TT 15: Superconductivity - Tunneling, Josephson Junctions, SQUIDs

Time: Tuesday 14:00–17:15 Location: H20

TT 15.1 Tue 14:00 H20

Untersuchung von planaren HTSL Flip-Chip dc-SQUID Gradiometern — •Christoph Becker[1], Alexander Steppke[1], Veit Grosse[1], Hendrik Schneidewind[2], Lutz Redlich[2], Frank Schmidl[1] und Paul Seidel[1] — [1]Institut für Festkörperphysik, Friedrich- Schiller-Universität Jena, Germany — [2]Institut für Physikalische Hochtechnologie e.V., Jena, Germany

Die Feldgradientenauflösung von planaren hochtemperatursupraleitenden (HTSL) dc-SQUID Gradiometern kann mittels supraleitenden Flußtransformern gesteigert werden. Die Gradiometer wurden dabei hinsichtlich der Fehlerrate optimiert. Die Gradiometer sind mit unserem Standard U-Form dc-SQUID-Layout versehen, das photolithografisch aus den 150 nm dünnen YBCO Schichten auf 10x10 mm^2 $SrTiO_3$ Bikristallsubstraten strukturiert wird. Die Schichtherstellung erfolgt mittels PLD. Als supraleitende Flußtransformer werden einerseits YBCO Antennen auf vorgeformten $SrTiO_3$ Substraten verwendet. Andererseits kommen Flußtransformer aus 200 nm dünnen TBCCO Schichten auf 2"$LaAlO_3$ oder Saphir-Substraten zum Einsatz. Diese werden nach der Schichtherstellung strukturiert und geschnitten.

Vorgestellt werden die elektrischen Eigenschaften der verschiedenen Flip-Chip Konfigurationen, wie $I_C R_N$-Produkt, Spannungshub, die effektive Fläche der Sensoren und deren Balance. Die Ergebnisse zur Langzeitstabilität der SiO_2 Passivierung und das Verhalten der Sensoren in magnetisch geschirmter und ungeschirmter Umgebung werden gezeigt. Spezielles Augenmerk wird dabei auf die Rauscheigenschaften in magnetisch ungeschirmter Umgebung gelegt.

TT 15.2 Tue 14:15 H20

Coupling mechanism of a mm wave radiation to Josephson junctions in an open resonator — •A. M. Klushin, M. He, M. Kurochka, and N. Klein — Institute of Bio- and Nanosystems and CNI-Centre of Nanoelectronic Systems for Information Technology Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

We have explored the coupling mechanism of a millimeter wave radiation to bicrystal Josephson junction arrays embedded in a hemispherical Fabry-Perot resonator [1]. We have found that our high-temperature superconductor array can be modeled as a thin film grid polarizer. In agreement with this model, a strong dependence of the coupling of the Josephson junctions on the polarization of the electric filed in the resonator was observed. We achieved a maximum Josephson voltage about 30 mV for an array of 182 bicrystal junctions at a temperature of 75K and a frequency of 75 GHz. Our results showed that such circuits are challenging for application in a quantum voltage metrology. It is important to note that our quasioptical coupling method can be extended up to terahertz frequencies. Here, our approach appears very promising for the realization of THz sources and detector arrays. Finally, our approach could be useful for irradiation of large arrays of niobium Josephson junctions as well. In this case, a substantial simplification of the technology of niobium arrays, and an increase of the irradiation frequency could be achievable.

[1] Appl. Phys. Lett. 89, 232505 (2006)

TT 15.3 Tue 14:30 H20

Unusual Properties of High–T_c SQUIDs — •Christof Schneider[1], Florian Loder[1], Thilo Kopp[1], John Kirtley[2], Helene Raffy[3], and Jochen Mannhart[1] — [1]Lehrstuhl für Experimentalphysik VI, Institut für Physik, Universität Augsburg, D-86135 Augsburg — [2]IBM Thomas J. Watson Research Center, P.O.Box 218, Yorktown Heights, New York 10598, USA — [3]Laboratoire de Physique des Solides, Université de Paris-Sud, 91405 Orsay, France

Current-voltage characteristics of SQUIDs show a periodic variation of the critical current as a function of the applied magnetic field. Usually, the periodicity corresponds to one flux quantum $\Phi_0 = h/2e$. Low-inductance high–T_c grain boundary SQUIDs with a 0°/45° misorientation however, display systematically a characteristic periodicity of the critical current of $1/2 \times \Phi_0$ in small magnetic fields. In this contribution we present a systematic study of high–T_c SQUIDs with different grain boundary misorientation angles. For most misorientations, critical current oscillations with periods of $1/2 \times \Phi_0$ in small magnetic fields have been identified. SQUIDs prepared on 24° and 30° bicrystalline substrates show highly unusual and complex diffraction patterns. The interpretation of the phase–sensitive experiments is only partly consistent with higher harmonics of the current–phase relation for the Josephson current.

TT 15.4 Tue 14:45 H20

Coupling of external electromagnetic fields to supercurrents: From SQUID to SQIF — •Nils Schopohl — Eberhard-Karls-Universitaet Tuebingen, Institut fuer Theoretische Physik, Lehrstuhl Theoretische Festkoerperphysik, Auf der Morgenstelle 14, D-72076 Tuebingen

Basic principles of Josephson junction based interferometers are reviewed. Key features of parallel and also serial Superconducting Quantum Interference Filters (SQIFs) are explained in detail. Results of recent mixing experiments with radiofrequency signals between 100 MHZ and 20GHz are discussed and analyzed with help of a simple model.

TT 15.5 Tue 15:00 H20

Josephson tunnel junctions with ferromagnetic barrier layer — •Martin Weides[1], Hermann Kohlstedt[1], Matthias Kemmler[2], Dieter Koelle[2], Reinhold Kleiner[2], and Edward Goldobin[2] — [1]Institute for Solid State Research, Research Centre Jülich — [2]Physikalisches Institut - Experimentalphysik II,

We have fabricated $Nb/Al_2O_3/Ni_{0.6}Cu_{0.4}/Nb$ Josephson tunnel junctions[1]. Depending on the thickness of the ferromagnetic $Ni_{0.6}Cu_{0.4}$ layer and on the ambient temperature, the junctions were in the 0 or π coupled ground state[2]. The Al_2O_3 tunnel barrier allows to achieve rather low damping. The critical current density in the π state was up to 5 A/cm^2 at $T = 2.1$ K, resulting in a Josephson penetration depth λ_J as low as 160 μm. Experimentally determined junction parameters are well described by theory taking into account spin-flip scattering in the $Ni_{0.6}Cu_{0.4}$ layer and different interface transparencies. Using a ferromagnetic layer with a step-like thickness we obtain a 0–π junction with equal lengths and critical currents of 0 and π parts. The $I_c(H)$ pattern shows a clear minimum in the vicinity of zero field. The ground state of our 330 μm (1.3 λ_J) long junction corresponds to a spontaneous vortex of supercurrent pinned at the 0–π phase boundary, carrying $\sim 6.7\%$ of the magnetic flux quantum Φ_0[3].

[1] Weides *et al.*, Physica C **437-438**, 349 (2006)
[2] Weides *et al.*, Appl. Phys. Lett. **89**, 122511 (2006)
[3] Weides *et al.*, Phys. Rev. Lett. (12/2006)

15 min. break

Invited Talk TT 15.6 Tue 15:30 H20

Fractional flux quanta in Josephson junctions — •Edward Goldobin[1], Kai Buckenmaier[1], Tobias Gaber[1], Matthias Kemmler[1], Martin Weides[2], Judith Pfeiffer[1], Hermann Kohlstedt[2], Dieter Koelle[1], Reinhold Kleiner[1], and Michael Siegel[3] — [1]Physikalisches Institut – Experimentalphysik II, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany — [2]Center of Nanoelectronic Systems for Information Technology (CNI), Research Centre Jülich, D-52425 Jülich, Germany — [3]Institut für Mikro– und Nanoelektronische Systeme, Universität Karlsruhe, Hertzstr. 16, D-76187 Karlsruhe, Germany

Fractional Josephson vortices may appear in the so-called 0-κ Josephson junctions (κ is an arbitrary number) and carry magnetic flux Φ, which is a fraction of the magnetic flux quantum $\Phi_0 \approx 2.07 \times 10^{-15}$ Wb. Their properties are very different from the usual integer fluxons: they are pinned, and often represent the ground state of the system with spontaneous circulating supercurrent. They behave as well controlled macroscopic spins and can be used to construct bits, qubits, tunable photonic crystals and to study the (quantum) physics of spin systems.

In this talk we discuss recent advances in 0-π junction technology and present recent experimental results: evidence of the spontaneous flux in the ground state[1], spectroscopy of the fractional vortex eigenfrequencies[2] and observation of dynamics effects related to the flipping of the fractional vortices.

[1] M. Weides et al., Phys. Rev. Lett. **97**, 247001 (2006).
[2] K. Buckenmaier et al., cond-mat/0610043.

Invited Talk TT 15.7 Tue 16:00 H20

SQUID Technology for Geophysical Exploration — •Hans-Georg Meyer, Ronny Stolz, Andreas Chwala, Sven Linzen, and Volkmar Schultze — Institute for Physical High Technology, Albert-Einstein-Straße 9, D-07745 Jena, Germany

Magnetic measurements are widely used for geophysical exploration. The fields of applications are ranging from mineral exploration, environmental and military monitoring to archaeometry. During the past few years several SQUID systems for geomagnetic measurements have been developed and successfully tested. Compared to conventional systems their outstanding performance was demonstrated. The latest of such systems are mainly based on LTS SQUIDs and shall be summarized here.

Airborne geophysics is extremely interesting in prospecting, since they allow effectively covering large areas with sufficiently high spatial resolution in a short period of time. Geomagnetics detects basically anomalies of the Earth's magnetic field. In order to use sensitive SQUID gradiometers in airborne applications a high common mode rejection is necessary, since the parasitic areas of the SQUID gradiometer lead to motion noise if the gradiometer is tilted in the Earth's magnetic field. The recently developed planar LTS SQUID gradiometers with a base length of 3.5 cm show an intrinsic balance of about 10ˆ4. In this way a noise limited gradient field resolution better than 100 fT/[m*sqrt(Hz)] down to 0.1 Hz is achieved. By means of the airborne SQUID system the complete gradient tensor of the Earth's magnetic field was measured with superior accuracy never reached so far.

TT 15.8 Tue 16:30 H20

A LTS-SQUID System for Geomagnetic Prospection — •Sven Linzen[1], Ronny Stolz[1], Volkmar Schultze[1], Andreas Chwala[1], Marco Schulz[1], Tim Schüler[2], Nikolai Bondarenko[1], Sebastian Hauspurg[1], and Hans-Georg Meyer[1] — [1]Institute for Physical High Technology, A.-Einstein-Str. 9, D-07745 Jena — [2]Thuringian State Office for Archaeology, Humboldtstr. 11, D-99423 Weimar, Germany

The geomagnetic mapping of large areas gains in importance in archaeology. High sensitive sensors are necessary to resolve the small magnetic signals of buried structures like adobe walls, tombs or magnetic traces of ancient wood palisades which are completely decomposed nowadays. The sensitivity and bandwidth of state-of-the-art caesium magnetometer systems, however, are not sufficient in many cases. Thus, we built a niobium SQUID based system to overcome these limitations. Our highly balanced planar gradiometers as well as the SQUID electronics and data acquisition are carried by a nonmetallic cart which allows a soft and fast motion over ground. An inertial system as well as differential GPS completes the setup which provides us the local position of our gradiometers with a resolution of 10 cm. Fast mapping with about one hectare per hour can be performed with the system pulled by a cross-country car. We present experimental data which were acquired during several field campaigns in Europe and South America. Furthermore, we discuss the application of our system in foundation soil analysis.

This work was supported by the German BMBF, the Free State of Thuringia, and the European Union.

TT 15.9 Tue 16:45 H20

Compact noise thermometer for mK-temperatures based on integrated SQUID magnetometers — •Alexander Kirste[1], Jörn Beyer[1], Dietmar Drung[1], Jost Engert[1], Margret Peters[1], Cornelia Assmann[1], Thomas Schurig[1], Astrid Netsch[2], Andreas Fleischmann[2], and Christian Enss[2] — [1]Physikalisch-Technische Bundesanstalt, AG Kryosensoren, Abbestraße 2-12, 10587 Berlin, Germany — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, D-69120 Heidelberg, Germany

We report on the development and optimization of very compact noise thermometers for the temperature range of the PLTS-2000. They are based on the detection of the magnetic field fluctuations above the surface of a metal body by means of thin film SQUID magnetometers. The thermally driven Johnson noise currents inside a metal body produce fluctuating magnetic fields, which can be detected by highly sensitive low-Tc dc-SQUID magnetometers or gradiometers placed close to the metal surface. The fundamental fluctuation-dissipation theorem provides a direct relation between temperature and noise currents or field fluctuations to be measured: The power spectral density of the thermal magnetic flux density noise is strictly proportional to the temperature, provided the electrical conductivity does not change. Thus, the temperature of the metal body can be determined from the spectrum of the magnetic flux detected by the SQUID, making up a semi-primary thermometer. Since the spectrum of these fluctuations depends significantly on the configuration of pick-up coil and metal body, it must be optimized to achieve the largest noise signal (power) for a limited chip area. This has been done resulting in thin film miniature multiloop SQUID gradiometers. We present measurements of the integrated magnetic field fluctuation thermometer characterizing its sensitivity and speed.

TT 15.10 Tue 17:00 H20

Macroscopic Quantum Tunneling of $Bi_2Sr_2CaCu_2O_{8+\delta}$ Intrinsic Josephson Junction SQUIDs — •X. Y. Jin, J. Lisenfeld, Y. Koval, A. V. Ustinov, and P. Müller — Physikalisches Institut III, Universität Erlangen-Nürnberg

The properties of $Bi_2Sr_2CaCu_2O_{8+\delta}$ superconducting rings broken by intrinsic Josephson junction stacks were studied. The stack height was between 4 and 50 junctions. SQUID behavior was observed in all devices. The modulation depth of the critical currents increased with decreasing number of junctions in the stack, and conformed to the β_L values. Crossover temperatures between the thermal and the quantum regime were in the range of 300 to 600 mK. Whereas the small stacks behaved like series arrays of independent junctions, the larger stacks were uniform and showed anomalous enhancement of escape rates. An unconventional correlated retrapping was observed, i.e., the retrapping probability decayed exponentially with the trapped flux. This phenomenon indicates that the intrinsic SQUID is a strongly driven Tera-Hertz harmonic oscillator in phase space, where intrinsic Josephson junction stacks can provide both very high inductance and very high charging energy simultaneously. Possible implications for the realization of high-T_c phase qubits are discussed.