TT 82: Cryogenic Detectors and Sensors

Time: Thursday 15:00–16:30 Location: HSZ/0103

TT 82.1 Thu 15:00 HSZ/0103

2D germanium-based micro-bolometers for quantum information readout — •Julius Werner, Martina Trahms, Johannes Höfer, Frederic Gustavo, Jean-Luc Thomassin, Clemens Winkelmann, and Boris Brun — Univ. Grenoble Alpes, CEA, Grenoble INP, IRIG-Pheliqs, Grenoble, France

We develop and investigate micron-scale bolometers based on a two-dimensional hole gas (2DHG) in a Ge/SiGe semiconducting heterostructure. Such devices have promising applications for quantum sensing and the readout of quantum communication signals. The high-transparency interfaces formed between germanium and superconducting aluminum leads allow using the proximity Josephson effect in the 2DHG for thermometry, which is sensitive down to 50 mK. To enable time-resolved thermometry and bolometry with MHz-bandwidth operation, the Josephson inductance is read out via its contribution to a radio-frequency resonant circuit. We present a full thermal balance investigation of the 2DHG-based bolometer at millikelvin temperatures, allowing us to determine the thermal equilibration mechanisms at play and showcase the potential of the Ge 2DHG for quantum heat-detector applications.

TT 82.2 Thu 15:15 HSZ/0103

High-Resolution Spectroscopy of Muon Induced X-ray Emission on a Prehistoric Human Tooth using Metallic Magnetic Calorimeters — •Hendrik Hadenfeldt, Andreas Abeln, Daniel Hengstler, Daniel Kreuzberger, Andreas Reifenberg, Daniel Unger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

High-resolution X-ray spectroscopy of muonic atoms provides a powerful tool for probing nuclear and elemental properties. Muon-induced X-ray emission (MIXE), developed at the Paul-Scherrer-Institute (PSI), enables non-destructive elemental analysis. Using metallic magnetic calorimeters (MMCs), we aim to improve the precision of MIXE measurements of light muonic atoms. MMCs are low-temperature photon detectors operated at a few tens of mK. When a photon is absorbed, its energy causes an increase in the temperature of the absorber. This temperature increase leads to a change in magnetization of a paramagnetic Ag:Er sensor, which is then read out by SQUID magnetometers. In this talk, a newly developed MMC detector setup for high-resolution muonic X-ray spectroscopy used during beamtime at PSI is presented. The detector achieved an unprecedented energy resolution of better than 50 eV full width at half maximum (FWHM) at photon energies around 120 keV. Data collected during measurements performed on a prehistoric human tooth have been analyzed to demonstrate the applicability of this detector technology to non-destructive elemental analysis.

TT 82.3 Thu 15:30 HSZ/0103

High resolution measurement of the ^{65}Zn spectrum with magnetic microcalorimeters (MMCs) — •Michael Paulsen[1], Philipp Ranitzsch[2,3], Jörn Beyer[1], Alexander Göggelmann[2], Sebastian Kempf[4,5], Karsten Kossert[2], Ole Nähle[2], Constantin Schuster[1,2], Mariia Sidorova[1,2], and Mathias Wegner[5,4] — [1]Physikalisch-Technische Bundesanstalt (PTB) Berlin — [2]PTB Braunschweig — [3]DLR e.V., Hamburg — [4]IMS, Karlsruhe Institute of Technology (KIT) — [5]IPE, KIT

MMCs have proven to be among the best spectrometers for beta transitions and electron capturing (EC) radionuclides. To achieve a high energy resolution, the sensor and absorber heat capacities are kept as low as possible. Thus, the absorber dimensions are very small, yet simultaneously large enough to ensure that a sufficient detection efficiency is achieved. This is challenging when studying EC radionuclides, such as ^{65}Zn since the emission energies range from 0 to over 1 MeV for high-intensity gamma rays. We present a high-resolution spectrum of ^{65}Zn featuring K, L and M peaks below 10 keV. For the β^+ branch ($E_{\max} = 329.9$ keV), additional complications arise. Each emitted positron typically annihilates with an electron in the absorber and generates gamma rays with a combined energy of 1022 keV. These additional events cannot be time resolved by the detector due to the very short lifetimes of the positrons (~ 100 ps). This yields a distorted beta spectrum with a substantial number of counts above $E_{\max}$. We consider how this relates to the issue of detector efficiency and how to unfold such spectra using Monte-Carlo based simulation methods.

TT 82.4 Thu 15:45 HSZ/0103

A novel dilution refrigerator based microwave impedance microscopy — •Yizhou Wei and Berthold Jäck — The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

Microwave Impedance Microscopy (MIM) is an advanced imaging technique that offers remarkable sensitivity in detecting spatial variations of the electric conductivity with a spatial resolution of between 10 and 100 nanometers. This makes it a powerful tool for investigating 2D materials, especially in the context of topological and many-body physics of moiré materials. Despite its scientific potential, several technical challenges hinder the broader application of MIM for the study of quantum materials at cryogenic temperatures. Major issues are the pervasive noise introduced by dry cryogenic systems, particularly due to the pulse tube, and the thermalization of the microscopy module to temperatures below 100 mK. To address these challenges, we have designed and realized a novel MIM system that is both noise-resistant and capable of operating at ultra-low temperatures. In this talk, we will present key design considerations as well as first results from test measurements that validate the performance of our experimental setup.

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TT 82.5 Thu 16:00 HSZ/0103

Detecting single itinerant microwave photons by stroboscopic measurement — •Hanna Zeller[1], Lukas Danner[1,2], Max Hofheinz[3], Ciprian Padurariu[1], Joachim Ankerhold[1], and Björn Kubala[1,2] — [1]ICQ and IQST, Ulm University, Ulm, Germany — [2]German Aerospace Center (DLR), Institute of Quantum Technologies, Ulm, Germany — [3]Institut Quantique, Université de Sherbrooke, Sherbrooke, Québec, Canada

Josephson-photonics devices have predominantly been used to create microwave radiation in a process where a Cooper pair tunneling across a dc-biased Josephson junction creates photonic excitations in a microwave cavity connected in series. In scenarios where incoming photons are required to enable Cooper pair transfer and trigger subsequent photon emission, their use as amplifiers [1] or single (microwave-) photon detectors [2] has also been investigated.

Here, we present a scheme utilizing a Josephson-photonics device with two cavities as a microwave detector of itinerant photons, where the Josephson-photonics effect implements a stroboscopic projective measurement. Using recently developed techniques to describe the incidence of generic traveling pulses of quantized radiation onto a quantum device [3,4], we optimize the device and find promising performance numbers.

[1] R. Albert, et al. Phys. Rev. X **14**, 011011 (2024).
[2] L. Danner et al., arXiv:2510.08030
[3] A. H. Kiilerich et al., Phys. Rev. Lett. **123**, 123604 (2019).
[4] A. H. Kiilerich et al., Phys. Rev. A **102**, 023717 (2020).

TT 82.6 Thu 16:15 HSZ/0103

Vortex Energy Barriers in Meandering Superconducting Nanowires: Controlling Jitter in SNSPDs via magnetic field and bias currents — •Carlos Alberto Diaz Lopez[1], Joachim Ankerhold[1], Björn Kubala[1,2], and Ciprian Padurariu[1] — [1]Institute of Complex Quantum Systems, University of Ulm, Ulm, Germany — [2]German Aerospace Center (DLR), Ulm, Germany

We present a theoretical and computational study of vortex dynamics in meandering superconducting nanowires (e.g., SNSPDs). Building upon established methods for computing vortex energies in non-conventional geometries, our work incorporates the effect of screening currents induced by an external magnetic field. We calculate the total Gibbs free energy landscape to determine sets of parameters (B_z, I_{bias}) to engineer a tunable energy barrier for vortex crossing events. We seek barriers high enough to suppress spontaneous vortex-crossing (the mechanism underlying dark counts and timing jitter) yet remain low enough to permit crossing upon localized perturbations (e.g., a hotspot following single-photon absorption)

This analytical approach is benchmarked against a heuristic approach via simulations of the generalized time-dependent Ginzburg-Landau (gTDGL), performed using the open-source package py-TDGL. Our findings offer a design principle for optimizing operating conditions of SNSPDs to achieve maximal timing resolution and dark-count suppression.