TT 71: Superconductivity: Cryodetectors and Cryotechnique

Time: Thursday 15:00–18:00 Location: HSZ 201

TT 71.1 Thu 15:00 HSZ 201

Photon number resolving superconducting nanowire single-photon detectors — •Ekkehart Schmidt[1], Eric Reutter[1,2], Hannes Rotzinger[2], Konstantin Ilin[1], Alexey V. Ustinov[2], and Michael Siegel[1] — [1]Institut für Mikro- und Nanoelektronische Systeme (IMS), Karlsruher Institut für Technologie, Herzstraße 16, 76187 Karlsruhe, Deutschland — [2]Physikalisches Institut (PHI), Karlsruher Institut für Technologie, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Deutschland

Superconducting nanowire single-photon detectors (SNSPDs) are attractive for a variety of applications like integrated photonics, quantum key distribution and deep space communication. They have a high detection efficiency, single photon sensitivity, low dark count rate and very good time resolution but they lack intrinsic photon number resolution (PNR). By splitting of the SNSPD in several pixels using integrated shunts [1] quasi-PNR can be achieved, thereby allowing amplitude multiplexing of detected number of photons. We developed technology and demonstrated quasi-PNR functionality of SNSPDs made of 4.9 nm thick and 80 nm wide NbN nanowires on sapphire, which were shunted by integrated palladium resistors with a resistance of ~20 Ohms. Optical excitation of these detectors with an SWIR fs-laser clearly shows a power-depending photon statistic. Further details on the study of operation and optical response of quasi-PNR SNSPD will be presented and discussed.

[1]S. Jahanmirinejad et al. Opt. Express 20 2012, 5017-5028

TT 71.2 Thu 15:15 HSZ 201

Current Sensing Noise Thermometer for Milli-Kelvin Temperatures with optimized dc-SQUIDs for Cross Correlated Readout — •Felix Mücke, Andreas Reifenberger, Marius Hempel, Daniel Richter, Sebastian Kempf, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institut für Physik, INF 227, Universität Heidelberg, 69120 Heidelberg

Within our search for easy-to-use reliable thermometers for milli-Kelvin and micro-Kelvin temperatures we recently developed a noise thermometer, where the Johnson current noise of a massive cylinder of high purity silver is monitored simultaniously by two current sensing dc-SQUIDs. The Si-Chip carrying the two SQUIDS is glued directly onto the noise source. Operating both SQUIDS in voltage biased mode in 2-stage SQUID configurations allows to reduce the power dissipation as well as the noise of the SQUIDS to a minimum. By computing the cross-correlation of the two SQUID signals the noise contribution of the read-out is suppressed to a level which is marginal even at micro-Kelvin temperatures. To further increase the suppression we fabricated a new SQUID design with minimal mutual inductance of input and feedback coil. We compare the thermometer to a previously developed magnetic field fluctuation thermometer in the temperature range from 2.5 K down to 9 mK. Statistical uncertainties below 0.5 % are achieved within 10 s of measurement time. Within this uncertainty no self heating was observable at base temperature. This agrees with predictions from the thermal model of the thermometer, which suggests that self heating should be marginal even at temperatures well below 1 mK.

TT 71.3 Thu 15:30 HSZ 201

Development and Implementation of a New Compact Low-Noise Pulse Tube Cryocooler for Temperatures of 5 - 10 K — •Bernd Schmidt[1,2], Matthias Vorholzer[1,2], Marc Dietrich[1], 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, Justus-Liebig-University Giessen, Germany

Two-stage Pulse Tube Cryocoolers (PTC) are closed-cycle machines which provide cooling power near 4 K without the necessity of regularly buying and refilling Helium. In addition, PTC show lower intrinsic disturbances than other closed-cycle cryocoolers.

Since the invention of 4 K two-stage PTCs, further developments aimed at high cooling powers in order to compete with GM-cryocoolers. However, sensitive applications suffer from intrinsic disturbances of the cryocooler. To address this issue, the development of PTCs with small cooling powers is essential.

In this talk we present the development of a new two-stage GM-type PTC, designed to work with only 1 kW input power. After modeling the PTC, a first prototype was fabricated and then operated and optimized. Up to now, the PTC reaches a minimum temperature of about 4 K and provides a cooling power of 50 mW at 5 K, which is sufficient for cooling small cryoelectronic or optical devices. A comparison of the simulated and measured cooling performance will also be presented.

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TT 71.4 Thu 15:45 HSZ 201

High efficiency thermoelectric devices based on superconductor-quantum dot hybrid — •Sun-Yong Hwang[1,2], Rosa Lopez[2], and David Sanchez[2] — [1]Theoretische Physik, Universitat Duisburg-Essen, D-47048 Duisburg, Germany — [2]Institut de Física Interdisciplinària i Sistemes Complexos IFISC (UIB-CSIC), E-07122 Palma de Mallorca, Spain

Superconductors are perfect electric conductors but poor thermal conductors which would be excellent for generating thermoelectric effects. However, the superconducting density of states exhibits particle-hole symmetry suppressing the thermovoltage creation. Therefore, one needs to devise a way to break this symmetry for thermoelectric applications. We propose that superconductor-quantum dot hybrid systems can pave the way for versatile thermoelectric devices with high efficiencies. By attaching a ferromagnetic lead to the quantum dot, this device can act as a thermoelectric engine with a large figure-of-merit ZT [1]. Moreover, nonlinear thermocurrents of this device show strong rectification and diode effects [2]. We also discuss interesting nonlinear cross coupling effects in the subgap regime [3]. Importantly, this device can be easily tunable by a gate potential and a magnetic field applied to the quantum dot.

[1] S.-Y. Hwang et al., Phys. Rev. B 94, 054506 (2016).
[2] S.-Y. Hwang et al., New J. Phys. 18, 093024 (2016).
[3] S.-Y. Hwang et al., Phys. Rev. B 91, 104518 (2015).

TT 71.5 Thu 16:00 HSZ 201

Silicon as an optical material for precision applications at cryogenic temperatures — •Rene Glaser[1], Stefanie Kroker[2], Johannes Dickmann[2], Carol B. Rojas-Hurtado[2], and Ronny Nawrodt[1] — [1]Friedrich-Schiller University Jena, Institute for Solid State Physics, Helmholtzweg 5, 07743 Jena, Germany — [2]Physikalisch-Technische Bundesanstalt, Metrology for Functional Nanosystems, Bundesallee 100, 38116 Braunschweig, Germany

Silicon is a promising candidate material for precision instrumentation applications such as laser stabilization cavities or future interferometric gravitational wave detectors. Here, applications benefit from the low opto-mechanical noise and its excellent thermal properties.

We present a systematic study of optical properties of silicon-based optical components and show the influence of optical properties on the metrological applications. The focus of our studies lies on properties at 1550 nm in a wide temperature range from 4.2 K to 300 K.

TT 71.6 Thu 16:15 HSZ 201

Electric Field Dependence of Nuclear Quadrupole driven Relaxation in Glasses at Very Low Temperatures — •Annina Luck, Andreas Schaller, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institut für Physik, Universität Heidelberg, INF 227, D-69120 Heidelberg

The universal behavior of amorphous solids at low temperatures, governed by two level tunneling systems and described by the standard tunneling model, has long been a generally accepted fact. Broadband dielectric measurements of glasses containing significant amounts of isotopes carrying very large nuclear electric quadrupole moments, have, however, revealed a relaxation mechanism involving nuclear spins, which is dominant at low frequencies and at temperatures below several hundred millikelvin. In particular, we have measured dielectric properties over eight orders of magnitude in frequency performed on the two multicomponent glasses N-KZFS11 and HY-1, containing significant amounts of tantalum and holmium respectively. As ^{181}Ta and ^{165}Ho both carry very large nuclear electric quadrupole moments, these glasses are ideal candidates to investigate the influence of these moments. In the regime where the nuclear spin enabled relaxation dominates, both glasses show a fundamentally different response to high electric fields, than observed in other glasses and predicted by theory. The observed saturation of the nuclear driven relaxation process at high fields allows a clear distinction between nuclear spin and phonon enabled effects and can help us gain a more detailed insight into the microscopic origin of the nuclear driven relaxation process.

15 min. break.

TT 71.7 Thu 16:45 HSZ 201

Development of a 64 pixel metallic magnetic calorimeter based detector array with integrated microwave SQUID multiplexer — •Mathias Wegner, Loredana Gastaldo, Andreas Fleischmann, Michael Keller, Daniel Richter, Sebastian Kempf, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, D-69120 Heidelberg

Microwave SQUID multiplexing (μMUXing) appears to be the most promising readout technique for arrays of low-temperature microcalorimeters requiring a large bandwidth per pixel. It is therefore highly suited for reading out metallic magnetic calorimeters (MMCs) that uniquely combine an intrinsically fast signal rise time, an excellent energy resolution and a highly linear detector response.

In this contribution we present the first demonstration of μMUXing of MMCs using a 64 pixel detector array that is read out by an integrated, on-chip multiplexer. Each detector features two $5\,\mu$m thick X-ray absorbers and is optimized for soft X-ray spectroscopy. The estimated energy resolution for all pixels within the array is below 10 eV. We will present our design and discuss a detailed characterization of the device. In particular, we will show that its performance is as expected when considering the geometry and the thermodynamical properties of the detectors as well as the multiplexer parameters. In addition, we will summarize the status of the development of a software defined radio based readout electronics as well as our advances concerning flux ramp modulation which we will use for linearizing the multiplexer output signal.

TT 71.8 Thu 17:00 HSZ 201

Development of a combined photon and phonon detector for rare-event experiments — •Clemens Hassel[1], Felix Ahrens[1], Christian Enss[1], Andreas Fleischmann[1], Loredana Gastaldo[1], Sebastian Kempf[1], Yong-Hamb Kim[2], Wonsik Yoon[2], Martin Loidl[3], Xavier-Francois Navick[3], and Matias Rodrigues[3] — [1]Kirchhoff-Institute for Physics, Heidelberg University, Germany. — [2]IBS Center for Underground Physics, Daejeon, Rep. of Korea — [3]CEA, Saclay, France.

Scintillating crystals in cryogenic experiments searching for a direct interaction of dark matter particles and for the neutrinoless double beta decay, as in AMoRE or LUMINEU, allow for an efficient active background reduction due to particle mass discrimination. This is achieved by the simultaneous measurements of heat and light generated by the interaction of a particle in the scintillating crystal. We are developing phonon and large area photon detectors based on metallic magnetic calorimeters (MMCs) to readout both types of excitations. We will present the design for a photon detector P1 with an expected energy resolution of $\Delta E_{\mathrm{FWHM}} < 5$ eV and a signal rise time of $\tau < 50\ \mu s$ and discuss its fabrication and first experimental results. Furthermore we will present the design and the fabrication of the integrated photon and phonon detector P2, with a light detector inspired by P1 and three phonon sensors with $\Delta E_{\mathrm{FWHM}} < 100$ eV and $\tau < 200\ \mu s$ on the same chip. This allows for a very efficient readout, a minimum of material for support structures and further background reduction by position sensitive phonon signals.

TT 71.9 Thu 17:15 HSZ 201

Development of metallic magnetic micro-calorimeters for ECHo — •Dorothea Fonnesu for the ECHo-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University, Germany.

The Electron Capture ^{163}Ho experiment ECHo aims to probe the electron neutrino mass on a sub-eV level via analysis of the calorimetrically measured electron capture spectrum of ^{163}Ho. For this metallic magnetic calorimeters (MMC) will be used, which are operated at millikelvin temperature. The performance achieved by first prototypes of MMC detector arrays with embedded ^{163}Ho already show that an energy resolution of $\Delta E_{\mathrm{FWHM}} <$ 3eV and a signal rise time of $\tau <$ 1 μs for ECHo can be reached. We present the current status of the detector developments for ECHo-1k, which is the first phase of the experiment with an activity of 1 kBq of the source and an expected sensitivity on the neutrino mass of below 10 eV. This includes the design and fabrication of the ECHo-1k detector and the necessary not standard fabrication processes to prepare the detector for the ion implantation of ^{163}Ho at RISIKO in Mainz. We also present simulations and experimental studies concerning the implantation process itself and measurements of the expected additional heat capacity of the detector due to the implantation of ^{163}Ho which is a crucial parameter for the detector performance.

TT 71.10 Thu 17:30 HSZ 201

SiM-X: The first step towards a large silicon microcalorimeter array — •Pascal Andree Scholz[1], Victor Andrianov[2], Artur Echler[3,4], Peter Egelhof[3,4], Oleg Kiselev[3], Saskia Kraft-Bermuth[1], and Damian Muell[1] — [1]Justus-Liebig-Universität, Giessen, Germany — [2]Lomonosov Moscow State University, Moscow, Russia — [3]GSI Helmholtz Center, Darmstadt, Germany — [4]Johannes-Gutenberg Universität, Mainz, Germany

High-precision X-ray spectroscopy of highly-charged heavy ions provides a sensitive test of quantum electrodynamics in very strong Coulomb fields. Due to their excellent energy resolution for X-ray energies around 100 keV, silicon microcalorimeters, based on silicon thermistors and tin absorbers, have already demonstrated their potential to improve the precision in previous experiments at the Experimental Storage Ring (ESR) of the GSI Helmholtz Center for Heavy Ion Research. In june 2016 a new compact detector design along with a new cryogen-free cryostat equipped with a pulse tube cooler was applied in a test experiment at the ESR. This test was an important benchmark for designing a larger detector array with three times the active detector area, which is currently in preparation, and, thus, with an improved lateral sensitivity and statistical accuracy. In this presentation, we will introduce the ESR test experiment following results and discuss current developments and potential future applications.

TT 71.11 Thu 17:45 HSZ 201

Application of Calorimetric Low Temperature Detectors for the Investigation of Z-Yield Distributions of Fission Fragments — •Santwana Dubey[1,2], Shawn Bishop[4], Aurelien Blanc[5], Johannes O. Denschlag[2], Artur Echler[1,2], Peter Egelhof[1,2], Friedrich Goennenwein[6], Jose Gomez[4], Patrick Grabitz[1,2], Ulli Koester[5], Saskia Kraft-Bermuth[3], Werner Lauterfeld[2], Manfred Mutterer[1], Pascal Scholz[3], and Stefan Stolte[2] — [1]GSI, Germany — [2]Univ. Mainz, Germany — [3]Univ. Giessen, Germany — [4]Technical Univ. Munich, Germany — [5]ILL Grenoble, France — [6]Univ. Tübingen, Germany

Precise fission fragment yield data are of great interest for a better understanding of the fission process. In a recent experiment, performed at the research reactor ILL Grenoble, Calorimetric Low Temperature Detectors (CLTDs) were applied for the first time for the investigation of Z-yield distributions of fission fragments. Fission fragments, produced by thermal neutron induced fission of 235U, were passed through the LOHENGRIN separator to filter required mass and energy, followed by SiN degrader foils to separate elements with different Z within a mass, and were detected on an array of CLTDs. Preliminary data for the mass region 82<A<132 will be presented, which would lead to a better understanding of the fission process, as well as of reactor neutrino oscillations and the reactor neutrino anomaly.