TT 66: Cryogenic Detectors

Time: Friday 9:30–11:30 Location: HSZ 304

Invited Talk TT 66.1 Fri 9:30 HSZ 304

Towards ultrasensitive calorimetric detection in superconducting quantum circuits — •Bayan Karimi[1,2], Kuan-Hsun Chiang[2], Yu-Cheng Chang[2], Danilo Nikolic[3], Joonas T. Peltonen[2], Wolfgang Belzig[3], and Jukka P. Pekola[2] — [1]QTF Centre of Excellence, Department of Physics, Faculty of Science, University of Helsinki, Finland — [2]Pico group, QTF Centre of Excellence, Department of Applied Physics, Aalto University, Finland — [3]Fachbereich Physik, Universität Konstanz, D-78467, Germany

We demonstrate experimentally an ultra-sensitive thermal detector formed of an electronic absorber coupled to a phonon bath, which reaches the ultimate noise level dictated by the fundamental thermal fluctuations [1]. A scheme of coupling a superconducting qubit to this calorimeter is presented and we conclude positively about sufficient signal-to-noise ratio (SNR) in detecting a microwave photon emitted by it [2,3,4]. Recently this scheme was applied to the thermal detection of quantum phase slips in a Josephson junction [5], and currently we are performing experiments on the proposed qubit calorimetry.

[1] J. P. Pekola and B. Karimi, Rev. Mod. Phys. 93, 041001 (2021)
[2] B. Karimi and J. P. Pekola, Phys. Rev. Lett. 124, 170601 (2020)
[3] B. Karimi, D. Nikolic, T. Tuukkanen, J. T. Peltonen, W. Belzig, and J. P. Pekola, Phys. Rev. Applied 13, 054001 (2020)
[4] J. P. Pekola and B. Karimi, Phys. Rev. X 12, 011026 (2022)
[5] E. Gumus, D. Majidi, D. Nikolic, P. Raif, B. Karimi, J. T. Peltonen, E. Scheer, J. P. Pekola, H. Courtois, W. Belzig, and C. B. Winkelmann, arXiv:2202.08726 [cond-mat.mes-hall]

TT 66.2 Fri 10:00 HSZ 304

Novel concept for a superconducting microcalorimeter with tunable gain — •Constantin Schuster, Gabriel Jülg, and Sebastian Kempf — Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Karlsruhe, Germany

Cryogenic microcalorimeters such as metallic magnetic calorimeters (MMC) or transition edge sensors (TES) are becoming a mature technology and are hence presently used in various applications requiring an excellent energy resolution. They rely on transducing the temperature rise upon the absorption of an energetic particle into a change of magnetic flux (MMC) or electrical current (TES) which is measured using a SQUID. Despite the overall great success, it turns out that the resolving power still lacks behind the fundamental limit set by fluctuations of thermal energy among different degrees of freedom of the detector. Against this background, we present a novel detector concept which may help to improve the energy resolution. It is based on the strong temperature dependence of the magnetic penetration depth of a superconductor close to its critical temperature. By embedding a properly chosen superconductor directly into the SQUID loop and using a special input circuit configuration, a change in temperature is transduced into a change in magnetic flux threading the SQUID loop. Moreover, it turns out that the temperature to flux transfer coefficient can be tuned in-situ. We present our detector concept and gauge the possible performance and energy resolution of this novel detector concept by discussing simulating results and and first experimental data.

TT 66.3 Fri 10:15 HSZ 304

Advances in microwave SQUID multiplexing of magnetic microcalorimeters — •Martin Neidig, Alexander Maatz, Felix Schuderer, Marvin Völlinger, Mathias Wegner, Stefan Wünsch, and Sebastian Kempf — Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Karlsruhe, Germany.

The excellent energy resolution, very fast signal rise time and almost ideal linear detector response over a wide energy range makes magnetic microcalorimeters (MMCs) an exceedingly attractive detector technology for applications in various fields of science. The increasing necessity to operate large-scale detector arrays consisting of thousands to millions of individual detectors inherently poses the challenge of developing a suitable multiplexing technique. The presently most promising one is microwave SQUID multiplexing. Here, each individual detector is inductively coupled to a non-hysteretic, unshunted rf-SQUID that, in turn, is inductively coupled to a superconducting microwave resonator having a unique resonance frequency. In this configuration, an actual detector event results in a change of the effective SQUID inductance and hence in the resonance frequency of the related resonator. Moreover, capacitively coupling many of such readout channels to a single transmission line ultimately allows to read out hundreds to thousands of detectors simultaneously. In this contribution, we summarize our latest developments regarding the implementation of a microwave SQUID multiplexer for MMC readout. This includes aspects regarding to microfabrication as well as device characterization using software defined radio based readout electronics.

TT 66.4 Fri 10:30 HSZ 304

Design, fabrication and characterization of magnetic microcalorimeters for radionuclide metrology within the EMPIR project PrimA-LTD — •Michael Müller, Fabienne Bauer, Ria-Helen Zühlke, Trung Duc Tran, Alex Mocanu, and Sebastian Kempf — Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Karlsruhe.

The EMPIR project “PrimA-LTD” aims to provide ultra-precise measurements of the decay spectra of several radionuclides to enable activity standardization for medicine and industry. As the measurements require an outstanding energy resolution and great linearity over a wide energy range, magnetic microcalorimeters (MMCs) are used as detector technology. The latter are cryogenic particle detectors that make use of a paramagnetic temperature sensor linked to a particle absorber in which the radionuclide is embedded. The sensor is biased by a magnetic field to create a temperature dependent sensor magnetization which is altered by the temperature rise upon a radioactive decay within the absorber and measured using a SQUID. To provide a flexible detector platform, we designed three optimized MMC layouts allowing for different methods of source preparation. For in-house microfabrication of the detectors, we established deposition processes for the various materials needed. This particularly includes an electroplating process for thick, highly conductive absorbers made of gold that are free-standing on stems having a diameter of only 5 μm. We summarize the detector layouts as well as the fabrication status of the detectors and discuss characterization measurements of detector prototypes.

TT 66.5 Fri 10:45 HSZ 304

Fluxon counters and velocimeters at superconducting strips — •Oleksandr Dobrovolskiy — University of Vienna, Faculty of Physics, Nanomagnetism and Magnonics, SuperSpin Laboratory

Thin strips with large critical current Ic are required for superconducting microstrip single-photon detectors (SMSPDs) [1] and Cherenkov generators/detectors of spin waves by ultra-fast moving fluxons [2]. In this regard, high Ic implies blocking of the penetration of vortices via the strip edges and their control via material and edge-barrier engineering [3]. Thus, at sufficiently large transport currents Itr, a slit at the edge of a superconducting strip acts as a gate for the vortices entering into it. These vortices form a jet, which is narrow near the slit and expands due to the repulsion of vortices as they move to the opposite edge of the strip, giving rise to a transverse voltage Vp. In my talk, I will present our experimental results on voltage kinks in the I-V curves which occur each time the number of fluxons crossing the strip is increased by one [4]. I will also dwell on the appearance of the non-monotonic Vp in MoSi strips with slits milled by FIB at various distances from the transverse voltage leads [5]. Our findings are relevant for the performance of SMSPDs and superconducting devices operated in the single-fluxon regime.

[1] Korneeva et al., PRAppl. 13, 024011 (2020)
[2] Dobrovolskiy et al., arXiv:2103.10156
[3] Budinska et al., PRAppl. 17, 034072 (2021)
[4] Bevz et al., submitted
[5] Bezuglyj et al., PRB 105, 214507 (2022)

TT 66.6 Fri 11:00 HSZ 304

Superconducting 3D-cavity architecture for microwave single-photon detection — •Yuki Nojiri[1,2], Kedar E. Honasoge[1,2], Daniil Bazulin[1,2], Florian Fesquet[1,2], Maria-Teresa Handschuh[1,2], Fabian Kronowetter[1,4], Michael Renger[1,2], Achim Marx[1], Kirill G. Fedorov[1,2], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institute, Bavarian Academy of Sciences and Humanities, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany — [4]Rohde &

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Microwave single-photon detectors (SPDs) are essential quantum devices required in a large variety of quantum communication and quantum computation protocols. First microwave SPDs have been realized with the help of superconducting qubits and resonators. Here, we experimentally study an SPD design compatible with the superconducting 3D cavity architecture. We exploit the multimode nature of horseshoe aluminum cavities in combination with transmon qubits to experimentally realize efficient detection of single microwave photons. We analyze the performance of such devices and discuss possible ways to improve it.

TT 66.7 Fri 11:15 HSZ 304

Novel susceptibility thermometer for mK-temperatures based on Au:Er micro-fabricated on a copper substrate — •Nathalie Probst, Andreas Fleischmann, Andreas Reifenberger, Andreas Reiser, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University

There are not too many options for fast, highly sensitive and reliable thermometers for use at low and ultra-low temperatures. Here, we present a novel concept of a susceptibility thermometer based on the paramagnetic alloy Au:Er that has the potential to meet these requirements. To ensure very good thermal contact, the superconducting readout coils and the paramagnetic materials are micro fabricated on a polished copper wafer. In this concept, four planar meander-shaped niobium coils each with a width of 5μm and a total length of 20m, are arranged as a Wheatstone bridge. Two opposite coils are covered with sensor material. The inductances of the covered and uncovered coils were chosen so that the bridge is balanced at a certain temperature, as indicated by the zero detector. This temperature can be conveniently set by the erbium concentration and the design of the coils. For certain applications, this can serve as an individual fixed point for precise temperature stabilization. The imbalance due to the paramagnetic contribution of the Au:Er at different temperatures is used to establish a temperature scale by calibration with another thermometer. We will discuss the design, fabrication, function and readout of this novel susceptibility thermometer.