TT 17: Cryogenic Detectors and Cryotechnique

Time: Wednesday 9:30–12:00 Location: H22

TT 17.1 Wed 9:30 H22

TES sensors design for the CRESST experiment — •Francesca Pucci[1], Antonio Bento[1,2], Anna Bertolini[1], Lucia Canonica[1], Nahuel Ferreiro Iachellini[1,3], Abhiji Garai[1], Dieter Hauff[1], Athoy Nilima[1], Michele Mancuso[1], Federica Petricca[1], Franz Proebst[1], and Dominik Fuchs[1] — [1]Max-Planck-Institut für Physik, D-80805 München, Germany — [2]LIBPhys-UC, Departamento de Fisica, Universidade de Coimbra, P3004 516 Coimbra, Portugal — [3]Excellence Cluster Origins, D-85748 Garching, Germany

The CRESST experiment aims at the direct detection of sub-GeV dark matter particles via elastic scattering off nuclei in different target crystals at cryogenic temperatures. Each detector consists of an absorber crystal and a Transition Edge Sensors (TES), which measures the temperature variations caused by an energy deposition in the crystal. The TES are made of tungsten thin films and they are operated in the middle of their superconducting transition, at around 15 mK. These very sensitive detectors allow for a leading energy threshold worldwide. The studies on the TES sensor design and its development at the Max Planck Institute for Physics are presented.

TT 17.2 Wed 9:45 H22

Beta spectrometry measurements with metallic magnetic calorimeters — •Michael Paulsen[1], Jörn Beyer[1], Christian Enss[2,6], Sebastian Kempf[3,6], Karsten Kossert[4], Martin Loidl[5], Riham Mariam[5], Ole Nähle[4], Philipp Ranitzsch[4], Matias Rodrigues[5], and Mathias Wegner[6,3] — [1]Physikalisch-Technische Bundesanstalt, Berlin, Germany — [2]Kirchhoff-Institute for Physics, Heidelberg University, Germany — [3]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [5]Université Paris-Saclay, CEA, List, Laboratoire National Henri Becquerel, Palaiseau, France — [6]Institute for Data Processing and Electronics, Karlsruhe Institute of Technology, Germany

Precise beta spectra measurements are important for radionuclide metrology, the validation of theoretical calculations and nuclear medicine. Metallic Magnetic Calorimeters (MMCs) with the radionuclide sample embedded in a 4π absorber have proven to be among the best beta spectrometers in terms of energy resolution and threshold, linearity and detection efficiency, notably for low energy beta transitions. In this work, two measurements of the spectrum of the 2nd forbidden non-unique beta transition of ^{99}Tc ($Q^- = 297.5\,\mathrm{keV}$) are presented. They were acquired using two independent MMC based detectors in two different laboratories and show excellent agreement. The results suggest a spectral shape which deviates significantly from hitherto theoretical calculations and semi-empirical extrapolations at lower energies ($< 50\,\mathrm{keV}$) reported in the literature.

TT 17.3 Wed 10:00 H22

Low-noise, impedance matched current-sensing dc-SQUIDs for magnetic microcalorimeter readout — •Fabienne Bauer[1,2], Christian Enss[1], and Sebastian Kempf[1,2] — [1]Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institute of Micro- and Nanoelectronics Systems, Karlsruhe Institute of Technology, Hertzstraße 16, 76187 Karlsruhe

Direct-current superconducting quantum interference devices (dc-SQUIDs) are the devices of choice for reading out low-impedance cryogenic particle detectors such as magnetic microcalorimeters (MMCs). MMCs use a paramagnetic or superconducting temperature sensor, placed in a weak magnetic field and inductively coupled to a superconducting pickup coil, to convert deposited energy into a change of magnetic flux threading the pickup coil. The latter is sensed using a low-noise SQUID. To maximize sensitivity and hence energy resolving power, impedance matching between SQUID and pickup coil as well as a SQUID white noise level close to the quantum limit are crucial. As current-sensing SQUIDs with input inductances between 1 nH and 10 nH and suited for mK-operation temperatures are rarely or not at all commercially available, custom SQUIDs for MMC readout must be developed. In this context, we discuss design and performance of three current-sensing dc-SQUIDs impedance matched to MMCs that are foreseen for neutrino mass investigation, X-ray spectroscopy and mass spectrometry, respectively. To achieve low-noise performance, the SQUIDs rely on the use of cross-type Josephson junctions to minimize junction capacitance and hence readout noise.

TT 17.4 Wed 10:15 H22

Flux ramp modulation based hybrid microwave SQUID multiplexer — •Constantin Schuster[1,2], Mathias Wegner[1,2], Christian Enss[1], and Sebastian Kempf[1,2] — [1]Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg — [2]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Karlsruhe

For the readout of cryogenic detector arrays, microwave SQUID multiplexers (μMUXes) are presently being developed. Using non-hysteretic rf-SQUIDs, each multiplexer channel transforms the detector signal into a change of amplitude or phase of a microwave signal probing the resonance frequency of a superconducting resonator. In this way, numerous detectors can be simultaneously read out by coupling multiple resonators to a common transmission line. The resonator bandwidth is adjusted according to the detector speed and sets a lower limit for the frequency spacing of resonators. This limit, however, can in practice only be reached if the fabrication accuracy is very high. As a result, the channel density is very often limited by fabrication rather than the inherent channel capacity of the transmission line. We present a hybrid microwave SQUID multiplexer combining two frequency-division readout techniques to allow multiplexing a given number of detectors with only a fraction of readout resonators. We present insights of our approach based on information theory and discuss benefits and drawbacks using Monte-Carlo simulations. We further discuss the performance of a prototype device indicating that our technique is very well suited for reading out ultra-large bolometric detector arrays.

TT 17.5 Wed 10:30 H22

Transport properties of superconducting thin films and superconducting single-photon detectors — •Fabian Wietschorke[1], Stefan Strohauer[2], Rasmus Flaschmann[1], Lucio Zugliani[1], Christian Schmid[1], Sven Ernst[2], Stefanie Grotowski[2], Simone Spedicato[2], Björn Jonas[1], Mirco Metz[1], Kai Müller[1], and Jonathan Finley[2] — [1]Walter Schottky Institute and Department for Electrical and Computer Engineering, Technical University of Munich, 85748 Garching, Germany — [2]Walter Schottky Institute and Physics Department, Technical University of Munich, 85748 Garching, Germany

Superconducting single-photon detectors (SSPDs) play a crucial role in the rapidly growing field of quantum communication and computation. Hereby, NbTiN is an established candidate for superconducting thin films that is used as the active part of the SSPDs. To achieve high detection efficiencies, the superconducting properties of NbTiN films, deposited via magnetron sputtering, need to be optimized. In this contribution, we present transport measurements characterizing the influence of the deposition process onto the superconducting properties, which assists in a systematic optimization of the detectors. We are able to estimate detection efficiency and depairing current of the SSPDs, even before fabricating the nanostructures, utilizing the hotspot model and the Ginzburg-Landau model. Finally, we use the thin film transport measurements and detector measurements to assess the quality of our nanofabrication process.

15 min. break

TT 17.6 Wed 11:00 H22

Opimization of MoSi film deposition for superconducting single-photon detectors in the telecom c-band — •Stefanie Grotowski[1], Lucio Zugliani[2], Rasmus Flaschmann[2], Stefan Strohauer[1], Christian Schmid[2], Fabian Wietschorke[2], Sven Ernst[1], Simone Spedicato[1], Mirco Metz[2], Björn Jonas[2], Kai Müller[2], and Jonathan Finley[1] — [1]Walter Schottky Institute and Physics Department, Technical University of Munich, Germany — [2]Walter Schottky Institute and Department for Electrical and Computer Engineering, Technical University of Munich, Germany

Superconducting single-photon detectors (SSPDs) are a crucial building block for photonic quantum technologies. With regard to the telecommunication infrastructure, SSPDs sensitive in the telecom c-band are required. A promising material in this regard is MoSi, as it unites a small superconducting energy gap enabling high sensitivity while maintaining a high transition temperature. In this work we aim at optimizing the magnetron co-sputtering deposition to achieve high transition temperatures (T_c). We vary the stoichiometry and find maximized T_c values for Mo rich films until an upper limit of around 80% Mo is reached. Above this critical concentation grazing incidence diffration reveals the transition to a polycrystalline phase in the material. Moverover, the working pressure during deposition influences both T_c and structure as well. We find that a low working pressure improves the T_c, but a minimum pressure is required to ensure an amorphous deposition. Finally, with the optimized parameter set we measured a T_c of 8.4 K for 20 nm and 6.2 K for 4.5 nm thin films.

TT 17.7 Wed 11:15 H22

Superconducting single-photon detectors on lithium-niobate-on-insulator — •Christian Schmid[1], Rasmus Flaschmann[1], Lucio Zugliani[1], Stefan Strohauer[2], Björn Jonas[1], Fabian Wietschorke[1], Sven Ernst[2], Stefanie Grotowski[2], Simone Speticato[2], Mirco Metz[1], Kai Müller[1], and Jonathan Finley[2] — [1]Walter Schottky Institute and Department for Electrical and Computer Engineering, Technical University of Munich, Germany — [2]Walter Schottky Institute and Physics Department, Technical University of Munich, Germany

Superconducting single-photon detectors (SSPDs) are a key building block in photon-based quantum computation and communication. To realize a scalable photonic quantum computer, integration of single-photon sources, electronics and crucially SSPDs is necessary. One of the most promising material platforms for quantum photonic integration is lithium-niobate-on-insulator (LNOI), which offers a broad optical window and a large non-linearity.
In this work, we present the thin film superconducting properties of NbTiN grown on crystalline LNOI and compare them to films deposited on amorphous Si/SiO_2 wafer. SSPDs fabricated from films on both substrates are further characterized with respect to their quantum efficiency, dark count rate, recovery time and timing jitter.

TT 17.8 Wed 11:30 H22

Cooling performance of a 4 K two-stage pulse tube cryocooler in tilted operation along main azimuthal orientations — •Jack-Andre Schmidt[1,2], Bernd Schmidt[1,2], Jens Falter[1,2], and Andre Schirmeisen[1,2] — [1]Justus-Liebig-University Giessen — [2]TransMIT GmbH

Closed-cycle cryocoolers, here Gifford-McMahon (GM) type pulse tube cryocoolers (PTC), offer long measurement periods and low maintenance, but they exhibit undesired intrinsic effects due to the working principle [1]. Cooling performance of GM-type PTCs is strongly depending on the orientation and is set to be strictly vertical, which is not suitable for experiments where the cryostat needs to be tilted [2, 3]. We report an experimental study of the effect of tilting from vertical orientation on the cooling performance of a U-shaped 4 K pulse tube cryocooler (PTC) with 7 kW electrical input power. An investigation of cooling performance over tilt angles from 0 to 60 degree for selected azimuthal orientations of the PTC is performed. The non-coaxial arrangement of the tubes suggests an asymmetric cooling performance while tilting along the first or second stage heat exchanger due to natural convection in the pulse tubes [3]. The increase of no-load temperatures upon tilting by +/- 50 degree will be discussed. While the regime of tilt angles within 30 show moderate loss in cooling power an almost sudden decrease of cooling power is revealed and analyzed for high tilt angles.
[1] G. Thummes et al., Cryocoolers 9 (1997) 393
[2] T. Tsan et al., Cryogenics 117 (2021) 103323
[3] C. Risacher et al., IEEE 39 (2014)
[4] L. Zhang, et al., Cryogenics 51 (2011) 85

TT 17.9 Wed 11:45 H22

Cross Correlated Current Noise Thermometer for Milli-Kelvin Temperatures — •Christian Ständer, Pascal Willer, Nathalie Probst, Andreas Reifenberger, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University.

Within our search for easy-to-use and 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 silver is monitored simultaneously by two current sensing dc-SQUIDs. Operating each SQUID in voltage bias mode in a 2-stage configuration allows to reduce the power dissipation of the SQUIDs to a minimum. To further reduce the parasitic effect of correlated amplifier noise, a mathematical method to suppress the noise coupled from the feedback to the input coil of the SQUIDs is introduced. By cross-correlating the two SQUID signals, the noise contribution of the read-out electronics is suppressed to a marginal level.
We recently assembled a first small series of such thermometers to best reliability, reproducibility and user friendliness. In the complete investigated temperature range from 4 K down to 5 mK, the measured noise power is linear in temperature. The 12 thermometers of the series agree within less than 0.1% in the complete temperature range and show a good agreement with the PTLS-2000 temperature scale. Also a new sensor material, with the goal of counteraction observed ageing effects, is introduced.