TT 46: SC: Tunneling, Josephson Junctions, SQUIDs 1

Time: Thursday 10:30–13:00 Location: HSZ 301

TT 46.1 Thu 10:30 HSZ 301

Quasiparticle tunneling in superconducting qubits — •Juha Leppäkangas, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128, Germany

In this work we consider the effect of quasiparticle tunneling on Josephson qubits in the high E_J/E_C-limit. Such qubits are immune to pure dephasing due to background charge fluctuations or quasiparticle tunneling across the Josephson junctions. However, the induced energy-decay can still be relatively fast in the presence of typical nonequilibrium quasiparticle density. We consider energy-decay rates due to quasiparticle tunneling for both the equilibrium and nonequilibrium quasiparticles in few qubit designs.

TT 46.2 Thu 10:45 HSZ 301

Dependence of the macroscopic quantum tunneling rate on Josephson junction area — •Roland Schäfer[1,2], Christoph Kaiser[3], and Michael Siegel[2,3] — [1]Institut für Festkörperphysik, Karlsruhe Instituteof Technology, 76021 Karlsruhe — [2]Center for Functional Nanostructures, 76128 Karlsruhe — [3]Institut für Mikro- und Nanoelektronische Systeme, Karlsruhe Institute of Technology, 76187 Karlsruhe

We have carried out systematic Macroscopic Quantum Tunneling (MQT) experiments on Nb/Al-AlO_x/Nb Josephson junctions (JJs) of different areas. Employing on-chip lumped element inductors, we have decoupled the JJs from their environmental line impedances at the frequencies relevant for MQT. This allowed us to study the crossover from the thermal to the quantum regime in the low damping limit. A clear reduction of the crossover temperature with increasing JJ size is observed and found to be in accord with theory. Deviations of the observed quantum rate from theoretical predictions are thoroughly analized and discussed in the framework of Kramer's [1] turnover problem.

[1] H. A. Kramers, Physica (Utrecht), **7**, 284 (1940).

TT 46.3 Thu 11:00 HSZ 301

Nonreciprocal microwave transmission through a long Josephson junction — •Kirill G. Fedorov, Hannes Rotzinger, and Alexey V. Ustinov — Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

We are experimentally investigating microwave transmission through a long Josephson junction. In the flux-flow state, the transmission coefficient depends on the direction of fluxon propagation in the junction. This behavior is based on the modulation of the fluxon chain density by the external microwave radiation applied at the junction boundary.

We have measured the transmission characteristics of 10 GHz microwaves through a long Josephson junction embedded into a resonator that facilitates impedance matching. An enhancement of the microwave transmission occurs when the direction of flux flow coincides with the direction of microwave propagation. Reversal of either the in-plane magnetic field or bias current leads to suppression of the transmitted power due to the reversed direction of flux flow. We envision applications of the described effect for designing microwave on-chip isolators, circulators and amplifiers.

TT 46.4 Thu 11:15 HSZ 301

Cooper pair propagation in Josephson junctions chains — Roland Schäfer[1,2], Wanyin Cui[1,3], Birgit Kiessig[1,3], Kai Grube[1], •Jochen Zimmer[2,3], Hannes Rotzinger[2,3], and Alexey V. Ustinov[2,3] — [1]Institut für Festkörperphysik, Karlsruhe Intitute of Technology, 76021 Karlsruhe — [2]DFG-Center for Functional Nanostructures, 76128 Karlsruhe — [3]Physikalisches Institut, Karlsruhe Institute of Technology, 76128 Karlsruhe

We have studied the transport properties of aluminum SQUID chains comprising 255 loops. The chains form arrays of coupled islands with a charging energy E_c which is of the order of the Josephson coupling E_j at zero magnetic field. E_j can be tuned towards zero by applying a magnetic field amounting to $\Phi_0/2 = h/4e$ per SQUID loop. Our results are in accord with previous observations [1], displaying a pronounced blockade of Cooper-pair transport at low voltages with a hysteretic onset of a resistive branch. Above a destinct threshhold the array is characterized by a field dependent, but in bias constant slope. The branch scales like E_j^2 and gives clear evidence that charge transport is due to the incoherent motion of Cooper pairs.

[1] P. Ågren, K. Andersson, and D. B. Haviland, J. Low Temp. Phys. 124, 291 (2001).

TT 46.5 Thu 11:30 HSZ 301

Observation of phase diffusion in a two-dimensional SQUID potential — •Susanne Butz[1], Alexey K. Feofanov[1], Ralf Dolata[2], Brigitte Mackrodt[2], and Alexey V. Ustinov[1] — [1]Physikalisches Institut, Karlsruher Institut fürr Technologie, 76131 Karlsruhe, Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

We report experiments detecting two different escape mechanisms of a dc-SQUID from the zero voltage to the gap voltage state. The two underdamped Josephson junctions of the SQUID have the same critical current but different shunting capacitors, corresponding to a model of a virtual particle with spatially anisotropic mass moving in a two-dimensional (2D) potential. The measurements show the coexistence of escape either directly from the superconducting to the gap voltage state or from the phase diffusion regime. The latter is dominated by repeated escape and retrapping events and an increased dissipation. This coexistence is explained qualitatively by analyzing the shape of the 2D potential as well as the effect of the anisotropic mass of the phase particle. Using numerical simulations, the motion of the particle in the two different regimes is examined and it is shown that the anisotropy in mass results in anisotropic dissipation.

Measured and simulated switching current histograms and current-voltage characteristics are presented. A qualitative agreement between simulation and measurement is obtained, indicating simultaneously present escape by phase diffusion and the conventional switching from the superconducting state.

15 min. break

TT 46.6 Thu 12:00 HSZ 301

Sensitive dc SQUIDs for detection of small spin systems — •R. Wölbing[1], J. Nagel[1], M. Kemmler[1], K. Konovalenko[1], M. Turad[1], R. Werner[1], R. Kleiner[1], D. Koelle[1], O. Kieler[2], T Weimann[2], J. Kohlmann[2], A. Zorin[2], E. Kleisz[3], S. Menzel[3], B. Büchner[3], and R. Klingeler[3] — [1]Physikalisches Institut - Experimentalphysik II and Center for Collective Quantum Phenomena, Universität Tübingen, 72076 Tübingen, Germany — [2]Fachbereich 2.4 "Quantenelektronik", Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Leibnitz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, 01171 Dresden, Germany

Investigation on small spin systems, e.g. macromolecules, require ultrasensitive devices for sensing the magnetization reversal of such particles with the ultimate goal of single spin flip detection. For this purpose we examine submicron dimension SQUIDs, which can detect the magnetization reversal of small spin particles directly in strong magnetic fields. We fabricated dc SQUIDs based on Nb/HfTi/Nb Josephson junctions with areas down to 200 nm x 200 nm, as well as on $YBa_2Cu_3O_7$ (YBCO) grain boundary junctions (GBJs) with linewidths down to 80 nm. The critical current densities for both types of junctions are relatively large ($j_c > 10^5\,A/cm^2$ at 4.2 K), which provides high critical currents even for submicron sized junctions. The Nb/HfTi/Nb and the YBCO SQUIDs have been characterized by electric transport and noise measurements at low and high fields up to the tesla range, showing low noise performance.

TT 46.7 Thu 12:15 HSZ 301

Thermal and Quantum depinning of a fractional Josephson vortex — •Edward Goldobin[1], Tobias Gaber[1], Kai Buckenmaier[1], Uta Kienzle[1], Hanna Sickinger[1], Dieter Koelle[1], Reinhold Kleiner[1], Max Meckbach[2], Christoph Kaiser[2], Konstantin Il'in[2], and Michael Siegel[2] — [1]Physikalische Institut, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen — [2]Institut für Mikro- und Nanoelektronische Systeme, University of Karlsruhe, Hertzstraße 16, 76187, Karlsruhe

We investigate the bias current induced depinning of a fractional Josephson vortex in a 0-κ Josephson junction [1], where the κ-discontinuity of the phase is induced by current injectors. At high temperatures $T \gtrsim 100\,mK$ the depinning is governed by thermal fluctuations. By measuring a depinning current histogram and extracting the effective barrier height vs. κ, one can see the signatures of fractional vortex escape [2,3]. At low $T \lesssim 100\,\mathrm{mK}$, the escape is dominated by quantum fluctuations and the histogram width saturates. In spite of large currents involved (bias current $\sim 1\,\mathrm{mA}$, injector current $\sim 5\,\mathrm{mA}$), advanced experimental techniques such as superconducting bias filters and persistent mode loops for injector currents allow us to argue that the observed histograms correspond to MQT of a fractional vortex. We also discuss the particular histogram shape in this quantum regime.

[1] E. Goldobin et al., Phys. Rev. B **70**, 174519 (2004).
[2] U. Kinzle et al., Phys. Rev. B **80**, 014504 (2009).
[3] K. Vogel et al., Phys. Rev. B **80**, 134515 (2009).

TT 46.8 Thu 12:30 HSZ 301

Spin Currents in TFT-Josephson Junction — •Dirk Manske[1] and Philip Brydon[2] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]TU Dresden, Germany

The spin of the Cooper pair in a triplet superconductor provides a new degree of freedom in Josephson junction physics. This can be accessed by using a magnetically-active tunneling barrier, leading to a rich variety of unconventional Josephson effects. Because of the triplet state of the pairing wavefunction, triplet superconductor junctions in general also display a Josephson spin current, which can flow even when the equilibrium charge current is vanishing. Using the quasiclassical Green's function theory, we have examined the more general situation of a magnetically-active barrier which does not conserve the spin of a tunneling Cooper-pair [1]. We demonstrate that the Josephson spin currents on either side of the barrier need not be identical, with the magnitude, sign and orientation all allowed to differ. 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 [2,3].

[1] P.M.R. Brydon, C. Iniotakis, D. Manske, and M. Sigrist, Phys. Rev. Lett. 104, 197001 (2010).
[2] P.M.R. Brydon and D. Manske, Phys. Rev. Lett. 103, 147001 (2009).
[3] P.M.R. Brydon, C. Iniotakis, and D. Manske, New J. Phys. 11, 055055 (2009).

TT 46.9 Thu 12:45 HSZ 301

Long-range spin-triplet proximity effect in Josephson junctions with multilayered ferromagnets — •Luka Trifunovic[1,2] and Zoran Radovic[1] — [1]Department of Physics, University of Belgrade, Serbia — [2]Department of Physics, University of Basel, Switzerland

We study theoretically the Josephson effect and pairing correlations in planar SF_1F_2S junctions that consist of conventional superconductors (S) connected through two metallic monodomain ferromagnets (F_1 and F_2) with transparent interfaces. We solve self-consistently the Eilenberger equations for arbitrary orientation of in-plane magnetizations in the clean limit and for moderate disorder in ferromagnets. Both singlet and triplet pair amplitudes and the Josephson current-phase relations are calculated numerically. It is shown that for equally thick ferromagnetic layers (symmetric junctions) the long-range spin-triplet correlations are not dominant: For thin ferromagnetic layers all amplitudes are equally large, while for thick layers the long range triplet amplitude is very small. It is shown that for noncollinear magnetizations the long-range proximity effect can be dominant in highly non-symmetric SF_1F_2S junctions with particularly thin F_1 and thick F_2 ferromagnetic layers. We find that dominant triplet correlations in Josephson junctions with ferromagnetic bilayer always give dominant second harmonics in current-phase relations at low temperatures.