TT 29: Superconductivity: Tunnelling, Josephson Junctions, SQUIDs 1

Time: Wednesday 15:00–18:30 Location: H 2053

TT 29.1 Wed 15:00 H 2053

Tunable double well potential for fractional Josephson two-vortex molecule — •D. M. Heim[1], K. Vogel[1], W. P. Schleich[1], E. Goldobin[2], D. Koelle[2], and R. Kleiner[2] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Physikalisches Institut and Center for Collective Quantum Phenomena, Universität Tübingen, D-72076 Tübingen, Germany

We study a fractional Josephson two-vortex molecule in a long Josephson 0-κ-2κ junction. The ground state is degenerate, corresponding to two configurations with topological charges $(\kappa, \kappa-2\pi)$ and $(\kappa-2\pi, \kappa)$ of fractional vortices. We propose to use such a system to study macroscopic quantum phenomena involving fractional vortices. Similar to the previous proposal based on a 0-π-0 junction [1], the two-vortex-molecule states can be mapped to a double well potential. However, by changing the value of κ during experiment we are able to tune the energy barrier separating the two classical ground states. We calculate characteristic properties (e.g. barrier height, eigenfrequency) and demonstrate that a controlled transition into the quantum regime is possible in such a system.

[1] E. Goldobin et al., Phys. Rev. B **72**, 054527 (2005).

TT 29.2 Wed 15:15 H 2053

Current-voltage dependence of a one-dimensional Josephson junction array in the Coulomb blockade regime — •Nicolas Vogt[1], Alexander Shnirman[1,2], and Alexey V. Ustinov[3,2] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN) , Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [3]Physikalisches Institus, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

We theoretically investigate the transport characteristics of a one-dimensional Josephson junction array in the Cooper pair Coulomb blockade regime. Explanations for the hysteresis in the current-voltage characteristics and threshold voltage have been previously proposed within the mean field sine-Gordon model. This approach fails, however, to explain the recent experimental data. Experiments show a quadratic dependence of the differential conductance on the Josephson coupling energy which depends on the magnetic field. We introduce various models of dissipation into the mean field theory in order to numerically simulate the time resolved behavior of the voltage biased array.

TT 29.3 Wed 15:30 H 2053

Further investigations on dc-SQUID gradiometers based on growth modified bi-crystal grain boundaries — •Peter Michalowski, Christian Katzer, Daniel Kuhwald, Stefanie Koch, Frank Schmidl, and Paul Seidel — Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Helmholtzweg 5, 07743 Jena, Germany

The properties of grain boundaries of $YBa_2Cu_3O_{7-\delta}$ (YBCO) films grown on bi-crystal substrates can be modified by gold nano crystallites self-assembling from an intermediate gold layer during pulsed laser deposition [1]. These gold particles act as additional pinning centers in the YBCO layer [2]. Using a new layout, which enables us to restrict the gold nano crystallites only to the Superconducting QUantum Interference Device (SQUID) or the antenna structures, we fabricated dc-SQUID gradiometers. We present results of the temperature dependence of the London penetration depth as well as of noise measurements carried out with ac- and dc-bias. In addition we investigated the dependence of the superconducting properties on the thickness of the initial gold layer.

[1] P. Michalowski et al., Physica Status Solidi - Rapid Research Letters **5** (2011) 268-270.
[2] Katzer et al., EPL **95** (2011) 68005.

TT 29.4 Wed 15:45 H 2053

Temperature Dependence of Driven Duffing Oscillator — •Lingzhen Guo[1,4], Michael Marthaler[1,2], Vittorio Peano[1,3], and Gerd Schön[1,2] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN),Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [3]Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824, USA — [4]Department of Physics, Beijing Normal University, Beijing 100875, China

We investigate the temperature dependence of the stationary distribution for the Driven Duffing Oscillator (DDO). We focus on the fragility of the zero temperature solution. This unusual phenomenon means that the probabilities over the two stable vibrational states will endure an abrupt change in the presence of a small temperature. In this work, we first numerically demonstrate the fragility of the zero temperature solution. Realizing that this is due to the violation of the detailed balance condition, we find a condition for the divergency of the small temperature perturbation theory. Then an analytical expression for a critical temperature is obtained. Our results reveal that this fragility is more and more prominent as the number of states in the quasienergy potential wells increases which indicates a semiclassical regime. The fragile regime can be investigated with currently existing experimental setups.

TT 29.5 Wed 16:00 H 2053

Subgap density of states in the superconductor Aluminum — •Andreas Heimes[1], Michael Marthaler[1], Juha Leppäkangas[2], Jens Michelsen[1], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, D-76131 Karlsruhe, Germany — [2]Department of Microtechnology and Nanoscience - MC2, Chalmers University of Technology, SE-412 96 Göteborg, Sweden

In recent years great effort in screening envoironmental decoherence sources lead to an increased coherence time of Josephson based qubits. However there are still intrinsic mechanisms in the bulk superconductors that set a natural limit. According to that recent experiments measure a finite electronic density of states below the superconducting gap leading to incoherent quasiparticle tunneling. At the same time it was proposed that non-magnetic impurities at the superconductor-substrate interface or in the oxide tunneling barrier can cause magnetic impurities with a certain surface concentration which are believed amongst other to cause the $1/f$ flux noise. Here we propose that such surface spins could also be the reason for the observed subgap density of states in the phonon-mediated superconductor aluminum. We find that magnetic scattering in the bulk superconductor leads to a subgap tunneling rate that can be compared to the mentioned experimental observations.

TT 29.6 Wed 16:15 H 2053

Understanding the Josephson current through Kondo-correlated quantum dots — •David J. Luitz[1], Fakher F. Assaad[1], Tomaš Novotný[2], and Volker Meden[3] — [1]Institut für theoretische Physik und Astrophysik, Universität Würzburg, Germany — [2]Department of Condensed Matter Physics, Charles University Prague, Czech Republic — [3]Institut für Theorie der Statistischen Physik, RWTH Aachen, Germany

We study the Josephson current 0-π transition through correlated carbon-nanotube quantum dots tuned to the Kondo regime. The physics dominated by an interplay of two complex many-body effects, namely superconductivity and Kondo correlations, can be quantitatively captured by the numerically exact continuous time quantum Monte Carlo method within the single-impurity Anderson model with two superconducting leads. Comparison to existing experiments with the model parameters determined from the normal state linear conductance shows excellent agreement for the dependence of the critical Josephson current on the dot level position ϵ experimentally tuned by the gate voltage.

15 min. break.

Invited Talk TT 29.7 Wed 16:45 H 2053

Novel Josephson effect in triplet Josephson junctions: the story begins — •Dirk Manske — Max-Planck-Institut für Festkörperforschung, Heisenbergstr.1, 70569 Stuttgart

In the theoretical study of Josephson junctions, it is usually assumed that the properties of the tunneling barrier are fixed. This assumption breaks down when considering tunneling between two triplet superconductors with *misaligned* **d**-vectors in a TFT-junction (triplet–

ferromagnet–triplet) [1,2]. Such a situation breaks time-reversal symmetry, which radically alters the behaviour of the junction, stabilizing it in a fractional state, i.e. the free energy minimum lies at a phase difference intermediate between 0 and π. Fractional flux quanta are then permitted at the junction [3]. A further consequence of the **d**-vector misalignment is the appearance of a Josephson spin current, which flows even in the absence of an equilibrium charge current. Not only do our calculations enhance the physical understanding of transport through triplet superconductor junctions, but they also open the possibility of novel spintronic Josephson devices [4].

[1] B. Kastening, D.K. Morr, D. Manske, and K.H. Bennemann, Phys. Rev. Lett. 96, 047009 (2006)
[2] P. M. R. Brydon, B. Kastening, D. K. Morr and D. Manske, Phys. Rev. B **77**, 104504 (2008).
[3] P.M.R. Brydon, C. Iniotakis, D. Manske, and M. Sigrist, Phys. Rev. Lett. 104, 197001 (2010).
[4] P.M.R. Brydon and D. Manske, Phys. Rev. Lett. 103, 147001 (2009).

TT 29.8 Wed 17:15 H 2053

Grain boundary junctions with Co-doped Ba-122 — •Stefan Schmidt[1], Sebastian Döring[1], Frank Schmidl[1], Fritz Kurth[2], Kazumasa Iida[2], Silvia Haindl[2], Bernhard Holzapfel[2], and Paul Seidel[1] — [1]Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Helmholtzweg 5, 07743 Jena, Germany — [2]IFW Dresden, Institut für metallische Werkstoffe, Helmholtzstrasse 20, 01069 Dresden, Germany

Josephson junctions are a strong tool to investigate fundamental superconducting properties, such as gap behaviour, dependencies from external fields and the order parameter symmetry. Finding secure values enables the possibility of theoretical descriptions to understand the physical processes within the new iron-based superconductors. The superconducting quantum interference device (SQUID) symmetry provides a phase-sensitive tool to examine flux behaviour in a very precise.

Based on Co-doped $Ba(Fe_{0.9}Co_{0.1})_2As_2$ (Co:Ba-122) thin films produced via pulsed laser deposition (PLD) on $SrTiO_3$ bicrystal substrates (mismatch angles from 9° to 36°), we manufactured grain boundary junctions by using photolithography and ion beam etching. Based on the grain boundary junctions, SQUID structures can be realized.

We present first measurements on Co:Ba-122 grain boundary Josephson junctions and their temperature dependence.

This work was partially supported by the EU within project IRONSEA, no. FP7-283141 and the Landesgraduiertenförderung Thüringen.

TT 29.9 Wed 17:30 H 2053

Andreev Reflexion studies on planar hybrid SNS-junctions based on 122-thin films — •Sebastian Döring[1], Stefan Schmidt[1], Frank Schmidl[1], Volker Tympel[1], Silvia Haindl[2], Fritz Kurth[2], Kazumasa Iida[2], Bernard Holzapfel[2], and Paul Seidel[1] — [1]Friedrich-Schiller-Universität Jena, Institur für Festkörperphysik, Helmholtzweg 5, 07745 Jena — [2]IFW Dresden, Institut für metallische Werkstoffe, Helmholtzstraße 20, 01069 Dresden

To investigate the properties of iron-based superconductors, we prepared hybrid junctions in thin film technique [1]. Therefore two geometries were prepared, a planar SNS-junction and an edge junction. The base electrode was made of $Ba(Fe_{0.9}Co_{0.1})_2As_2$ thin films [2], a sputtered gold layer acts as normal barrier for the planar junction and for the counter electrode we used the conventional superconductor lead. We measured the electrical properties of each electrode, as well as the junctions itself. To obtain information about the order parameter symmetry, we show the differential conductance and compare with different variations of an extended BTK-model. We will show differences and commonalities between the results of both junction geometries.

This work was partially supported by DFG under project nos. HA5934/3-1 and SE664/15-1, the EU under project no. FP7-283141 (IRONSEA) and the Landesgraduiertenförderung Thüringen.
[1] S. Schmidt et al. APL. 97 (2010) 172504
[2] K. Iida et al. SST 24 (2011) 125009

TT 29.10 Wed 17:45 H 2053

Carrier injection into pnictide superconductors — •C. Steiner[1], S. Probst[1], Y. Simsek[1], Y. Koval[1], S. Wurmehl[2], B. Büchner[2], and P. Müller[1] — [1]Department of Physics and Interdisciplinary Center of Molecular Materials, Universität Erlangen-Nürnberg — [2]Institute for Solid State Research, IFW-Dresden

1111 pnictides have a layered structure consisting of FeAs planes separated by LaO layers. Doping is achieved by partial replacement of oxygen by fluorine. We have already shown that layered high-T_c cuprates can be doped by carrier injection along c-axis direction [1]. For our c-axis transport measurements of pnictides we selected very small single crystals (approximately $5 \times 5 \times 1\ \mu m^3$) from powder samples of $LaO_{1-x}F_xFeAs$ with $x = 0.06$ and $x = 0.1$. Mesa structures were prepared by electron beam lithography. Above a certain bias threshold, low temperature IV characteristics showed switching from a low resistive state to a high resistive state and back, indicating charge carrier trapping and release. By this type of switching, the resistance at T_c was changed approximately by a factor of 2. The c-axis critical current belonging to the low resistive state was higher by a similar ratio. This increase of critical current was accompanied by a T_c increase of ca. 2 K. We interpret these results by electron trapping in the LaO layers and compensation of this additional charge by a decrease of electron concentration in the FeAs layers.

[1] Y. Koval, X. Y. Jin, C. Bergmann, Y. Simsek, L. Özyüzer, P. Müller, H. B. Wang, G. Behr, B. Büchner Appl. Phys. Lett. **2010**, 96, 082507

TT 29.11 Wed 18:00 H 2053

Transport measurements of lateral MgB_2/Fe/MgB_2 junctions — •Savio Fabretti, Patrick Thomas, Markus Schäfers, Oliver Schebaum, and Andy Thomas — Bielefeld University

We fabricated MgB_2/Fe/MgB_2 lateral junctions by rf-dc co-sputtering. The MgB_2 films have a thickness of about 30nm and a critical temperature of up to 33 K. The samples were annealed in-situ between 450°C and 750°C. Our MgB_2 films were sputtered on different substrates such as (100) MgO and r-cut sapphire . Their crystalline structure and magnetic anisotropy were investigated. For transport measurement a thin iron cross strip of about 30 nm was placed between the MgB_2 strip. The MgB_2 strip was relieved by a groove of about 5 μm. The superconductivity of MgB_2 is suppressed due to the proximity effect near the junction area and builds a natural metallic barrier. With this configuration, we get a magnetoresistance due to the domain wall scattering in iron where the magnetoresistance was measured perpendicular and in plane of this array. Further, we investigated their I-V and dI/dV characteristics in dependence of an applied magnetic field up to 4T. The sigma gap as well as the pi gap was observed.

TT 29.12 Wed 18:15 H 2053

Superconductivity induced by current injection into non-superconducting $Bi_2Sr_2CaCu_2O_8$ — •Y. Simsek[1], Y. Koval[1], S. Probst[1], X.Y. Jin[2], C. Steiner[1], and P. Müller[1] — [1]Department of Physic and Interdisciplinary Center for Molecular Materials (ICMM) Universität Erlangen-Nürnberg, Germany — [2]Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

Unlike doping by oxygen excess, we are able to change the carrier concentration of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) single crystals by carrier injection. The electrons injected along c-axis of Bi2212 are trapped in BiO and SrO layers which increases the hole concentration in CuO layers. This method gives an opportunity to observe the evolution of c-axis transport properties of Bi2212 from the antiferromagnetic state to the superconducting overdoped phase on the same sample. In order to eliminate the contact resistance, we have fabricated double cross-bar crystal stacks on fully oxygen depleted Bi2212 single crystal which was not superconducting above 4.2 K. We have observed that by carrier injection the conductivity can be increased until superconductivity above 4.2 K is reached. Continuing the doping by carrier injection, optimum-doped and even overdoped states were obtained. In the superconducting phase, the critical current density exponentially increases by doping level. At the same time, the variation of the critical temperature with doping shows a well known parabolic behavior. Doping by carrier injection offers an unique opportunity of tuning the properties of high-T_c electronic devices in situ.