can occur only through the magnetic fields generated by these materials. We find that Pearl vortices (PV) are generated spontaneously in the superconductor within the skyrmion radius, while anti-Pearl vortices ($\overline{\text{PV}}$) compensating the magnetic moment of the Pearl vortices are generated outside of the Sk radius, forming an energetically stable topological hybrid structure. Finally, we analyze the interplay of skyrmion and vortex lattices and their mutual feedback on each other. In particular, we argue that the size of the skyrmions will be greatly affected by the presence of the vortices, offering another prospect of manipulating the skyrmionic size by the proximity to a superconductor.

FM 59.8 Wed 15:45 3043

Microwave spectroscopy reveals the quantum geometric tensor of topological Josephson matter — Raffael Klees[1], Gianluca Rastelli[1], Juan Carlos Cuevas[2], and •Wolfgang Belzig[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain

Concepts like Chern numbers and their relation to physical phenomena have become very familiar, but actually, key quantities like the quantum geometric tensor [1], which provides a much deeper information about quantum states, remain experimentally difficult to access. Recently it has been shown that multiterminal superconducting junctions constitute an ideal playground to mimic topological systems in a controlled manner [2]. We study the spectrum of Andreev bound states in topological Josephson matter and demonstrate that the quantum geometric tensor of the ground state manifold can be extracted with the help of microwave spectroscopy [3]. We develop the concept of artificially polarized microwaves, which can be used to obtain both the quantum metric tensor and the Berry curvature. The quantized integrated absorption provides a direct evidence of topological quantum properties of the Andreev states. [1] M. Kolodrubetz et al., Phys. Rep. 697, 1 (2017) [2] R.-P. Riwar et al., Nat. Commun. 7, 11167 (2016); [3] R. L. Klees et al., arXiv:1810.11277