TT 29: Poster Session: Cryogenic Particle Detectors and Cyotechnique

Time: Monday 15:00–19:00 Location: Poster B

TT 29.1 Mon 15:00 Poster B

Einfluss von Geometrie und Herstellungstechnologie auf das Zeitverhalten von SNSPD — Julia Brandel[1], •Oliver Brandel[1], Mario Ziegler[1], Sebastian Goerke[1], Ilya Charaev[2], Emanuel Knehr[2], Detlef Born[1], Michael Siegel[2] und Heidemarie Schmidt[1] — [1]Leibniz-Institut für Photonische Technologien e.V. (IPHT), Jena, Deutschland — [2]Karlsruher Institut für Technologie (KIT), Karlsruhe, Deutschland

Einzelphotonenzähler basierend auf ultradünnen supraleitenden Schichten (SNSPD) besitzen ein breites Anwendungsfeld von der Spektroskopie bis hin zur Quantenkryptografie, da sie in Bezug auf Dunkelzählrate und zeitlicher Genauigkeit herausragende Eigenschaften besitzen.

Die dafür eingesetzten Niobnitridschichten (NbN) wurden bislang mittels Reakivem Magnetron Sputtern hergestellt. Am IPHT wurde eine alternative Herstellungstechnologie entwickelt, mit der es möglich ist, diese Schichten durch Atomlagenabscheidung (ALD) herzustellen. Durch ALD wird neben einer idealen Schichtdickenkontrolle während des Herstellungsprozesses auch die Abscheidung auf dreidimensionalen Strukturen ermöglicht.

In unserem Beitrag werden sowohl die allgemeinen Schichteigenschaften der unterschiedlichen Herstellungstechnologien als auch der Einfluss der geometrischen Strukturierung des SNSPD untersucht.

TT 29.2 Mon 15:00 Poster B

MetroBeta: Beta Spectrometry with Metallic Magnetic Calorimeters in the Framework of the European Program of Ionizing Radiation Metrology — •Michael Paulsen[1,3], Jörn Beyer[1], Lina Bockhorn[2], Christian Enss[3], Daniel Györi[3], Sebastian Kempf[3], Karsten Kossert[2], Martin Loidl[4], Riham Mariam[4], Ole Nähle[2], Matias Rodrigues[4], and Marco Schmidt[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [3]Kirchhoff-Institute for Physics, Heidelberg University, Germany — [4]CEA, LIST, Laboratoire National Henri Becquerel, Saclay, France

MetroBeta is a European project that aims to improve the theoretical calculation and measurement of beta spectrum shapes. The project is part of a common European program of ionizing radiation metrology. The precise knowledge of beta spectrum shapes is required for measuring the activity of pure beta emitters, thus realizing the Becquerel unit for these nuclides. Metallic magnetic calorimeters (MMCs) with the beta emitter sample embedded in the absorber have proven to be among the best beta spectrometers. Four beta spectra will be measured: Sm-151 (Q = 76.3 keV), C-14 (Q = 156.5 keV), Tc-99 (Q = 293.8 keV), Cl-36 (Q = 709.5 keV). A crucial part of the research and development is concerned with source and absorber preparation techniques, which includes producing high quality nuclide samples that need to be integrated into the MMC absorbers.

TT 29.3 Mon 15:00 Poster B

Flux ramp modulation for Microwave SQUID Multiplexing — •Daniel Richter, Mathias Wegner, Andreas Fleischmann, Sebastian Kempf, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany.

Microwave SQUID multiplexing (μMUXing) based on non-hysteretic rf-SQUIDs appears to be the most suitable multiplexing technique to read out metallic magnetic calorimeter (MMC) arrays. The intrinsically fast signal rise time of MMCs, for example, can be maintained by providing sufficient bandwidth per channel. However, since rf-SQUIDs are intrinsically non-linear devices due to their periodic flux-to-voltage characteristic, the almost ideal linear detector response of MMCs is degraded unless suitable counter-measures are applied. Standard feedback techniques such as flux-locked loop can't be adapted for a microwave SQUID multiplexer since individual feedback lines would have to be routed to each pixel. In contrast, modulation techniques such as flux ramp modulation provide a conceptually easy solution for linearizing the output signal of the multiplexer.

In this contribution, we will first introduce the basic concept of flux ramp modulation. We will then discuss proof-of-principle as well as comprehensive characterization measurements for which we used customized dc-SQUIDs as well as a microwave SQUID multiplexer. Finally, we will outline present challenges as well as other applications where flux ramp modulation might significantly simplify the SQUID based readout.

TT 29.4 Mon 15:00 Poster B

Superconducting GHz Resonators for Microwave SQUID Multiplexing of MMCs — •Felix Ahrens, Mathias Wegner, Andreas Fleischmann, Sebastian Kempf, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University, Germany

Microwave SQUID multiplexing is the most promising way to read out large metallic magnetic calorimeter (MMC) detector arrays. A key element of cryogenic multiplexing is superconducting GHz resonators, which provide the required frequency encoding. To maintain the very fast signal rise time of MMCs we design our resonators to have a bandwidth of $\sim$1 MHz. This value directly sets the required frequency spacing between two neighbouring channels to $\sim$10 MHz taking into account our present fabrication accuracy and the required crosstalk level below 10^{-4}. Using capacitively coupled CPW transmission line resonators, the resonance frequency f_r and the loaded quality factor Q_l of a resonator can be set by adjusting the resonator length and the geometry of the coupling capacitor. We simulate the electromagnetic properties of different coupler geometries to find a proper resonator design matching our readout requirements. Since both f_r and Q_l depend strongly on the accuracy of the physical resonator dimensions, we optimise the microfabrication process in order to minimise fabrication inaccuracies. In addition, to minimise the influence of stray light, the kinetic inductance and tunnelling systems causing low-frequency phase noise, we investigate different superconducting materials. In this contribution, we present different aspects related to the optimisation of our superconducting resonators.

TT 29.5 Mon 15:00 Poster B

Characterisation of a MMC-based integrated photon and phonon detector for $0\nu\beta\beta$ search — •Patricia Kuntz[1], Daniel Unger[1], Clemens Hassel[1], Felix Ahrens[1], Christian Enss[1], Andreas Fleischmann[1], Loredana Gastaldo[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

In the search for $0\nu\beta\beta$, scintillating crystals in cryogenic experiments allow for an efficient background reduction due to active particle discrimination. This is achieved by the simultaneous measurement of heat and light generated upon the interaction of a particle in a scintillating crystal. We developed, in the framework of the AMoRE and LUMINEU experiments, for the search of $0\nu\beta\beta$ in ^{100}Mo, large area integrated photon and phonon detectors based on metallic magnetic calorimeters (MMCs) able to simultaneously measure the two signals. We will present the design of the P2 detector, which consists of a photon detector, with an expected energy resolution of $\Delta E_\mathrm{FWHM} <$ 10 eV and a demonstrated signal rise time of $\tau < 50\ \mu s$ and three phonon detectors with expected $\Delta E_\mathrm{FWHM} <$ 100 eV and $\tau < 200\ \mu s$. Furthermore, we will discuss experimental results obtained from the characterization of a P2 detector, still without any scintillating crystal, using an external x-ray calibration source. For the first time, we could investigate the time response of the four detectors on the P2 wafer, the energy resolution as well as the crosstalk among the detectors.

TT 29.6 Mon 15:00 Poster B

Towards X-ray spectroscopy with sub-eV energy resolution: Metallic magnetic calorimeters with direct sensor readout. — •Matthäus Krantz, Sebastian Kempf, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany.

Metallic magnetic calorimeters (MMCs) are energy dispersive particle detectors that are typically operated well below 100 mK. They make use of a paramagnetic temperature sensor to convert the energy deposited by an X-ray photon within an absorber into a change of sensor magnetization which can be precisely measured using a SQUID. For state-of-the-art detectors, the temperature sensor is transformer-coupled to the input coil of a current-sensing SQUID. However, parasitic inductances in the flux transformer, as well as transformer losses, lead to a reduction of the signal size, therefore impairing the energy resolution. For this reason we have started to develop detectors with direct sensor readout for which the temperature sensor is placed on top of the SQUID loop to maximize signal coupling. In our present design the SQUID is a first-order parallel gradiometer with meander-shaped SQUID inductance. Due to the greatly enhanced flux coupling as well as optimized SQUID parameters we expect this detector to surpass our current MMC world record energy resolution of 1.6 eV (FWHM) for 6 keV X-rays and push the present limit well below 1 eV. We discuss the optimization process, design and microfabrication processes as well as very recent results for these devices.

TT 29.7 Mon 15:00 Poster B

Gamma spectroscopy to measure the ^{229}Th isomer energy using a 2-dimensional array of metallic magnetic microcalorimeters — •J. Geist[1], J. Bussmann[1], D. Hengstler[1], M. Krantz[1], R. Pons[1], P. Schneider[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], G.A. Kazakov[2], S.P. Stellmer[2], and T. Schumm[2] — [1]Heidelberg University — [2]Vienna University of Technology

The isotope ^{229}Th has a nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physic with a potential application in a nuclear clock. In order to verify and improve the accuracy of the currently most accepted energy value, (7.8 ± 0.5) eV, we want to resolve the 29.18 keV doublet in the γ-spectrum following the α-decay of ^{233}U, corresponding to the decay into the ground and isomer state, to measure the isomer transition energy without additional theoretical input parameters.

We developed the detector array maXs-30 consisting of 8x8 metallic magnetic calorimeters with an expected energy resolution below 6 eV, providing a large detection area of 16 mm^2 to face the low rate of the 29.18 keV transitions.

In first measurements we observed the 29.18 keV transitions as a single peak with an instrumental resolution of 33 eV.A strong background contribution due to β-radiation from accumulated decay products in the ^{233}U-source was discovered. We present results of the latest measurements with an adjusted maXs-30 detector, new generation SQUIDs and an updated setup in the cryostat.

TT 29.8 Mon 15:00 Poster B

Polar-maXs: Micro-calorimeter based x-ray polarimeters — •C. Schötz[1], D. Hengstler[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], G. Weber[2,3], R. Märtin[2,3], O.M. Herdrich[4], and Th. Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]Helmholtz Institute Jena — [3]GSI Darmstadt — [4]Jena University

We are developing the x-ray detector system polar-maXs, which will combine for the first time the high energy resolution, large dynamic range and excellent linearity of magnetic micro-calorimeters with the idea of a Compton- or Rayleigh-polarimeter.

The x-ray polarimeter comprises two layers. The first layer consists of a scatterer behind a corresponding collimator. Depending on the energy range of interest and whether Compton or Rayleigh scattering is to be used, this scatterer are fabricated from low-Z or high-Z material. The active scatter area is 32mm in diameter. The second layer is the detector itself which is based on microfabricated metallic magnetic calorimeters (MMC). The scattered x-rays are detected by an array of 64 x-ray absorbers and read-out by 64 paramagnetic temperature sensors. The latter are arranged to form a rectangular frame which is protected from direct x-ray hits by the collimator. Each absorber covers an area of 1.250mm x 1.250mm and is made of 30 micrometer thick gold, to guarantee high stopping power for x-rays with energies up to 30 keV and an energy resolution of better than 20eV (FWHM) in the complete energy range. We discuss the results of Monte-Carlo simulations for a variety of scatter materials as well as first measurements at 20mK in a dilution refrigerator.

TT 29.9 Mon 15:00 Poster B

MOCCA: A 4k-pixel molecule camera for the position and energy resolving detection of neutral molecule fragments at the Cryogenic Storage Ring CSR — •Dennis Schulz[1], Steffen Allgeier[1], Christian Enss[1], Andreas Fleischmann[1], Lisa Gamer[1], Loredana Gastaldo[1], Sebastian Kempf[1], Oldřich Novotný[2], and Andreas Wolf[2] — [1]Kirchhoff-Institute for Physics, Heidelberg — [2]Max Planck Institute for Nuclear Physics, Heidelberg

The Cryogenic Storage Ring CSR at the Max Planck Institute for Nuclear Physics in Heidelberg can be used to prepare and store molecular ions in their rotational and vibrational ground states, enabling state-resolved studies on electron-ion interactions. The use of Metallic Magnetic Calorimeters for particle detection allows for identifying all neutral reaction products, using the deposited energy of incident particles into MMC absorbers as a measure of the particle mass. To resolve the complete reaction kinematics, a position sensitive coincident detection of multiple reaction products is necessary.

For those measurements we designed MOCCA, a 4k-pixel molecule camera based on MMCs with a detection area of 45 mm×45 mm, which is segmented into 64×64 absorbers and read out using only 32 SQUIDs. We discuss the detector design, multi-hit capability, cross-talk and the integration of its ^{3}He/^{4}He dilution refrigerator into the setup of the CSR. We show first measurements and the expected energy resolution.

TT 29.10 Mon 15:00 Poster B

Cross Correlated Noise Thermometer for Milli-Kelvin Temperatures — •Christian Ständer, Andreas Reifenberger, Felix Mücke, Marius Hempel, Daniel Richter, Sebastian Kempf, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University.

Within our search for easy-to-use reliable thermometers for milli-Kelvin and micro-Kelvin temperatures we developed a noise thermometer, where the Johnson noise of a massive cylinder of high purity (5N) silver is monitored simultaneously by two current sensing dc-SQUIDs. 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 cross-correlating the two SQUID signals the noise contribution of the read-out-electronics is suppressed to a marginal level even at micro-Kelvin temperatures. To further reduce the correlated amplifier noise we fabricated SQUIDs with a new design featuring minimal coupling of input and feedback coil. We compare two thermometers of this type to a previously developed noise thermometer in the temperature range from 3K down to 4mK. Statistical uncertainties below 0.5% are achieved within 10s of measurement time. Within this uncertainty no self-heating was observable at base temperature.

TT 29.11 Mon 15:00 Poster B

Quickly Tunable Rerigerator for Superconducting Quantum Circuits — •Vasilii Sevriuk[1], Kuan Tan[1], Shumpei Masuda[1], Jan Goetz[1], Matti Partanen[1], Dibyendu Hazra[1], Eric Hyyppä[1], Joonas Govenius[1], Russell Lake[2], Visa Vesterinen[3], Leif Grönberg[3], Juha Hassel[3], Slavomir Simbierowicz[3], Marton Gunyho[1], Aarne Keränen[1], Jani Tuorila[1], Tapio Ala-Nissila[4], Matti Silveri[1], Hermann Grabert[5], and Mikko Möttönen[1] — [1]QCD Labs, COMP Centre of Excellence, Department of Applied Physics, Aalto University, PO Box 13500, FI-00076 Aalto, Finland — [2]National Institute of Standards and Technology, Boulder, CO, United States. — [3]VTT Technical Research Centre of Finland Ltd, VTT, Finland. — [4]Departments of Mathematical Sciences and Physics, Loughborough University, Loughborough, United Kingdom. — [5]Department of Physics, University of Freiburg, Freiburg, Germany.

In the past decade, the research on superconducting quantum circuits has provided a great number of superior microwave components such as superconducting qubits, amplifiers, and sensors. Especially in the opertation of qubits, it is of utmost importance to be able to quickly remove any unwanted qubit excitations on demand for fast and accurate initialization. We recently introduced a device referred to as a quantum-circuit rerigerator [K. Y. Tan, et al., Nat. Commun. 8, 15189 (2017)]. In our experiments, we show how we can tune the dissipation of a superconducting resonator by orders of magnitude just by applying a bias voltage on the refrigerator. The time scale for switching the dissipation on and off is in the nanosecond range.

TT 29.12 Mon 15:00 Poster B

Applications for "Dry" Cooling with damped two-stage Pulse Tube Cryocoolers at their low temperature limit — •Jack-André Schmidt[1,2], Jens Falter[1], Bernd Schmidt[1,2], Günther Thummes[1,2], and André Schirmeisen[1,2] — [1]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany, — [2]Institute of Applied Physics (IAP), Justus-Liebig-University Giessen, Germany

Today's scientific research often requires cooling systems that provide low background noise and high cooling performance. Pulse Tube Cryocoolers (PTC) [1] fulfill these requirements and combine them with a regenerative system for long time measurements. PTCs are a preferable choice of "dry" cryostats because of the absence of moving parts inside the cold head.

PTCs are filled with a working gas (Helium), which is compressed and expanded in cycles of about 1-2 Hz. This induces intrinsic mechanical and thermal variation in all systems with cryocoolers. As a consequence the adaptation of PTCs to sensitive equipment is a complex procedure and needs intricate techniques for thermal as well as mechanical damping. In this work we present the intrinsic variations of PTCs with strategies to minimize the influence on delicate equipment for long time measurements [2]. Different temperature and vibration damping units and cryostat designs are discussed, together with a presentation of the cooling performance of PTCs working under these conditions.

[1] G. Thummes, Cryogenics, Vol. 38, (1998) 337
[2] R. Schrödel et al., Meas. Sci. Technol. 23 (2012) 094004

TT 29.13 Mon 15:00 Poster B

A versatile demagnetization refrigerator — •Alexander Regnat, Jan Spallek, Christopher Duvinage, and Christian Pfleiderer — Physik Department, Technische Universität München

Cooling devices providing temperatures well below 1 K are a key prerequisite for modern research and development, e.g., in materials science, quantum applications and the cooling of sensors and detectors. Here we present a versatile and compact demagnetization refrigerator for the cryogen-free generation of sub-Kelvin temperatures.

TT 29.14 Mon 15:00 Poster B

Lab::Measurement – measurement control with Perl — •Simon Reinhardt[1], Charles E. Lane[2], Christian Butschkow[1], Alexei Iankilevitch[1], Alois Dirnaichner[1], and Andreas K. Hüttel[1] — [1]Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany — [2]Department of Physics, Drexel University, Philadelphia, USA

`Lab::Measurement` is a collection of Perl 5 modules providing control of test and measurement devices. It allows for quickly setting up varying and evolving complex measurement tasks with diverse hardware. Instruments can be connected by means such as GPIB (IEEE 488.2), USB-TMC, or VXI-11 / raw network sockets via Ethernet. Internally, third-party backends as e.g. Linux-GPIB, National Instruments' NI-VISA library or Zurich Instruments' LabOne API are used, as well as lightweight drivers for USB and TCP/IP-based protocols. The wide range of supported connection backends enables cross-platform portability. Dedicated instrument driver classes relieve the user from taking care of internal or vendor-specific details. A high-level layer provides fast and flexible creation of nested measurement loops, where e.g. several input variables are varied and output data is logged into a customizable folder structure. `Lab::Measurement` has already been successfully used in several low temperature transport spectroscopy setups. It is free software and available at `http://www.labmeasurement.de/`

TT 29.15 Mon 15:00 Poster B

Phase-sensitive dynamic susceptibility measurement in a pulsed magnetic field — •Lars Postulka, Bernd Wolf, and Michael Lang — Physikalisches Institut, Goethe Universität, SFB/TR49, Frankfurt, DE

Dynamic susceptibility, commonly referred to AC susceptibility, is a powerful tool to characterize magnetic phase transition or spin relaxation processes in the presence of a magnetic field. The standard technique for accessing this quantity is based on measurements of the voltage in a coil which is induced by magnetization changes of a sample due to a small outer oscillating field. Importantly, this setup allows for a phase-sensitive detection of the susceptibility, thereby providing direct access to the dynamics of the spin system. This method is well established for the use in constant magnetic fields. However, in modern solid state physics, interesting physical phenomena emerge in high fields, conveniently accessible by the use of pulsed-field technology. Whereas various techniques to infer the in-phase part of the susceptibility are regularly used, methods to determine the out-of-phase part have not yet been reported. Here we present the first realization of an AC susceptometer for measurements in pulsed field. In particular, we focus on technical aspects including all electronic devices and a possible coil design. We prove the feasibility by measurements of the susceptibility on a spin chain compound.

TT 29.16 Mon 15:00 Poster B

A low-temperature vector-field ultrahigh vacuum scanning tunneling microscope facility for the study of quantum materials — •Qingyu He, Xinglu Que, Lihui Zhou, Andreas Rost, and Hidenori Takagi — Max-Planck Institute ,Heisenberg Strasse 1, Vaihingen, Stuttgart, Germany

A low-temperature vector-field ultrahigh vacuum scanning tunneling microscope facility for the study of quantum materials

Scanning tunneling microscopes (STM) play a very important role in the study of quantum materials by correlating electronic properties with structures at the atomic scale. In my poster, I will present our home built ultrahigh vacuum STM facility with a base temperature of 1.2 K. A 3 T vector field as well as 9 T perpendicular to the sample surface can be applied. It features a compact design and has a long holding time. Updating with a 3He refrigerator is ongoing, which will enable us to reach a higher energy resolution.