TT 17: Superconductivity: Tunnelling, Josephson Junctions, SQUIDs

Time: Monday 15:00–18:30 Location: HSZ 201

TT 17.1 Mon 15:00 HSZ 201

Fabrication of a transparent NbAl interface in hybrid Josephson junctions and flux qubits with π-shifters and their low-temperature measurements. — •Anastasia Shcherbakova[1], Kirill Fedorov[2], Kirill Shulga[3], Valery Ryazanov[4], Vitaly Bol'ginov[4], Detlef Beckman[5], and Alexey V. Ustinov[1,2,5] — [1]Physikalisches Institut, Karlsruhe Institut fuer Technologie, D-76131, Karlsruhe, Germany — [2]Walther-Meißner-Institut, D-85748, Garching, Germany — [3]National University of Science and Technology MISIS, 119049 Moscow, Russian Federation — [4]Institute of Solid State Physics, Chernogolovka, 142432 Russian Federation — [5]RQC, BC "Ural", Skolkovo, Moscow region, 143025 Russian Federation

Aluminum-based superconducting flux qubits can be made very compact and employ high-quality Josephson junctions. An external magnetic flux need to be applied in order to set the flux qubit to a working point at minimal frequency. Adding a π-junction to the qubit loop makes applying the magnetic flux unnecessary, thus removing possible source of external fluctuations. The conventional fabrication of π-junctions requires depositing of niobium layers separated by a ferromagnet. We report fabrication of composite Al/Nb flux qubits with Nb/CuNi/Nb junctions embedded in the loop. The π-biased qubits show the characteristic microwave spectrum shifted by a half of a magnetic flux quantum. The reported technological approach opens way to a variety of quantum circuits employing Nb and Al elements.

TT 17.2 Mon 15:15 HSZ 201

φ-Josephson junctions based on current injectors — •rosina menditto[1], hanna sickinger[1], johannes maximilian meckbach[2], michael merker[2], konstantin ilin[2], michael siegel[2], dieter kölle[1], and reinhold kleiner[1] — [1]Physikalisches Institut and Center vor Collective Quantum Phenomena in LISA+, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Institut für Mikro- und Nanoelektronische Systeme, Karlsruher Institut für Technologie, Hertzstrasse 16, D-76187 Karlsruhe, Germany

We propose and implement φ-Josephson junctions with high critical current density fabricated using Nb/AlO_x/Nb technology. In previous works we showed that in conventional junctions a π, or more general a κ, phase discontinuity can be realized by means of a pair of tiny current injectors placed in the middle of the junction. Currently, we introduced two additional pairs of injectors in asymmetric positions, in order to obtain a φ-junction completely tunable electronically. By controlling the external magnetic field and the current flowing in the secondary injectors, we are able to investigate several effects: preparation and readout of the initial state, rearrangements of fractional vortices, thermal/resonant escape and retrapping of the phase.

TT 17.3 Mon 15:30 HSZ 201

Tuning the ground state of a φ-Josephson junction with current injectors — •Matthias Zimmermann, Karl Vogel, and Wolfgang Schleich — Institut für Quantenphysik, Universität Ulm, D-89069 Ulm

We propose to use a pair of tiny current injectors to control the ground states of a φ-Josephson junction. The system is based on a $0-\pi$-Josephson junction with different lengths of the 0- and π-regions. To describe this asymmetric system, we use analytic solutions of the Sine-Gordon equation and apply an external magnetic field as additional control parameter. As a result we are able to calculate the energy of the stationary states as a function of the injected current and the external magnetic field. Furthermore, we show that the injected current can be used to prepare the Josephson junction in one of its doubly degenerate ground states.

TT 17.4 Mon 15:45 HSZ 201

Hybrid superconducting magnetic tunnel junctions: Coexistence of TMR and Josephson effects — •Ondrej Vavra[1,2], Rohit Soni[2], Nico Ruppelt[2], Adrian Petraru[2], Hermann Kohlstedt[2], and Christoph Strunk[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Nanoelektronik, Technical Faculty, University of Kiel, D-24143 Kiel, Germany

We report on the latest results observed on hybrid superconducting SFIFS Josephson junctions with ferromagnet thickness-wedge (F). The Nb-Fe-Al_2O_3-Fe-Nb junctions were deposited by means of dc-magnetron sputtering technique. Junctions exhibit both Josephson effect and tunneling magnetoresistance (TMR) effect. Fraunhofer magnetic field dependence of the critical current I_C(B) proves the homogeneity of the barrier over the 4 inch wafer. The properties of the junctions such as I_C, normal conductance G_n and the tunneling magnetoresistance (TMR), respectively, strongly dependent on the oxidation parameters of the barrier (Al2O3). The different thickness of intermediate Al gives rise to the over- or under-oxidation, resulting in the Nb-Fe-Fe*-Al_2O_3-Fe-Nb or the Nb-Fe-Al-Al_2O_3-Fe-Nb, respectively. The layers denoted as Fe* (by oxygen affected Fe) and Al (residual Al layer underlying the Al_2O_3) are considered as parasitic since they suppress TMR. The impact of different thickness of both ferromagnetic layers d_F on density of states, TMR and Josephson effect will be presented too.

TT 17.5 Mon 16:00 HSZ 201

Bicrystal Grain Boundary Junctions of P-doped and Co doped Ba-122 Thin Films — •Stefan Schmidt[1], Sebastian Döring[1], Frank Schmidl[1], Volker Tympel[1], Fritz Kurth[2], Kazumasa Iida[2], Bernhard Holzapfel[2], Takahiko Kawaguchi[3], Yasuhiro Mori[3], Hiroshi Ikuta[3], and Paul Seidel[1] — [1]Friedrich-Schiller-University Jena, Institute of Solid State Physics, Jena, Germany — [2]IFW Dresden, Institute for Metallic Materials, Dresden, Germany — [3]Nagoya University, Department of Crystalline Materials Science, Nagoya, Japan

We prepared grain boundary (GB) junctions of $BaFe_2(As_{0.66}P_{0.34})_2$ thin films on bicrystal [001]-tilt LSAT and MgO substrates with GB angles of $\theta = 45°$. The junctions show clear Josephson effects and distinct Shapiro steps under microwave irradiation. Electrical characterization shows symmetric I-V characteristics which can be described with a combination of flux-flow behavior and the resistively shunted junction (RSJ) model. A large excess current I_{ex} is observed. Their formal I_CR_N product is up to 50 μV at 4.2 K, which is decreased to 11 μV when taking I_{ex} into account. Additionally, measurements on GB junctions of Fe-buffered $Ba(Fe_{0.9}Co_{0.1})_2As_2$ thin films on STO bicrystal substrates ($\theta = 30°$) are shown for comparison. Their asymmetric RSJ behavior exhibits a formal I_CR_N product of 20 μV, whereas the excess corrected value is 6.5 μV.

This work was partially supported by DFG under project no. SE 664/15-1, the EU under project no. FP7-283141 (IRON-SEA), and the Landesgraduiertenförderung Thüringen.

TT 17.6 Mon 16:15 HSZ 201

Planar hybrid Josephson junctions with $BaFe_{2-x}Co_xAs_2$ base electrode and a conventional Pb counter electrode using barriers from Au and TiO_x — •Sebastian Döring[1], Stefan Schmidt[1], Manuel Monecke[1], Volker Tympel[1], Frank Schmidl[1], Fritz Kurth[2], Kazumasa Iida[2], Ingolf Mönch[3], Bernhard Holzapfel[2,4], and Paul Seidel[1] — [1]Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Helmholtzweg 5, 07743 Jena — [2]IFW Dresden, Institut für Metallische Werkstoffe, Helmholtzstraße 20, 01069 Dresden — [3]IFW Dresden, Institut für Integrative Nanowissenschaften, Helmholtzstraße 20, 01069 Dresden — [4]Karlsruhe Institute of Technology, Institut für Technische Physik, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen

We prepared Josephson junctions from $BaFe_{2-x}Co_xAs_2$ thin films using photolithography and ion beam etching to pattern the base electrode and sputtering of SiO_2 for the preparation of insulation frameworks. The counter electrode was made from thermally evaporated lead in-situ covered by indium to avoid degradation. As barriers we use sputtered gold layers or additional layers from sputtered and subsequently oxidized titanium, respectively. While for the pure gold barrier we reached an I_cR_n-product of about 18 μV it could be increased to 90 μV using the additional TiO_x layer. The current noise behavior and microwave response of the Josephson junctions could be improved, too.

15 min. break.

TT 17.7 Mon 16:45 HSZ 201

Coherent terahertz emission from $Bi_2Sr_2CaCu_2O_8$ intrinsic Josephson junction stacks — •Fabian Rudau[1], Boris Gross[1],

Deyue An[2,3], Nickolay Kinev[4], Xianjing Zhou[2], Min Ji[2,3], Ya Huang[2], Takeshi Hatano[3], Roman Mints[5], Peiheng Wu[2], Valery Koshelets[4], Huabing Wang[2,3], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalisches Institut, Universität Tübingen — [2]Institute of Superconductor Electronics, Nanjing University — [3]National Institute for Materials Science, Tsukuba — [4]Kotel'nikov Institute of Radio Engineering and Electronics, Moscow — [5]School of Physics and Astronomy, Tel Aviv University

Josephson Junctions (JJs) offer a natural way to convert a dc voltage into high-frequency electromagnetic radiation. In the high-transition temperature superconductor $Bi_2Sr_2CaCu_2O_8$ JJs form intrinsically, allowing to fabricate stacks of hundreds of junctions easily. Such arrays are promising candidates to be used as generators of electromagnetic waves in the terahertz regime. Ranging from 0.4 to 1 THz, coherent radiation has been detected from large, rectangular $Bi_2Sr_2CaCu_2O_8$ mesa structures, producing several tens of microwatt in power. The mesas are believed to work as a cavity for electromagnetic standing waves, synchronizing all the junctions in the stack. We report on the investigation of the heat distribution and electromagnetic standing waves in such mesa structures, as well as the generation of terahertz radiation, using a combination of transport measurements, direct radiation detection, low temperature scanning laser microscopy and computer assisted modelling.

TT 17.8 Mon 17:00 HSZ 201

Quantum Brownian motion in an oscillating tilted periodic potential: application to a Josephson junction under microwave irradiation in the dual regime — •Angelo Di Marco[1], Gianluca Rastelli[2], and Frank W. J. Hekking[1] — [1]LPMMC-CNRS, Université Joseph Fourier, 25 Avenue des Martyrs BP166 38042, Grenoble Cedex, France — [2]Zukunftskolleg, Fachbereich Physik, Universität Konstanz, D-78457, Konstanz, Germany

We study a current-biased Josephson junction in the presence of an applied microwave field and influenced by an external electromagnetic environment. This problem can be mapped onto the one of a quantum Brownian particle moving in a tilted periodic potential under the effect of an oscillating force. We focus on the regime where the junction's Josephson energy E_J dominates its charging energy E_C. In this case, it is the dynamics of the so-called quasi-charge that accounts for the current-voltage characteristic of the junction. Using a full quantum approach, we study numerically and analytically the I-V curve at low temperature. In particular, we analyze the role of the quantum fluctuations on the theoretically expected Shapiro steps for current. We compare our results with the one based on a classical approach for the dynamics of the quasi-charge.

TT 17.9 Mon 17:15 HSZ 201

Coherent radiation from the fractional Josephson effect — •Christoph Ohm and Fabian Hassler — Institut für Quanteninformation, RWTH Aachen

At a Josephson junction between two topological superconductors single electrons are transported coherently between the two superconducting reservoirs. This effect is known as the fractional Josephson effect. It has been shown that a voltage-biased fractional Josephson junction produces radiation at a frequency that is half of the ordinary Josephson frequency. We study the coherence properties of this unconventional Josephson radiation including phase- and frequency-fluctuations. We show that the coherence time of the emitted radiation is dominated by quasi-particle poisoning. In addition, we discuss the fermionic parity constraint as well as pinning of the Josephson frequency in terms of second order correlation functions between radiation fields from different emitters.

TT 17.10 Mon 17:30 HSZ 201

Long Range Triplet Josephson Current and $0-\pi$ Transition in Tunable Domain Walls — Thomas E. Baker[1,2], Adam C. Richie-Halford[1,3], and •Andreas Bill[1] — [1]Dept. of Physics & Astronomy, California State University, Long Beach, CA 90840, USA — [2]Dept. of Physics & Astronomy, University of California, Irvine, CA 92697, USA — [3]Department of Physics, University of Washington, Seattle, WA 98195, USA

The order parameter of superconducting pairs penetrating an inhomogeneous magnetic material can acquire a long range triplet component (LRTC) with non-zero spin projection of the pairs ($S_z = \pm 1$). This state has been predicted and generated recently in proximity systems and Josephson junctions. We show using an analytically derived domain wall of an exchange spring how the LRTC emerges and can be tuned with the twisting of the magnetization [1]. We also introduce a new kind of Josephson current reversal, the triplet $0-\pi$ transition, that can be observed in one and the same system either by tuning the domain wall or by varying temperature. Finally, we show how the LRTC may be manipulated to produce a singlet current and how it can be observed in a superconducting-magnetic multilayer.

We gratefully acknowledge the support of the National Science Foundation (DMR-0907242), the Army Research Laboratory and the Research Corporation.

[1] T.E. Baker, A. Richie-Halford, and A. Bill, arXiv:1310.6632

TT 17.11 Mon 17:45 HSZ 201

Quantum transport signatures of chiral edge states in Sr_2RuO_4 — •Rakesh Tiwari[1], W Belzig[2], M Sigrist[3], and C Bruder[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [3]Theoretical Physics, ETH Zurich, CH-8093 Zurich, Switzerland

We investigate transport properties of a double quantum dot based Cooper pair splitter, where the superconducting lead consists of Sr_2RuO_4. The proposed device can be used to explore the symmetry of the superconducting order parameter in Sr_2RuO_4 by testing the presence of gapless chiral edge states, which are predicted to exist if the bulk superconductor is described by a chiral p–wave state. The odd orbital symmetry of the bulk order parameter ensures that we can realize a regime where the electrons tunneling into the double dot system come from the chiral edge states and thereby leave their signature in the conductance. The proposed Cooper pair splitter has the potential to probe order parameters in unconventional superconductors.

TT 17.12 Mon 18:00 HSZ 201

Quasiperiodicity and revivals in dynamics of quantum phase slips in Josephson junction chains and superconducting nanowires — •Gianluca Rastelli[1,3], Mihajlo Vanević[2], and Wolfgang Belzig[3] — [1]Zukunftskolleg, Universität Konstanz, Germany — [2]Department of Physics, University of Belgrade, Serbia — [3]Fachbereich Physik, Universität Konstanz, Germany

Quantum phase slips in superconducting loops threaded by an external magnetic field provide a coupling between macroscopic quantum states with supercurrents circulating in opposite directions. We analyze dynamics of the phase slips as a function of the superconducting loop length, from fully coherent dynamics for short loops to dissipative dynamics for the long ones. For intermediate lengths of the superconducting loop, we find that the phase slips are coupled to a discrete bath of oscillators with frequencies comparable to the phase-slip amplitude. This gives rise to a quasi-periodic dynamics of the phase slips which manifests itself as a decay of oscillations between the two counterpropagating current states at short times, followed by oscillation revivals at later times. We analyze possible experimental implications of this non-adiabatic regime in Josephson junction chains and superconducting nanowires.

TT 17.13 Mon 18:15 HSZ 201

Correlated transport through junction arrays in the small Josephson energy limit: incoherent Cooper-pairs and hot electrons — Jared Cole[1], Juha Leppäkangas[2], and •Michael Marthaler[3] — [1]Chemical and Quantum Physics, RMIT University, Melbourne — [2]Department of Microtechnology and Nanoscience, Chalmers University of Technology — [3]Institut für Theoretische Festkörperphysik, KIT, Karlsruhe

We study correlated transport in a Josephson junction array for small Josephson energies. In this regime transport is dominated by Cooper-pair hopping, although we observe that quasiparticles can not be neglected. We assume that the energy dissipated by a Cooper-pair is absorbed by the intrinsic impedance of the array. This allows us to formulate explicit Cooper-pair hopping rates without adding any parameters to the system. We show that the current is correlated and crucially, these correlations rely fundamentally on the interplay between the Cooper-pairs and equilibrium quasiparticles.