TT 7: Superconductivity: Cryodetectors

Time: Monday 9:30–13:00 Location: HSZ 03

TT 7.1 Mon 9:30 HSZ 03

First demonstration of a TES with High-Frequency Readout at 0.65 THz — •Artem Kuzmin[1], Michael Merker[1], Sergey Shitov[2,3], Nikolay Abramov[2], Mathias Arndt[1], Stefan Wuensch[1], Konstantin Ilin[1], Alexey Ustinov[2,4], and Michael Siegel[1] — [1]Institut für Mikro- und Nanoelektronische Systeme, Karlsruher Institut für Technology — [2]National University of Science and Technology MISIS — [3]Kotel'nikov Institute of Radio Engineering and Electronics RAS — [4]Institute of Physics and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology

We suggested an antenna-coupled TES bolometer embedded in a high-Q GHz resonator as a load to isolate the sensitive element from excess noise and disturbances. The resonator is weakly coupled to the readout transmission line. This approach allows for biasing the TES with RF power at their individual resonance frequencies and readout incident THz signal as modulation of this RF biasing signal with "conversion gain" ¿ 1, thus it is possible to use a single broadband low-noise HEMT amplifier for a relatively large number of TES bolometers in array. This approach could be used down to 300 mK without a SQUID amplifier [1-2]. To proof the concept of the new device we fabricated sub-micron sized prototypes of single-pixel RF-TES from Nb for operation temperature of 5.0 K. Results of DC and RF characterization of the TES devices along with measurement of the optical sensitivity at 0.65 THz and NEP will be presented and discussed.

[1] Technical Physics Letters **37** (2011) 932
[2] IEEE Trans. Terahertz Sci. and Tech.**3** (2013) 25

TT 7.2 Mon 9:45 HSZ 03

Detecting single infrared photons with a Transition Edge Sensor for ALPS-II — •Friederike Januschek[1], Noemie Bastidon[2], Jan Dreyling-Eschweiler[1,2], Dieter Horns[2], and Axel Lindner[1] — [1]Deutsches Elektronen-Synchrotron, Hamburg — [2]Institut für Experimentalphysik, Universität Hamburg

For the ALPS-II experiment at DESY, which will be looking for ultralight fundamental bosons, a detector with the ability to measure rates below 10^{-3} s^{-1} of single NIR photons with a wavelength of 1064 nm is necessary. Therefore, the ALPS-II detection system is required to have even lower dark count and background rates, while keeping a reasonable efficiency for photons with an energy of about 1.165 eV. For this purpose, a detector system with a superconducting Transition Edge Sensor chip from NIST, being read out by SQUIDs, was set up inside an Adiabatic Demagnetisation Refrigerator and operated at 80 mK. In this talk, results of the characterisation of this system will be presented. The focus will be on the achievable and achieved background rates of intrinsic background and background from black body radiation.

TT 7.3 Mon 10:00 HSZ 03

Design and commissioning of a X-ray spectroscopy detector setup at storage rings — •Pascal Scholz and Saskia Kraft-Bermuth — Justus-Liebig-Universität, Gießen, Germany

X-ray spectroscopy of highly-charged heavy ions in the X-ray regime, commonly performed at storage ring facilities, provides a sensitive test of quantum electrodynamics. Silicon microcalorimeters have already demonstrated their potential for such experiments. To improve performance, a cryogen-free cryostat has been commissioned, which is equipped with a side arm with the detector mounted on a cold finger centered in the front of this side arm. For inherent correction of Doppler shifts, a new detector array with improved design and pixels for high as well as low x-ray energies will be equipped. This upgrade will improve the lateral sensitivity and detector resolution in the further analysis. The design serves also as a benchmark for a larger array with approximately 100 pixels. The design and performance results will be presented with this talk.

TT 7.4 Mon 10:15 HSZ 03

High-precision X-ray spectroscopy of highly-charged ions with silicon microcalorimeters — •Saskia Kraft-Bermuth[1], Victor Andrianov[2,3], Alexander Bleile[2], Artur Echler[1,2], Peter Egelhof[2], Patrick Grabitz[2], Caroline Kilbourne[4], Oleg Kisselev[2], Dan McCammon[5], and Pascal Scholz[1] — [1]Institut f. Atomphysik, Justus-Liebig-Universität, Gießen, Germany — [2]Helmholtzzentrum f. Schwerionenforschung, Darmstadt, Germany — [3]Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia — [4]NASA/Goddard SFC, Greenbelt, USA — [5]Dept, Physics, University of Wisconsin, Madison, USA

High-precision X-ray spectroscopy of highly-charged ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. Silicon microcalorimeters with absorbers of lead and tin have been applied in two experiments for the determination of the 1s Lamb shift in hydrogen-like lead and gold at the Experimental Storage Ring (ESR) at GSI. The experimental results agree well with theoretical predictions. The obtained uncertainty is comparable to conventional detection techniques. Further improvement may be obtained, in addition to an improved detector setup, by using decelerated beams at the socalled CRYRING and HITRAP facilities currently under construction at GSI. This talk will present the results of the ESR experiments and discuss perspectives for experiments at CRYRING and HITRAP as well as for experiments at the future FAIR facility, with a focus on detector development and technical challenges.

TT 7.5 Mon 10:30 HSZ 03

Application of Calorimetric Low Temperature Detectors (CLTD's) for Precise Stopping Power Measurements of Heavy Ions in Matter — •Artur Echler[1,2,3], Peter Egelhof[2,3], Patrick Grabitz[2,3], Heikki Kettunen[4], Saskia Kraft-Bermuth[1], Mikko Laitinen[4], Katrin Müller[1], Mikko Rossi[4], Wladyslaw Trzaska[4], and Ari Virtanen[4] — [1]Justus-Liebig-Universität, Gießen — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]Johannes Gutenberg Universität, Mainz — [4]University of Jyväskylä

Precise data on stopping powers (i.e. specific energy loss dE/dx) of heavy ions in matter are needed in many fields of basic and applied science, and for our understanding of the interaction of energetic ions with matter. As the available datasets are still scarce, in particular for heavy projectiles at energies below the Bragg-peak, and discrepancies between measured and theoretical values are often significant, CLTD's have been recently applied in combination with a time-of-flight detector to perform transition-type energy loss measurements at the accelerator facility of the University of Jyväskylä. As compared to conventional ionization detectors, CLTD's provide substantially better energy resolution and linearity (with the absence of any pulse height defect) for heavy ion detection, which leads to a higher sensitivity and accuracy for dE/dx measurements using the E-TOF method, and allows to extend the accessible energy range towards lower energies. The new experimental technique was used to determine precise stopping power data for 0.05 - 1 MeV/u ^{131}Xe ions in Carbon, Nickel and Gold.

TT 7.6 Mon 10:45 HSZ 03

Solid state physics and engineering to push resolving power of magnetic calorimeters beyond 10000 — •Daniel Hengstler, Anna Ferring, Lisa Gamer, Jeshua Geist, Mathäus Krantz, Andreas Pabinger, Christian Pies, Christian Schötz, Sebastian Kempf, Loredana Gastaldo, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institut für Physik, Universität Heidelberg, INF 227, 69120 Heidelberg

Metallic magnetic calorimeters are energy dispersive particle detectors, operated at temperatures below 50 mK that make use of a paramagnetic temperature sensor to convert the energy 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've been optimizing the signal size of MMCs by numerical optimizations and the consequent use of micro-fabrication 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 on the one hand is a world record, on the other hand is much less than expected from the signal-to-noise-ratio in those measurements. Such discrepancies can easily arise from instabilities of the total gain, or — more interestingly — from a-thermal phonon loss or position dependencies.

In this talk we summerize the physics of MMCs, highlighting the presently done homework in solid state physics and engineering to reach resolving powers beyond 10000, and show recent results of MMCs in various applications.

TT 7.7 Mon 11:00 HSZ 03

Current sensing SQUIDs for the readout of low impedance cryogenic particle detectors — •S. Kempf, A. Ferring, M. Wegner, A. Fleischmann, L. Gastaldo, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University.

Superconducting quantum interference devices (SQUIDs) are presently the most sensitive wideband devices for measuring various physical quantities that can be converted in magnetic flux. They are commonly used in measurement systems in which a very sensitive sensor or an ultra low noise wideband amplifier is required. A prominent example for the use of SQUIDs is the readout of low impedance cryogenic particle detectors (LTDs). Here, the SQUIDs are used as very fast current sensors that are compatible with the very low operation temperature of LTDs. Driven by the need for devices that are matched to state-of-the-art LTDs, we have recently started the development of low-T_c current sensing SQUIDs. In particular, we are developing cryogenic frequency-domain multiplexers that are based on non-hysteretic rf-SQUIDs as well as single channel dc-SQUIDs.

After a presentation of our multiplexer and dc-SQUID designs as well as our fabrication process that is based on selective Niobium etching, we will discuss the measured performance of both types of devices. We will show that the devices are operational and that their performance can be numerically predicted with confidence, thus allowing for a design optimization with respect to the readout requirements of low impedance LTDs. Finally, we outline future developments that are forseen to improve the noise performance of our devices.

15 min. break.

Topical Talk TT 7.8 Mon 11:30 HSZ 03

Probing Decoherence in Atomic-Sized Defects Using a Superconducting Qubit — •Jürgen Lisenfeld, Georg Weiss, and Alexey V. Ustinov — Physikalisches Institut, Karlsruhe Institute for Technology (KIT), Karlsruhe, Germany

Advances in nanotechnology lay the ground for a thriving variety of novel devices suitable to explore new realms of quantum phenomena on the mesoscopic scale. Superconducting quantum bits, as an example, have reached very long coherence times by designs that weaken their undesired coupling to environmental degrees of freedom. One particular problem are parasitic Two-level systems (TLS), reported to cause noise in single-photon detectors, SETs, SQUIDs, and microwave- as well as nano-mechanical resonators, although their physical origin remains in dispute.

A particular strong coupling between superconducting qubits and TLS occurs when they reside in the tunnel barrier of Josephson junctions, and this renders qubits ideal tools for the study of single material defects in the coherent regime. Here, we use a phase qubit to directly manipulate and readout the TLS quantum state. We tune TLS properties by the applied mechanical strain and perform high-resolution defect spectroscopy to obtain their distribution and to reveal mutual TLS coupling. By analyzing their coherent dynamics, we utilize single microscopic defects as quantum spectrum analyzers that provide a view into their environment. These new techniques grant multifaceted insights into the TLS nature, which is a prerequisite for avoiding their detrimental effects in nanoscale devices.

TT 7.9 Mon 12:00 HSZ 03

Dc SQUIDs for the detection of Bose-Einstein-Condensates — •Matthias Rudolph[1], Michael Merker[2], Johannes Maximilian Meckbach[2], Martin Knufinke[1], Petra Vergien[1], Florian Jessen[1], Simon Bell[1], Patrizia Weiss[1], Helge Hattermann[1], Konstantin Ilin[2], Michael Siegel[2], József Fortágh[1], Reinhold Kleiner[1], and Dieter Koelle[1] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, Universität Tübingen, Auf der Morgenstelle 14,D-72076 Tübingen, Germany — [2]Institut für Mikro- und Nanoelektronische Systeme, Karlsruhe Institute of Technology, Hertzstr. 16, D-76187 Karlsruhe, Germany

One example of an exciting quantum hybrid system is created by coupling a SQUID with an ensemble of ultra cold atoms. Here we suggest using a gradiometric dc SQUID to non-destructively detect the center of mass motion of Bose-Einstein Condensates (BECs) which are confined in a magnetic trap. The Gradiometer, fabricated using a self-aligning Nb/AlO$_x$/Nb process, has been characterized with respect to its transport and noise properties at a temperature of $T = 4.2$ K, revealing an equivalent density of flux noise $S_\Phi^{1/2} \approx 350\,\mathrm{n}\Phi_0/\mathrm{Hz}^{1/2}$ in a magnetically unshielded environment. Numerical simulations based on the London equations suggest that with these noise properties we can expect to detect a rubidium BEC with 10^5 atoms at a distance of $10\,\mu$m from the SQUID with a signal-to-noise ratio SNR ≈ 10.

TT 7.10 Mon 12:15 HSZ 03

Magnetic Johnson noise thermometry for μK temperatures — Daniel Rothfuss, •Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

Noise thermometry instrinsically is a non-driven method. When minimal heat input is required this method is highly advantageous. Our noise thermometer is a magnetic Johnson noise thermometer. The noise source is a cold-worked high purity copper cylinder with a diameter of 5 mm and a length of 20 mm. The magnetic flux fluctuations caused by the brownian motion of the electrons are measured inductively by two dc-SQUID magnetometers simultaneously. The signals from these two channels are cross-correlated. This leads to a reduction of parasitic noise by more than one order of magnitude. Applying this technique together with the highly sensitive SQUID preamplifiers allows the measurement of the tiny noise powers at microkelvin temperatures. Experimentally we characterized the thermometer for temperatures between $43\,\mu$K and 0.8 K. The measuring time is approximately 400 seconds for one temperature, the extremely low heat input to the thermometer allows a continuous measurements without heating effects.

TT 7.11 Mon 12:30 HSZ 03

Manipulation of a two-photon pump in superconductor – semiconductor heterostructures — •Peter P. Orth[1], Paul Baireuther[2], Ilya Vekhter[3], and Jörg Schmalian[1] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology (KIT), , 76131 Karlsruhe, Germany — [2]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands — [3]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana, 70803, USA

We investigate the photon statistics, entanglement and squeezing of a pn-junction sandwiched between two superconducting leads, and show that such an electrically-driven photon pump generates correlated and entangled pairs of photons. In particular, we demonstrate that the squeezing of the fluctuations in the quadrature amplitudes of the emitted light can be manipulated by changing the relative phase of the order parameters of the superconductors. This reveals how macroscopic coherence of the superconducting state can be used to tailor the properties of a two-photon state.

TT 7.12 Mon 12:45 HSZ 03

Luminescence and photon coherence in superconducting pn-heterostructures — •Patrik Hlobil, Peter Orth, and Jörg Schmalian — Karlsruhe Institute of Technology, Germany

Semiconducting pn-heterostructures coupled to superconducting leads appear to be promising candidates as a source of entangled and squeezed light. Due to an applied bias voltage V, we have to use a non-equilibrium field theory approach to study the electron-photon system. Particular emphasis is placed on the consequence of the superconducting coherence for the photon statistics, the luminescence and possible feedback on the electronic system.