TT 46: Superconductivity: Tunnelling, Josephson Junctions, SQUIDs 2

Time: Thursday 17:45–20:00 Location: H 2053

TT 46.1 Thu 17:45 H 2053

Josephson junction with magnetic-field tunable current-phase relation — •Edward Goldobin[1], Hanna Sickinger[1], Markus Turad[1], Roman Mints[2], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalische Institut and Center for Collective Quantum Phenomena in LISA$^+$, University of Tübingen, 72076 Tübingen, Germany — [2]Tel Aviv University, Tel Aviv 69978, Israel

We consider an asymmetric 0-π Josephson junction consisting of 0 and π regions of different lengths L_0 and L_π in an applied magnetic field H. This system can be described by an effective sine-Gordon equation for the spatially averaged phase ψ. We demonstrate that the effective current-phase relation contains a negative term $\propto \sin(2\psi)$ as well as an additional term $\propto H\cos\psi$ [1]. Thus, the current phase relation and the ground state(s) are *tunable* by magnetic field. The first experimental evidences will be presented.

[1] E. Goldobin, et al., Phys. Rev. Lett. **107**, 227001 (2011).

TT 46.2 Thu 18:00 H 2053

Quantum phase slip interference device based on a shaped superconducting nanowire — •Alexander Zorin and Terhi Hongisto — Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany

As was predicted by Mooij and Nazarov, the superconducting nanowires may exhibit, depending on the impedance of external electromagnetic environment, not only quantum slips of phase, but also the quantum-mechanically dual effect of coherent transfer of single Cooper pairs. We propose and realize a transistor-like superconducting circuit including two serially connected segments of a narrow (10nm by 18nm) nanowire joint by a wider segment with a capacitively coupled gate in between. This circuit is made of amorphous NbSi film and embedded in a network of on-chip Cr microresistors ensuring a high external impedance ($\gg h/e^2 \approx 25.8$ kΩ) and, eventually, a charge bias regime. Virtual quantum phase slips in two narrow segments of the wire lead in this case to quantum interference of voltages on these segments making this circuit dual to the dc SQUID. Our samples demonstrated appreciable Coulomb blockade voltage (analog of critical current of the SQUID) and remarkable periodic modulation of this blockade by an electrostatic gate (analog of flux modulation in the SQUID). The obtained experimental results and the model of this QPS transistor will be presented.

TT 46.3 Thu 18:15 H 2053

Influence of heating in on-chip resistors on frequency-to-current conversion in short arrays of small Josephson junctions — •Felix Maibaum, Sergey V. Lotkhov, and Alexander B. Zorin — Physikalisch-Technische Bundesanstalt Braunschweig

Small Josephson junctions can exhibit charge quantization effects and Bloch oscillations which are very much the electromagnetic dual to the behaviour of larger junctions. As such they can exhibit constant-current steps at I=2ef when an external drive of frequency f is applied, dual to the well known constant-voltage Shapiro steps exhibited by larger junctions. This is of interest for a possible current standard. Observation of these steps demonstrating phase lock of the Bloch oscillations with the external drive requires a high-impedance environment for the junctions, which is provided by on-chip resistors close to the junctions. Those resistors will inevitably be heated by the produced current. We experimentally determine the temperature dependance of miniature on-chip resistors on heating current and present circuit simulations incorporating this data as well as realistic values for stray capacitances and junction parameters. These simulations show that with harmonic drive there is practically no parameter window where observation of a flat current plateau is possible. However, a pulsed drive analogous to what is employed for AC voltage standards could enable direct frequency-to-current conversion with current technology. We also discuss potential problems not addressed in the simulations, in particular non-equilibrium quasiparticles in the superconductor.

TT 46.4 Thu 18:30 H 2053

Single crystal gold nanowire Josephson junctions and superconducting quantum interference devices — •Yusuf H. Günel[1,2], Nick Borgwardt[1,2], Huijun Yao[3], Gregor Panaitov[4], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2,5] — [1]Peter Grünberg Institute -9, Forschungszentrum Jülich, 52425 Jülich, Germany, — [2]JARA-Fundamentals of Future Information Technology — [3]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, People's Republic of China — [4]Peter Grünberg Institute -8, Forschungszentrum Jülich, 52425 Jülich, Germany, — [5]II. Physikalisches Institut, RWTH Aachen University, Aachen, Germany

We have used single crystal Au nanowires, grown by electrochemical deposition method, contacted by two Niobium (Nb) superconducting material to form a Josephson junction. The fabricated devices have been characterized in a filtered ^{3}He cryostat in a temperature range from 0.3 K up to 6 K as well as a magnetic field up to 7 T. The critical current of the Josephson devices has been investigated as a function of temperature and magnetic field. Furthermore, we have observed clear sub-harmonic gap structures in the differential resistance measurements, indicating multiple Andreev reflection.

As an important application of Josephson junctions, we have also fabricated and characterized the properties of superconducting quantum interference devices (SQUIDs) formed by two individual Nb/Au-nanowire/Nb Josephson junctions.

15 min. break.

TT 46.5 Thu 19:00 H 2053

Measurements of single fluxon radiation spectra in annular Josephson junctions — •Kirill G. Fedorov and Alexey V. Ustinov — Physikalisches Institut and DFG Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We report measurements of single fluxon radiation from annular Josephson junctions using a low noise cryogenic microwave amplifier. Measurements in the frequency domain show very rich fine structure of the fluxon current-voltage characteristic. Distinct resonances that are found in the fine structure are explained by fluxon interaction with small-amplitude plasma waves. The linewidth of fluxon radiation is investigated for different bias points and temperatures down to mK range. We present a comparison of the existing theories for fluxon radiation linewidth with our data.

TT 46.6 Thu 19:15 H 2053

Strain tuning atomic tunneling systems in a Josephson junction — •Grigorij J. Grabovskij, Torben Peichl, Jürgen Lisenfeld, Georg Weiss, and Alexey V. Ustinov — Karlsruhe Institute of Technology, Physikalisches Institut, 76131 Karlsruhe

The so-called tunneling model assumes transitions of atoms between different localized configurations of the disordered structure of the solid. A transition like that is attributed to the two-level system (TLS) formed by the two lowest energy states of atoms tunneling in a double-well potential. The development of superconducting circuits based on Josephson junctions as active elements grants access to single microscopic defect states located inside the disordered tunneling barrier. The spectra of Josephson phase qubits show avoided level crossings corresponding to individual coherent TLSs. We performed an experiment in which a chip with a phase qubit was bent using a piezo actuator. The tiny displacement of atoms on the chip surface, which is estimated to be of the order of the nuclei size, changes the potential of TLSs. We observed a change of the TLS resonance frequency as a function of the strain field that confirms the tunneling model assumptions for TLSs and yields unique data for the TLS potential.

TT 46.7 Thu 19:30 H 2053

Experiments with SQUID-based Metamaterials — •Susanne Butz[1], Philipp Jung[1], Sergey V. Shitov[2,3], and Alexey V. Ustinov[1,3] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Institute of Radio Engenieering and Electronics (IREE RAS), Moscow 125009, Russia — [3]National University of Science and Technology MISIS, Moscow 119049, Russia

Metamaterials consist of elements that are artifically created to obtain a specific, predetermined interaction with an electromagnetic wave. The size of individual elements is much smaller than the wavelength of the incoming radiation. Conventionally, split ring resonators are used to interact with the magnetic field component of the wave. The interaction with the electric component is realized by thin metallic wires. We designed a Josephson junction based metamaterial where the split ring resonators are replaced by rf-SQUIDs. The benefits compared to conventional metamaterials are that the losses are reduced and that the inductance of the Josephson junction can be tuned by an external magnetic field. This, in turn, changes the resonance frequency of the metamaterial, making the magnetic permeability, μ_r, tunable in situ. We will report on first experiments investigating such a SQUID metamaterial composed of a coplanar waveguide coupled to a one-dimensional array of rf-SQUIDs. The experimental results will be compared with numerical simulations.

TT 46.8 Thu 19:45 H 2053

Versatile Multi-Layer Josephson Junction Process for Vortex Molecules — •Johannes Maximilian Meckbach[1], Simon Bühler[1], Michael Merker[1], Konstantin Il'in[1], Michael Siegel[1], Kai Buckenmaier[2], Tobias Gaber[2], Uta Kienzle[2], Benjamin Neumaier[2], Edward Goldobin[2], Reinhold Kleiner[2], and Dieter Koelle[2] — [1]Institut für Mikro- und Nanoelektronische Systeme, KIT, Germany — [2]Physikalisches Institut - Experimentalphysik II, Universität Tübingen, Germany

In long Josephson junctions magnetic flux may penetrate the barrier resulting in a so-called Josephson-Vortex carrying one flux quantum Φ_0. In recent years a new type of Josephson-Vortex became available, which carries any arbitrary fraction $\Phi = -\Phi_0\kappa/2\pi$ of magnetic flux. These fractional vortices ($\wp$-vortices) spontaneously appear at discontinuities of the Josephson phase along the junction, which in turn are created using a pair of current injectors.

We present a new Nb/Al-AlO_x/Nb process for the fabrication of Josephson junctions of very high quality. Placing two injector pairs along the strongly underdamped long junctions allows the investigation of fractional vortex molecules. The topological charge of each vortex and their interaction can be altered even during experiment by changing the individual injector currents. Vortex molecule states have been measured using asymmetric DC-SQUIDs coupled to the vortices by overlying pick-up loops. To uphold the $\wp$-vortices we use persistent currents, which can be altered using heat switches. Fractional vortex molecules are promising candidates for a new type of qubits.