TT 6: Superconductivity: Cryodetectors

Time: Monday 9:30–12:30 Location: H 2053

TT 6.1 Mon 9:30 H 2053

Solid State Physics and Engineering to Push the Resolving Power of Magnetic Calorimeters Beyond 10 000 — •D. Hengstler, J. Geist, M. Keller, M. Krantz, C. Schötz, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University

Metallic magnetic calorimeters are energy dispersive particle detectors operated at temperatures below 100 mK. They make use of a paramagnetic temperature sensor to convert the energy that is deposited by an absorbed particle into a magnetic flux change in a SQUID, which can be read-out as a voltage signal with low noise and large bandwidth.

During the last decade we have been optimizing the signal size of MMCs by numerical optimizations and by the consequent use of microfabrication techniques, while lowering the readout noise close to quantum limit. The combination of both rewarded us recently with an instrumental linewidth of 1.6 eV (FWHM) for 6 keV x-rays, which is a world record. Operating this detector with optimal parameters the signal-to-noise-ratio is actually equivalent to an energy resolution below 1.0 eV (FWHM). At energies in the keV-range however, this resolution could not be achieved. Such discrepancies can arise from a-thermal phonon loss or position dependencies.

In this talk we summerize the physics of MMCs focusing on solid state effects and show recent results of these detectors in various applications. This includes the use of Ag:Er as a paramagnetic sensor material instead of Au:Er to increase the energy resolution at temperatures below 50 mK.

TT 6.2 Mon 9:45 H 2053

Investigation of low-frequency excess noise in low-T_c dc-SQUIDs — •Sebastian Kempf, Anna Ferring, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany.

Dc-SQUIDs are the most sensitive wideband devices for measuring physical quantities that can be naturally converted into magnetic flux. They show exceptional low noise over the full frequency range and are therefore heavily used in a variety of applications. However, they exhibit a low-frequency noise contribution with a spectral density scaling as $1/f^\alpha$ arising either from critical current fluctuations or magnetic flux noise, e.g. due to surface magnetic moments. While the first seems theoretically well understood, the origin of excess magnetic flux noise is still unknown.

Very recently, we have fabricated a set of single SQUIDs as well as N-SQUID series arrays, both employing Nb/Al-AlO$_x$/Nb Josephson junctions, and measured their noise spectra down to mK temperatures. We found that the magnitudes of the $1/f^\alpha$ noise expressed as energy sensitivities $\epsilon_{1/f}(1\,\mathrm{Hz})$ are as low as $34\,h$ at mK temperatures and that they increase with α. While $\alpha \leq 0.7$ for our single SQUIDs, our SQUID arrays show typically true $1/f$ noise with $\alpha \simeq 1$. We discuss our current data set in the context of present theories and compare it with data reported earlier. We also discuss an experimental method allowing for a direct measurement of noise spectra of single SQUIDs without the need of subtracting preamplifier noise and show first experimental results obtained with this method.

TT 6.3 Mon 10:00 H 2053

Large-area detectors for position and energy resolving detection of neutral molecular fragments at CSR — •L. Gamer[1], D. Schulz[1], A. Fleischmann[1], L. Gastaldo[1], S. Kempf[1], C. Krantz[2], O. Novotny[3], A. Wolf[2], and C. Enss[1] — [1]Heidelberg Univ. — [2]MPI-K Heidelberg — [3]Columbia Astrophysics Laboratory

We present a detector with a circular detection area of 10 cm^2 based on metallic magnetic calorimeters that is suited for position and energy sensitive measurements of neutral particle hits from fragmentation of molecular ion beams at the Cryogenic Storage Ring at MPI-K. It consists of 16 large area particle absorbers, arranged like the 16 slices of a pizza of radius 36 mm, where the temperature of each is monitored by a paramagnetic temperature sensor positioned along the outer absorber edges. Due to the finite thermal diffusivity in the absorbers, the signal rise-time is a measure of the radial event position while the integrated signal amplitude is proportional to the particle energy. We show very successful prove-of-principle experiments of this detector using x-ray photons. We discuss measurements where fragments of 150 keV molecules where stopped in massive gold absorbers showing that the production of lattice defects can cause a major contribution to linewidth in this energy and mass range. As an outlook we move on to a 4096 pixels detector covering a detection area of 20 cm^2. It consists of 1024 temperature sensors that are read out by only 32 SQUID channels. Each temperature sensor is coupled to 4 absorbers using different thermal links, thus allowing to locate the event position within a set of absorbers again by measuring the rise-time of the detector signal.

TT 6.4 Mon 10:15 H 2053

Feasibility Study for the Determination of Z-distributions of fission fragments with Calorimetric Low Temperature Detectors — •Patrick Grabitz[1,2], Peter Egelhof[1,2], Saskia Kraft-Bermuth[3], Pascal Scholz[3], Artur Echler[3], Shawn Bishop[4], Jose Gomez[4], Manfred Mutterer[1], and Victor Andrianov[1,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Universät Mainz, Germany — [3]Universität Gießen, Germany — [4]Technische Universität München

Compared to conventional ionization detectors calorimetric low temperature detectors (CLTD's) provide, due to their detection principle, substantial advantages in detector performance, such as energy resolution, linearity and the absence of any pulse height defect. One potential application of such detectors is the determination of nuclear charge distributions of fission fragments from thermal neutron induced fission at the LOHENGRIN mass separator (ILL, Grenoble) by using the absorber method. After passing the mass separator, fission fragments have the same mass and the same kinetic energy, but different nuclear charges. For the separation of the nuclear charges one can exploit their nuclear charge dependent energy loss after passing through an absorber foil. This separation requires a high energy resolution detector system as well as degrader foils, optimized with respect to thickness, homogeneity, etc. A test experiment performed at the tandem accelerator at Munich (MLL, LMU) with stable ^{109}Ag and ^{127}I beams with different kinetic energies has demonstrated a good Z-selectivity, and thus the feasibility of the experimental method.

TT 6.5 Mon 10:30 H 2053

SQUID-based noise thermometer for sub-Millikelvin refrigerators — •Marco Schmidt[1], Jörn Beyer[1], Monique Klemm[1], Sassan Alivaliollahi[2], and Henry Barthelmess[2] — [1]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin — [2]Magnicon GmbH, Barkhausenweg 11, 22339 Hamburg

The magnetic field fluctuation thermometer (MFFT) is a high-accuracy SQUID-based noise thermometer suitable for sub-Kelvin thermometry. A highly sensitive low-Tc SQUID magnetometer detects inductively the magnetic field fluctuation above a metal surface. The fluctuations are generated by the thermal activated noise currents inside the metal body that is thermally anchored to the temperature stage to be measured. The spectral shape is independent of temperature as the electrical conductivity is constant and the geometry is fixed. The magnetic noise power spectral amplitudes at any frequencies are directly proportional to temperature. Hence, only one reference measurement at a known temperature is required for calibration. A complete MFFT thermometer system for the temperature range of ca. 4 K down to <10 mK is commercially available. We have now developed an integrated MFFT with an extended range of operation down to <1 mK. For this purpose the sensitivity of the SQUID sensor has been increased, the metal body geometry modified and the magnetic shielding of the MFFT module improved. These modifications make it possible to obtain a thermometer noise temperature of <10 μK. We discuss the rationale for our MFFT configuration and present numerical simulations and experimental results.

TT 6.6 Mon 10:45 H 2053

Nanofabrication of coulomb blockade thermometers — •Matthias Meschke[1], Ossi M Hahtela[2], Anna V Feshchenko[1], Antti Kemppinen[2], Martti Heinonen[2], Antti Manninen[2], and Jukka P Pekola[1] — [1]Aalto University, Espoo, Finland — [2]Centre for Metrology and Accreditation (MIKES), Espoo, Finland

Coulomb blockade thermometry (CBT) is one example of a practical primary thermometer that relates temperature directly to Boltzmann's constant (kB) via a voltage measurement. Such primary methods are

required for the realization of a proposed new international temperature scale that relates to thermodynamic temperature via an exact definition of kB.

Using cutting-edge electron beam lithography, we demonstrate the fabrication of arrays of small enough structures (30 nm x 30 nm) combined with extreme homogeneity (5%) widening the useful temperature range of precise CBT to higher temperatures up to about 40 K. We present a characterization of the remaining fabrication inhomogeneities as a part of the uncertainty budget of CBT that is one prerequisite for CBT measurements satisfying metrological standards. An improved accuracy of CBT sensors at elevated temperatures directly enhances the performance at lower temperatures via the improved homogeneity and the possibility to operate CBT in a stronger CB regime with enhanced signal magnitude.

Finally, we describe an experimental comparison of CBT, consisting of arrays of many (about 1000) tunnel junctions to thermometry realized using only a single tunnel junction.

15 min. break.

TT 6.7 Mon 11:15 H 2053

Characterisation of micro and nano SQUIDs at variable temperature and magnetic field — •Claudia Köhn, Jan-Hendrik Storm, Sylke Bechstein, and Thomas Schurig — Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin

SQUIDs are highly suited to investigate the magnetic properties of samples with small dimensions, such as nanoparticles, or to read out nanoelectromechanical systems (NEMS). Due to the small sample size, SQUIDs with dimensions in the μm or nm regime are desirable. These micro or nano SQUIDs should have a low noise and no hysteresis in the current-voltage-characteristic, even when operated in high magnetic fields of up to several 100 mT. To investigate such SQUID, we developed measurement setups which can simulate the measurement conditions of the intended SQUID application. The design and performance of two measurement setups will be shown and compared. One setup uses a dipstick that is immersed in liquid helium and can be evacuated to provide SQUID temperatures between 4.5 K and 10 K. The other one uses an evaporation cryostat so that the temperature can be varied from 2 K to 60 K. Both setups are equipped with coils to enable SQUID operation in variable magnetic field. To minimize noise, the output of the SQUID under test is preamplified by a SQUID series array which is operated at 4.2 K. First results of the characterisation of micro and nano SQUIDs will be presented.

This work was partly supported by the DFG under Grant No. SCHU1950/5-1 and within the European Metrology Research Program EMRP.

TT 6.8 Mon 11:30 H 2053

YBCO nanoSQUIDs applied to the investigation of small spin systems — •Maria Jose Martinez Perez[1], Tobias Schwarz[1], Roman Wölbing[1], Benedikt Müller[1], Christopher F. Reiche[2], Thomas Mühl[2], Bernd Büchner[2], Javier Sese[3], Reinhold Kleiner[1], and Dieter Koelle[1] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, Universität Tübingen, Germany — [2]Leibniz Institute for Solid State and Materials Research IFW Dresden, Germany — [3]Instituto de Nanociencia de Aragón and Advanced Microscopy Laboratory, Zaragoza, Spain

We present the realization of ultra-sensitive YBCO nanoSQUIDs based on submicron grain boundary junctions patterned by focused ion beam milling. White flux noise down to $\sim 50\mathrm{n}\Phi_0/\mathrm{Hz}^{1/2}$ has been achieved, yielding spin sensitivities of down to a few $\mu_\mathrm{B}/\mathrm{Hz}^{1/2}$ at $T = 4.2$ K. Moreover, we demonstrate that magnetic fields up to the tesla range can be applied, fulfilling a fundamental condition for the study of small spin systems. As a proof-of-principle we present the successful deposition of a Fe-filled carbon nanotube (~ 40 nm in diameter and ~ 14 μm in length) and an individual Co nanopillar (base diameter of ~ 50 nm and height ~ 10 nm) close to the nanoSQUID loop. We show that submicrometric control over the particle position lead to large magnetic coupling factors between the nano-loop and the spin system. Together with the possibility of applying large magnetic fields, the latter has allowed us to directly observe the magnetization reversal of these spin systems at different temperatures.

TT 6.9 Mon 11:45 H 2053

Development of a Compact Low-Noise Pulse Tube Cryocooler for Operation of Superconducting Optical Detectors near 5 K — •Bernd Schmidt[1,2], Jens Falter[1], André Schirmeisen[1,2], and Günter Thummes[1,2] — [1]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany — [2]Institute of Applied Physics (IAP), Justus-Liebig-University Giessen, Germany

The advantage of pulse tube cryocoolers (PTCs), when compared to Stirling- and Gifford-McMahon-coolers, is the absence of a cold moving displacer. This unique feature leads to a low level of mechanical vibrations, lower EMI, and increased reliability of the cold head. Therefore, two-stage PTCs are becoming more and more attractive for cryogen-free cooling at liquid-helium temperatures. The trend in the development of PTCs is towards high cooling powers, which reach up to more than 1 W at 4.2 K. However, the operation of many cryoelectronic devices requires only cooling powers well below 100 mW near 4-5 K. To date, the smallest 4 K PTC on the market operates with a 2 kW helium-compressor and delivers a cooling power of 250 mW at 4.2 K (TransMIT GmbH, model PTD4200). Within the new BMBF joint project "SUSY", we started the development of an even smaller two-stage PTC for cooling of superconducting IR-detectors at temperatures near 5 K. The compressor input power of this new cooler will be approx. 1 kW, significantly reducing the intrinsic residual vibrations of the cold head that result from the pressure-induced "breathing". The lower pressure oscillation will also improve the temperature stability. Work supported by the German BMBF under grant no. 13N13444

TT 6.10 Mon 12:00 H 2053

CFD-Simulations of a 4π-contiuous-mode dilution refrigerator for the CB-ELSA experiment — Timo Altfelde, Marcel Bornstein, Hartmut Dutz, Stefan Goertz, Roland Miebach, Scott Reeve, •Stefan Runkel, Marco Sommer, and Benjamin Streit — Physikalisches Institut, Bonn, Germany

The polarized target group at Bonn operates a dilution refrigerator for double polarization experiments at the Crystal Barrel in Bonn. To get high target polarizations and long relaxation times low temperatures are indispensable. To reach temperatures below 30 mK and to allow for the use of an internal polarization magnet, the polarized target group is building a new continuous mode dilution refrigerator. As a optimizing tool for the construction of dilution refrigerators and for a better understanding of the different incoming and outgoing fluid streams several CFD-simulations are done. First the different streams are simulated independently for different parts of the refrigerator to get a better estimation of the flow parameters. Then the simulation is extended to include the heat exchange between the different streams at the heat exchangers for different operational parameters of the refrigerator. Afterwards the precooling stages of the refrigerator will be tested to compare the predicted and the measured operational parameters.

TT 6.11 Mon 12:15 H 2053

Development of an thin, internal superconducting polarisation magnet for the Polarised Target — Timo Altfelde, •Marcel Bornstein, Hartmut Dutz, Stefan Goertz, Roland Miebach, Scott Reeve, Stefan Runkel, Marco Sommer, and Benjamin Streit — Physikalisches Institut, Bonn, Germany

In order to improve the figure of merit of double-polarisation experiments at CB-ELSA in Bonn, the Polarised Target is working on a new dilution refrigerator. For maximum polarisation of nucleons low temperatures and a high homogeneous magnetic field within the target area is needed. A thin, superconducting magnet is in development, which will create a continuous longitudinal magnetic field of 2.5 T and which will be used within the new refrigerator. The solenoidal geometry of this magnet uses two additional correction coils, placed at a well defined calculated position, for reaching the homogeneity criteria of 10^{-4} needed for the dynamic nuclear polarisation process. Practically, the superconducting wires as well as the correction coils have to be placed with maximum precision: Small fluctuations of the distance between the current loops can diminish the requested homogeneity.