TT 22: Superconductivity – Poster I

Time: Monday 18:00–20:00 Location: P1

TT 22.1 Mon 18:00 P1

Sextets in four-terminal Josephson junctions — •Miriam R. Ebert[1], David C. Ohnmacht[1], Wolfgang Belzig[1], and Juan C. Cuevas[2,3] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany — [2]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, 28049 Madrid, Spain — [3]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain

Multiterminal superconducting junctions have revitalized the investigation of the Josephson effect. One of the most interesting aspects of these hybrid systems is the occurrence of multi-Cooper pair tunneling processes that have no analog in two-terminal devices. Such correlated tunneling events are also intimately connected to the Andreev bound states (ABSs) supported by these structures. Josephson junctions with four superconducting terminals have attracted special attention because they are predicted to support ABSs with nontrivial topological properties. Here, we present a theoretical study of sextets, which are correlated tunneling processes involving three Cooper pairs and four different superconducting terminals [1]. We investigate how sextets can be identified from the analysis of the current-phase relation and show how sextets are connected to the hybridization of ABSs. Furthermore, we discuss their existence in recent experiments on four-terminal devices realized in hybrid Al/InAs heterostructures [2].

[1] M. R. Ebert et al., Phys. Rev. B 112, 195430 (2025)
[2] T. Antonelli et al., Phys. Rev. X 15, 031066 (2025)

TT 22.2 Mon 18:00 P1

Superconducting proximity effect in non-collinear antiferromagnets — •Anshuman Padhi[1], Prajwal Rigvedi Madhusudan Rao[1], Ajin Joy[2], Ajesh K Gopi[1], Jiho Yoon[1], Jaechun Jeon[1], Banabir Pal[1], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, 06120, Halle (Saale), Germany — [2]Indian Institute of Science, 560012, Bengaluru, India

Triplet Cooper-pair generation in superconducting hybrids is typically achieved using multilayer ferromagnetic structures with non-collinear magnetization, but such systems restrict material flexibility and can introduce vortex-related artefacts. Non-collinear antiferromagnets (NCAFMs) provide a promising alternative: their intrinsic spin textures and residual uncompensated moments can support long-range superconducting correlations without complex magnetic stacking. Here, we interface superconducting thin films (thickness lesser than the coherence length) with two magnetic phases of a Mn-based antiperovskite and track how their critical temperature evolves under magnetic fields of various orientations. The symmetry and spin configuration of the NCAFMs are expected to modify the Andreev spectrum at the interface and thereby affect the robustness of the superconducting condensate, a common indicator of triplet pairing. We further attempt to study the interface using tunneling spectroscopy and explore possible signatures of spin-dependent Andreev states.

TT 22.3 Mon 18:00 P1

RF-Driven Josephson Dynamics in an STM-Defined Pb-NbS_2 Junction — •Ajla Karic, Rian Ligthart, Alexander LaFleur, Kevin Hauser, Benjamin Froelich, and Fabian D. Natterer — Department of Physics, University of Zurich, Winterthurerstrasse 190, CH-8057, Switzerland

We use a scanning tunneling microscope to form an ultrasmall Josephson junction between a Pb tip and an NbS_2 sample at 1.5 K and investigate how its electromagnetic environment shapes the Josephson response. We apply radio-frequency (RF) driving up to 40 GHz and track the evolution of dI/dV spectra as a function of RF amplitude. The measurements reveal pronounced photon-assisted tunneling features and a strong modulation, suppression, and reemergence of the zero-bias Josephson peak, consistent with a phase-diffusive regime dominated by environmental fluctuations. In ongoing work, we increase the effective junction capacitance to directly probe how controlled changes in the junction capacitance modify the Josephson dynamics. Understanding these environmental effects is essential for identifying the conditions under which STM-based Josephson junctions can be pushed toward more coherent operation relevant for qubit applications.

TT 22.4 Mon 18:00 P1

prediction of SJTM observables in putative PDW state in cuprates — •Monikana Gope, Shaswat Chaturvedi, and Peayush Choubey — Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247667, Uttarakhand, India

The coexistence of competing electronic phases, such as pair-density wave (PDW) and charge-density wave (CDW), in high-temperature superconductors remains unresolved. These phases originate from distinct mechanisms, exhibit spatial modulations, and influence superconductivity differently. Scanning Josephson Tunnelling Microscopy (SJTM) enables atomic-scale probing of these modulations by measuring Josephson and quasiparticle tunnelling currents between a superconducting tip and a superconducting sample, thus serving as a direct local probe of the superconducting gap order parameter. Using this technique, we aim to distinguish PDW signatures from other competing orders in cuprates. Starting with the tJ model, which captures strong electron correlations and the interplay between electron hopping, exchange interactions, and strong correlation effects in cuprate superconductors, we stabilise a metastable PDW phase under specific doping and fixed-temperature conditions. We then compute the critical current for a superconducting s-wave tip in both PDW and PDW + dSC states, finding distinct modulations in Ic and abs(Ic). Finally, we employ a Wannier-function-based continuum approach to calculate the critical current and predict characteristic SJTM signatures of the PDW state.

TT 22.5 Mon 18:00 P1

Theory of ESR-STM in superconducting hybrids — •Marcel Polák and Björn Trauzettel — Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany

The electron spin resonance scanning tunneling microscopy (ESR-STM) is a technique that has emerged in the last few years and is a focus of both experimental and theoretical studies. It combines tunneling with an external rf field to probe magnetic adatoms with high resolution in energy and space. Such tunneling problems can be studied in the presence of superconducting electrodes. This leads to the presence of Yu-Shiba-Rusinov states, Andreev reflection and Shapiro steps. We employ the Green's function approach, to study the effect of an external rf driving on the tunneling current in superconducting hybrids in the presence of driven spins.

TT 22.6 Mon 18:00 P1

Schrieffer-Wolff-transformation approach to Josephson junctions: quasiparticle effects and Josephson harmonics — •Ádám Bácsi[1,2], Teodor Iličin[3,4], and Rok Žitko[3] — [1]Széchenyi István University, Győr, Hungary — [2]MTA-BME Lendület "Momentum" Open Quantum Systems Research Group, Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary — [3]Jožef Stefan Institute, Ljubljana, Slovenia — [4]University of Ljubljana, Ljubljana, Slovenia

We use the Schrieffer-Wolff transformation (SWT) to analyze Josephson junctions between superconducting leads described by the charge-conserving BCS theory. Starting from the single-electron tunneling terms, we directly recover the conventional effective Hamiltonian proportional to $\cos\phi$, with an operator-valued phase bias ϕ. The SWT approach has the advantage that it can be systematically extended to more complex scenarios. We show that if a Bogoliubov quasiparticle is present its motion couples to that of Cooper pairs, introducing correlated dynamics that reshape the energy spectrum of the junction. Furthermore, higher-order terms in the SWT naturally describe Josephson harmonics, whose amplitudes are directly related to the microscopic properties of the superconducting leads and the junction. We derive expressions that could facilitate tuning the ratio between the different harmonics in a controlled way.

TT 22.7 Mon 18:00 P1

Towards new precision measurements of the AC Josephson effect — •Sandip Saha[1], Oliver Kieler[1], Ralf Behr[1], Jörn Beyer[2], Johannes Kohlmann[1], and Mark Bieler[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2-12, 10587 Berlin, Germany

The AC Josephson effect is used today to realise the unit volt since it establishes a perfect relationship between voltage and frequency just based upon the magnetic flux quantum $\phi_0 = \frac{h}{2e}$. Around four decades ago, the universality of the Josephson effect was studied and experimentally verified with an uncertainty of 3 parts in 10^{19} [1]. Considering the recent progress in superconducting quantum technology and metrology, we believe that re-evaluating this uncertainty could shed new light on the precision of the AC Josephson effect. We plan to use two independent Josephson junction arrays comprising several thousand Josephson junctions, being driven by a microwave generator to synthesize DC voltages. To detect small voltage differences between these two arrays, which will be connected in a superconducting loop, a state-of-the-art DC SQUID will be inductively coupled and used as an extremely sensitive null detector. At the conference, we will explain the principle behind our experimental setup, provide a detailed introduction of the involved quantum devices, which will be fabricated using the established Nb thin film technology at PTB, and present a roadmap for the upcoming measurements.

[1] https://doi.org/10.1103/PhysRevLett.58.1165

TT 22.8 Mon 18:00 P1

Coulomb blockade in ultrasmall step-edge junctions made of granular aluminum — •Sergey Lotkhov and Lukas Grünhaupt — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We developed a fabrication routine and implemented a Coulomb blockade transistor with two step-edge junctions made of granular aluminum (grAl) superconductive film. Our process neither involves widely-used shadow-evaporated overlaps, nor the surface oxidation of aluminum for creating the tunnel barriers. This technique enables multijunction single-charge circuitry free of stray replicas. At low temperatures, the transistor exhibited a typical periodic structure of Coulomb diamonds adjacent to the superconducting voltage gap of grAl, both varying under experimental conditions. The gap was found to depend weakly on the transversal magnetic field up to at least 2 Tesla, which we explain by the microstructure of the superconductive grAl film. Furthermore, the charging effects persisted unaffected across the superconducting transistion of grAl, thus supporting a simple, single-electron tunneling picture of the Coulomb effects observed.

TT 22.9 Mon 18:00 P1

Towards next-generation Josephson arbitrary waveform synthesizers — •Nishtha Chaudhry, Oliver Kieler, Abdulrahman Widaa, Michael Haas, Omar M. Aladdin, and Johannes Kohlmann — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

With the rapid emergence of new quantum technologies, there is a crucial need for cryogenic microwave generation and detection systems that eliminate additional noise and improve signal quality. We put forward the Josephson Arbitrary Waveform synthesizer (JAWS) as a drive-signal source for these quantum devices for ultrabroadband operation at cryogenic temperatures. The JAWS consists of a pulse-driven series array of Niobium-based SNS Josephson junctions. JAWS delivers ultra-precise, quantum-accurate quantized arbitrary waveforms with exceptional spectral purity of up to -125 dBc and extremely low noise or voltage drift. In this conference presentation, we will introduce the current effort at PTB in which we are extending the operation of previously established JAWS circuits to temperatures as low as 1 K by exploring different substrate options and optimizing parameters of the Josephson junctions. The JAWS chips will be able to provide four different signal channels from DC to GHz and can also be placed close to the quantum chips at cryogenic temperatures.

TT 22.10 Mon 18:00 P1

Impedance-matched Josephson Parametric Amplifiers — •Amitesh Gupta — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Frequency-multiplexed microwave readout of superconducting qubits is greatly benefited by low-noise and wide-band amplification. Over the past decade, Josephson junction based amplifiers, like the impedance-matched Josephson parametric amplifiers (JPAs), have become one of the solutions, offering quantum-limited noise performance along with bandwidth of a few hundreds of MHz. We present a streamlined way to design a matching network for JPAs using quarter-wave and half-wave transmission lines. It relies on eliminating the complex part of the impedance of the JPA*s dc-SQUID, and matching the input to the negative resistance arising from pumping the JPA. We present harmonic balance simulations of our designs, and show first experimental results of the devices fabricated using Nb-trilayer technology.

TT 22.11 Mon 18:00 P1

Charge Sensitive Superconducting Transmon Qubits for Infrared Radiation Detection — •Jonathan Huschle[1], Markus Griedel[1,2], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut (PHI), Karlsruhe Institute for Technology — [2]Institute for Quantum Materials and Technologies (IQMT), Karlsruhe Institute for Technology

In superconductors, the absorption of photons with energies exceeding the energy gap breaks Cooper pairs. This increases the population of quasiparticles, enhances noise, and introduces additional dissipation at microwave frequencies. The coherence of superconducting qubits is particularly sensitive to these effects and can thus serve as probes of quasiparticle dynamics. To enhance the sensitivity, we use a charge susceptible transmon qubit to investigate charge noise. In combination with a controllable infrared radiation source, we study the impact on both the charge noise and the coherence time of the modified transmon qubit. We present the qubit design and report on our measurement results at millikelvin temperatures.

TT 22.12 Mon 18:00 P1

Tuneup Protocol for Superconducting Qubits — •Paul Kugler[1], Nicolas Gosling[1], Masum Uddin[2], Asen Georgiev[3], Li-Wei Chang[3], Shroya Vaidya[2], Hiresh Jadoenathmissier[4], Mahmut Çetin[4], Philipp Lenhard[1], Nicolas Zapata[1], Lukas Scheller[5], Robert Gartmann[5], Wang N. Wong[2], Manognya Acharya[2], Tobias Lindström[2], Mark Bieler[3], Sebastian de Graaf[2], Lukas Grünhaupt[3], and Ioan Pop[1,6,7] — [1]IQMT, KIT, Karslruhe — [2]NPL, Teddington, United Kingdom — [3]PTB, Braunschweig — [4]Orange Quantum Systems, Delft, The Netherlands — [5]IPE, KIT, Karlsruhe — [6]PHI, KIT, Karlsruhe — [7]PI1, Stuttgart University, Stuttgart

We present a standardized, control-platform-agnostic procedure for tuning up superconducting qubits, developed to ensure consistency and reproducibility across laboratories and to enable metrological studies of qubit performance. A central component of the protocol is the calibration of a high-fidelity QND readout, which forms the foundation for all subsequent qubit measurements. Building on this, we establish the control pulses required for reliable qubit manipulation, including calibrated π and $\pi/2$ pulses. After completing the pulse-calibration workflow, we validate the tuneup through randomized benchmarking and readout-induced leakage benchmarking, providing quantitative checks of both gate performance and measurement backaction. This unified procedure supports transparent comparison of results across different control stacks and contributes to building a consistent metrological framework for superconducting-qubit experiments.

TT 22.13 Mon 18:00 P1

Investigation of Parasitic Two-Level Systems in Merged-Element Transmon Qubits — •Etienne Daum, Benedikt Berlitz, Alexey V. Ustinov, and Jürgen Lisenfeld — Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Straße 1, Karlsruhe, 76131, Baden-Württemberg, Germany

In conventional transmon qubits, decoherence is dominated by a large number of parasitic two-level systems (TLS) residing at the edges of its large area coplanar shunt capacitor and junction leads. Avoiding these defects by improvements in design, fabrication and materials proved to be a significant challenge that so far led to limited progress. The merged-element transmon qubit ("mergemon"), a recently proposed paradigm shift in transmon design, attempts to address these issues by engineering the Josephson junction to act as its own shunt capacitor. With its energy mostly confined within the junctions, efforts required to improve qubit coherence can be concentrated on the junction barrier, a potentially easier to control interface compared to exposed circuit areas. Incorporating an additional aluminium deposition and oxidation into the *in-situ* bandaged Niemeyer-Dolan technique, we were able to fabricate flux-tunable mergemon qubits achieving mean T_1 relaxation times of up to 130μs ($Q \approx 3.3 \times 10^6$). TLS spectroscopy under applied strain and electric fields, together with systematic design variations, revealed that even for mergemon qubits - despite their significantly reduced footprint and increased junction barrier volume - careful design considerations are still essential to avoid coherence limitations due to surface loss.

TT 22.14 Mon 18:00 P1

Superconducting quarton qubits with stacked Joseph-

son junctions — •Alex Kreuzer[1], Hossam Tohamy[1], Thilo Krumrey[1], Jürgen Lisenfeld[1], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut (PHI), Karlsruher Institut für Technologie (KIT) — [2]Institut für Quantenmaterialien und -technologien (IQMT), Karlsruher Institut für Technologie (KIT)

Realizing compact, low-loss inductive elements is a key challenge for scalable superconducting qubits. Although planar Josephson junction arrays offer large inductances, they also have a substantial footprint, which causes additional surface loss and increases the stray capacitance. We implement quarton flux qubits with a large positive anharmonicity using vertically stacked Josephson junctions, which offer compact inductance, low stray capacitance, and reduced surface participation.

We present DC transport characteristics of stacked junctions and microwave-loss measurements of quarton qubits. Qubit spectroscopy reveals numerous avoided crossings induced by two-level systems (TLS), suggesting the TLS in the array junctions as the dominant loss channel. We discuss how qubit coherence and the TLS density are influenced by stack geometry.

TT 22.15 Mon 18:00 P1

Building a Quantum Wheatstone Bridge — •Thilo Krumrey[1], Alex Kreuzer[1], Hossam Tohamy[1], Alan C. Santos[3], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]IQMT, Karlsruher Institut für Technologie, Karlsruhe, Germany — [3]Instituto de Física Fundamental (IFF), Consejo Superior de Investigaciones Científicas (CSIC), Madrid, Spain

Today's qubits, while still quite noisy, are sufficiently coherent for non-computing applications. We are exploring the possibility of using an arrangement of superconducting qubits to study the quantum version of the Wheatstone resistance bridge[1]. It would allow for comparative measurements of coupling energies using the interference of an excitation gradient across strongly coupled qubits. We propose an implementation of a quantum Wheatstone bridge using superconducting quantum circuits with quarton flux qubits. Here, the large positive anharmonicity and the tunability [2] of the operating frequency are beneficial for our application. We will discuss the current status on the qubits and resonators designs, simulation and fabrication results.

[1] K. Poulsen *et al.*, PRL **128**, 240401 (2022)
[2] F. Yan *et al.*, arXiv:2006.04130v1

TT 22.16 Mon 18:00 P1

Designing a W-band Josephson parametric amplifier. — •Jonas N. Kämmerer[1], Urs Strobel[1], Jakob Lenschen[1], Karapet Hambardzumyan[1], Sergei Masis[1], Jürgen Lisenfeld[1], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut (PHI), Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Institut für QuantenMaterialien und Technologien (IQMT), Karlsruher Institut für Technologie, 76344 Eggenstein-Leopoldshafen, Germany

Superconducting quantum circuits operating in the millimeter-wave regime are expected to offer several advantages that could impact the scalability of future quantum computing systems. These advantages include a reduced footprint, faster qubit manipulation, increased thermal resilience, and higher operating temperatures.

The realization of superconducting qubits in the millimeter-wave regime presents several challenges, one of which is an efficient readout chain. It should include a Josephson parametric amplifier (JPA), which is a nonlinear device that amplifies microwave signals with added noise approaching the quantum limit.

Here, we propose a tunable JPA design operating in the W-band at a frequency of about 100 GHz. Our approach employs a frequency-tunable DC-SQUID made using niobium-based Josephson junction technology. We present numerical simulations conducted to determine the optimal design and operating parameters for three- and four-wave mixing and also address the challenges to overcome in practical devices, such as pumping and coupling schemes.

TT 22.17 Mon 18:00 P1

Immersion Cooling of Transmon Qubits — •Vasilii Sevriuk[1], Amber Carreck[1], Daniel Doling[1], Zakaria Mohamed[1], Rais Shaikhaidarov[1], Lev Levitin[1], Petri Heikkinen[1], Tobias Lindstrom[2], Alexander Tzalenchuk[1,2], Sebastian de Graaf[2], Andrew Casey[1], and John Saunders[1] — [1]Royal Holloway University of London, UK — [2]National Physical Laboratory, UK

Superconducting qubits have become a standard platform both for developing new engineering approaches in quantum computation and for exploring fundamental questions in solid-state physics and quantum mechanics [1]. Despite this progress, achieving efficient thermalization of qubits remains an important challenge [2]. In this work, we present experimental results obtained by immersing a transmon qubit device into liquid helium and studying the temperature dependence of its key parameters. Our approach extends prior studies on immersion cooling of superconducting resonators [3].

[1] M. Devoret et al., arXiv:cond-mat/0411174
[2] D. Lvov et al., arXiv:2409.02784
[3] M. Lucas et al., Nat. Commun. 14, 3522 (2023)

TT 22.18 Mon 18:00 P1

Dual-tone spectroscopy of atomic tunneling systems in amorphous solids — •Anton Jarecka, Jan Blickberndt, Moritz Maur, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

The performance of state-of-the-art superconducting quantum devices is limited by noise and decoherence effects, which are known to originate from atomic tunneling systems (TSs) residing in interfaces and dielectric layers. With the goal of further understanding the dielectric properties of such TSs, we investigate their non-equilibrium response by performing radio-frequency dual-tone spectroscopy using a probe and a pump field. For that purpose, we have developed a superconducting microstructured LC-resonator consisting of four identical interdigital capacitors (IDCs) arranged in a Wheatstone bridge setup and two meander inductances, giving rise to two resonance branches. A bulk glass serves as the IDC's dielectric, providing an ensemble of TSs. We use the setup to probe a dielectric volume shared by the two resonances. Therefore, the resonances address the same ensemble of TSs. By tuning the TS-pump field interaction so that the dominant TS Rabi frequencies match the frequency difference of the resonant branches, we can precisely control the dielectric loss of our sample. The measurements are qualitatively described within a framework based on the dressing of tunneling states induced by strong pump fields. Probing these dressed state transitions provides insights into the non-equilibrium dynamics and, consequently, the dielectric response of atomic TSs.

TT 22.19 Mon 18:00 P1

Landau-Zener transitions in ultra-cold glasses — •Jan Blickberndt, Christian Ständer, Anton Jarecka, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

Atomic tunneling systems (TSs) are inherent to disordered structures and therefore appear not only in amorphous solids, but also in oxide layers, tunneling barriers and interfaces of superconducting micro-structured devices, deteriorating their performance by introducing noise and decoherence. Understanding their nature is thus crucial to mitigate the adverse effects of TSs on quantum devices. In this work we investigate the non-equilibrium dynamics of a resonantly driven TS ensemble, which is influenced by slowly varying electric or mechanical bias fields by tuning the TSs energy splitting. To directly probe the TSs dielectric response, we developed a superconducting lumped element resonator microfabricated onto a bulk glass substrate, enabling controlled excitation and readout of the underlying TS population. By varying the sweep rate of the applied bias, we demonstrate rate-dependent control over the dielectric loss of the sample. Furthermore, when applying sufficiently large bias amplitudes we observe a dispersive red shift of the resonator frequency due to an excess saturation of low-energy TSs. Introducing noise bias fields leads to a measurable reduction of effective TS coherence times, demonstrating their sensitivity to spectral fluctuations in their environment. To complement our experiments, we developed a GPU-accelerated Monte Carlo simulation of the tunneling dynamics to validate and extend our findings.

TT 22.20 Mon 18:00 P1

Optimization of cross-type dc-SQUIDs for the readout of MMCs — Alexander Stoll, •Lukas Münch, Daniel Hengstler, Andreas Reifenberger, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

Readout chains of ultra-low-temperature detector systems often limit the achievable energy resolution. Even superconducting quantum interference devices (SQUIDs), the state-of-the-art sensors for cryogenic detectors such as metallic magnetic calorimeters (MMCs), typically dominate the white-noise regime. The energy sensitivity of a dc-

SQUID $\epsilon \sim T\sqrt{LC}$ is mainly set by the inductance, intrinsic Josephson junction capacitance, and temperature. While the inductance is fixed for practical reasons, the capacitance can be reduced by moving from a window-type to a cross-type junction geometry. Furthermore, the operation temperature of the SQUIDs which typically decouples from the much lower mixing chamber temperature due to heat dissipation in the shunt resistors, can be lowered. Following an idea from Stephen Boyd and coworkers (to be published), we divide the cooling fins into multiple sectors across the shunt resistor to improve electronic heat dissipation. We describe the fabrication of cross-type dc-SQUIDs for MMC readout, emphasizing the role of CMP-based processing in achieving high wafer-scale yield and uniformity on three-inch wafers. Finally, we present their characterization and compare the noise performance to earlier dc-SQUID generations.

TT 22.21 Mon 18:00 P1

AuTi Magnetic Penetration Depth Thermometers for low temperature microcalorimeters — •Naemi Grun, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Daniel Hengstler, Florian Kaiser, Lukas Münch, Andreas Reifenberger, and Martin Schwendele — Kirchhoff Institute for Physics, University Heidelberg

Low temperature microcalorimeters reach high energy resolution in a wide energy range thanks to very sensitive thermometers. Magnetic penetration depth thermometers (MPTs) would represent a very interesting alternative with respect to commonly used metallic magnetic calorimeters (MMCs) and transition edge sensors (TESs). The working principle of MPTs is based on the Meissner-Ochsenfeld effect and the temperature dependence of the magnetic penetration depth. A temperature increase due to energy deposition in the absorber material translates into an increase in the magnetic penetration depth of the MPT, which can be read out by highly sensitive SQUID magnetometers. We are investigating AuTi bilayers as a possible MPT sensor material and are targetting a transition temperature below 100 mK. To avoid hysteretic effects, the sensor does not have a bulk geometry, but is deposited onto the readout coil in the geometry of separate stripes or dots. We discuss the properties of the AuTi bilayers and the results obtained with MPT prototypes based on different geometries.

TT 22.22 Mon 18:00 P1

Identification of Noise Sources in Superconducting Microstructures — •Krishnam Mimani, Daniel Hengstler, Matthew Herbst, David Mazibrada, Lukas Münch, Andreas Reifenberger, Markus Renger, Christian Ständer, Rui Yang, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University

Improving the performance of superconducting devices often means identifying and eliminating noise sources. Many noise sources are transferable across different device categories such as qubits, SQUIDs, and superconducting detectors due to the intrinsic nature of the microfabricated thin film materials. Our stand-alone device can analyze the specific noise contributions of these micro-fabricated thin films. The device consists of a Wheatstone-like bridge of four micro-fabricated superconducting inductors, two of which are filled with a sample material, and a pair of two-stage dc-SQUID read-out chains. We can use the method of cross-correlation, to suppress the noise of the read-out chains and derive the total noise contribution of our device, or drive the Wheatstone bridge with an ac-current to measure the complex acsusceptibility of the sample material. Our experiments are performed at temperatures between $T = 20\,\mathrm{mK}$ and $T = 800\,\mathrm{mK}$ in the frequency range from $f = 100\,\mathrm{mHz}$ to $f = 500\,\mathrm{kHz}$. We present the results of multiple measurements on thin films of SiO2, AuPd, Ag:Er, as well as Au:Er and perform a detailed comparison. We discuss our efforts to increase the frequency bandwidth for both our measurement modes, measuring towards noise levels of below $\sqrt{S_\Phi} = 10\,\mathrm{n}\Phi_0/\sqrt{\mathrm{Hz}}$.

TT 22.23 Mon 18:00 P1

Superconducting Resonators from Ultrathin NbN Films — •Hrishikesh Borah, Meenakshi Sharma, Haolin Jin, Yejin Lee, and Uri Vool — Max Planck Institute for Chemical Physics of Solids

We explore the transport and microwave response of ultrathin Niobium Nitride (NbN) of 3 nm thickness. Transport measurements confirm the 2D behavior of our system, consistent with the Berezinskii-Kosterlitz-Thouless transition. In such ultrathin limit, the inertia of the cooper pairs defined as kinetic inductance becomes dominant. Our films exhibit a high kinetic inductance of 300 pH/sq, which significantly impacts the response of superconducting microwave resonators patterned from the films. Moreover, temperature dependence measurements of the microwave response reveal that in low temperature regime, the superfluid density follows a power-law rather than the BCS prediction. Energy losses at low temperature are dominated by two-level system (TLS) defects while at higher temperatures, losses are caused by the breaking of Cooper pairs. This work investigates the ultrathin NbN regime for compact, high-impedance devices ideal for quantum circuits and sensitive detectors.

TT 22.24 Mon 18:00 P1

Chaotic Behavior of Josephson Diodes — •Vjeko Dimić[1], Simon Feyrer[1], Alexander Kirchner[1], Daniel Crawford[2], Davide Curcio[3], Giorgio Biasiol[3], Tero Heikkilä[2], Christoph Strunk[1], and Leandro Tosi[1,4] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [2]Department of Physics and Nanoscience Center, University of Jyväskylä — [3]CNR-Istituto Officina dei Materiali Laboratorio TASC, Italy — [4]Centro Atomico Bariloche, Comision Nacional de Energia Atomica, Argentina

The behavior of nonlinear resonators is well described by the Duffing oscillator model. For sufficiently high driving powers, the response of the system has three solutions, two metastable, and one unstable, i.e., the system enters bifurcation regime. This also applies for nonlinear superconducting resonators where the nonlinearity stems from the nonlinear behavior of Josephson junctions. If instead we have a junction exhibiting the Josephson diode effect, the Duffing model acquires an additional term which results in reemergence of stable solutions for certain parameters. Here we present the design and measurement of two tunable $\lambda/4$ resonators fabricated out of a hybrid Al/InAs heterostructure. One resonator is terminated with a single Josephson junction, while the other is terminated with a SQUID. We perform microwave measurements of the resonators and observe the onset of the bifurcation regime in both devices, while the reemergence of stable solutions is observed in the SQUID device. We have also explored the dependence with in-plane magnetic field, in particular the range where superconducting diode effect has been observed.

TT 22.25 Mon 18:00 P1

Planar Broadband Superconducting Waveguide for Coherent Control of Rare-Earth Spin Ensembles — •Arjun Bhasker[1,2], Georg Mair[2,1], Léa Richard[2,1], Michael Stanger[1], Andreas Erb[2,1], Hans Huebl[2,1,3], and Nadezhda Kukharchyk[2,1,3] — [1]School of Natural Sciences, Technische Universität München, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 München, Germany

Solid-state quantum memories based on rare-earth ions require highly homogeneous microwave fields to enable coherent control of large spin ensembles. While coplanar waveguides can be used for this purpose, they inherently produce non-uniform field distribution: The microwave field peaks at the center conductor, and the field direction varies substantially within the gaps, which leads to a variety of Rabi frequencies. To overcome this limitation, we introduce a new planar superconducting broadband transmission-line architecture implemented via a technique such as flip-chip bonding, designed to generate a highly uniform microwave field across the active region. In this approach, a $CaWO_4$ crystal doped with erbium ions has to be thinned producing a flat and uniform membrane to ensure proper impedance matching and optimal coupling to the microwave field. Such a design provides a promising platform for implementing rare-earth-based quantum memories with microwave superconducting quantum technologies.

TT 22.26 Mon 18:00 P1

High-quality superconducting broadband microwave structures for broadband electron spin resonance experiments — •Robert Pant[1,2], Georg Mair[1,2], Arjun Bhasker[1,2], Sebastian Dominguez-Calderon[1,2], Hans Huebl[1,2,3], and Nadezhda Kukharchyk[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]School of Natural Sciences, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 München, Germany

Electron spin resonance (ESR) spectroscopy is a powerful tool when it comes to studying the internal structure of materials and characterizing spins of unpaired electrons within. Superconducting microwave resonators are widely employed for such studies allowing to achieve strong coupling to spin systems. However, a generally narrow fre-

quency range of their operation limits the amount of simultaneously coupled spin states. Over-coupled resonating structures can provide a substantially broader spectrum of microwave frequencies for resonance absorptions, thus improving the measurement efficiency. In the following work, several promising configurations of superconducting coplanar waveguide resonators in the over-coupled regime are developed, including a $\lambda/2$ transmission-line resonator with implemented interdigital capacitors that ensure an increased coupling rate to spin ensembles in the low frequency range of 0−4 GHz.

TT 22.27 Mon 18:00 P1

Metallic-Magnetic Calorimeters for Efficient High Resolution X-ray Spectroscopy for Energies up to 150 keV — •Daniel Kreuzberger, Andreas Abeln, Hendrik Hadenfeldt, Daniel Hengstler, Andreas Reifenberger, Daniel Unger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

Metallic Magnetic Calorimeters are cryogenic detectors for broadband x-ray spectroscopy with high energy resolution and small, well understood non-linearity. They consist of a metallic particle absorber, typically made of gold and a paramagnetic temperature sensor made of an erbium doped noble metal host material. If a photon is absorbed, its energy is converted to heat, leading to a temperature change of the sensor material. This temperature rise changes the magnetization of the sensor material, which is read out by a sensitive SQUID magnetometer.
Experiments on highly charged ions and light muonic atoms have brought up the necessity to build densely packed arrays of MMCs with a high stopping power for photon energies up to 150 keV. This can be achieved with the presented new microfabrication-process for 120 μm thick absorbers made of electroplated gold. We also present fabrication results for the fast thermalization of the MMCs using the backside of the silicon substrate, which can be achieved by using DRIE processes, and filling these TSVs with copper. Finally we present characterization results for two different MMC arrays fabricated with those newly developed processes and results from most-recent beamtimes.

TT 22.28 Mon 18:00 P1

MMC-based photon and phonon detector for scintillating crystals at mK temperatures — •Ioana-Alexandra Nitu, Christian Enss, Andreas Fleischmann, Clara Marie Günther, Daniel Hengstler, Sebastian Hilscher, Ashish Jadhav, Cagla Mahanoglu, Andreas Reifenberger, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg University

Scintillating bolometers operated at mK temperatures provide a means to probe for neutrinoless double beta decay ($0\nu\beta\beta$) and Dark Matter. The ratio of light to heat signals permits discrimination between heavy particles, for instance α particles, and lighter ones, like β or γ particles. The AMoRE collaboration uses separate photon and phonon detectors based on metallic magnetic calorimeter (MMC) technology to search for $0\nu\beta\beta$ in ^{100}Mo using $LiMoO_4$ crystals.

We present an integrated photon-phonon (P2) detector concept, where both detectors are microfabricated on the same 3-inch silicon substrate and thermally separated by etched trenches. Presently, the optimization of the photon and phonon detectors is done separately. The development of the photon detector has been completed and preliminary results validate fabrication procedures. A phonon detector prototype was designed and microfabricated using the same steps as the pre-existing photon detector. We present the fabrication steps to obtain the target mechanical and thermal properties and discuss preliminary results in comparison to the expected performance.

TT 22.29 Mon 18:00 P1

Time response of an MMC-based large-area photon detector operated at mK — •Sebastian Hilscher, Christian Enss, Andreas Fleischmann, Clara Marie Günther, Daniel Hengstler, Ashish Jadhav, Cagla Mahanoglu, Ioana-Alexandra Nitu, Andreas Reifenberger, Christian Ritter, Daniel Unger, and Loredana Gastalo — Kirchhoff Institute for Physics, Heidelberg, Germany

We present a large-area photon detector based on low temperature metallic magnetic calorimeters (MMCs), for which the silicon substrate acts as absorber. The detector is designed for measuring light emission in scintillating crystals, for instance in the AMoRE experiment. The visible photons emitted in the scintillating crystal are absorbed on a central silicon area isolated by through-silicon trenches from the rest of the substrate. Prototype devices have been produced and characterized at mK temperatures with focus on the time profile of temperature pulses. Very important for the optimization of the detector is modeling this time profile. Here, we present simulations of the phonon propagation and scattering inside the silicon absorber, with either specular or diffusive reflections at the surfaces. These simulations provide a time dependence of the fraction of energy reaching the MMC sensor. We compare the results obtained from measurement and simulation and discuss the implications of the photon detector for the AMoRE experiment.

TT 22.30 Mon 18:00 P1

Towards large-area 256-pixel MMC arrays for high resolution X-ray spectroscopy — •Andreas Abeln, Daniel Hengstler, Lucas Herbstritt, Daniel Kreuzberger, Andreas Reifenberger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

Metallic Magnetic Calorimeters (MMCs) are energy-dispersive cryogenic particle detectors. Operated at temperatures below 50 mK, they provide very good energy resolution, high quantum efficiency as well as high linearity over a large energy range. In many precision experiments in X-ray spectroscopy the photon flux is small, thus a large active detection area is desirable. Therefore, we develop arrays with increasing number of pixels.
In this contribution we present a detector setup featuring a novel dense-packed 16×16 pixel MMC array. The pixels provide a total active area of $4\,\mathrm{mm} \times 4\,\mathrm{mm}$ and are equipped with $5\,\mu$m thick absorbers made of gold. This ensures a stopping power of at least 50 % for photon energies up to 20 keV. The expected energy resolution is 1.4 eV (FWHM) at an operating temperature of 20 mK. For the cost-effective read-out of the 128 detector channels we envisage the flux-ramp multiplexing technique. We present first results of the detector characterization obtained utilizing parallel 2-stage dc-SQUID read-out chains. We discuss the detector performance, focusing on the thermal behavior within the detector as well as to the thermal bath.

TT 22.31 Mon 18:00 P1

MOCCA: A molecule camera for the position and energy resolved detection of neutral molecule fragments — •N. Fiedler[1], A. Fleischmann[1], C. A. Jakob[2], D. Kreuzberger[1], A. Özkara[1], D. Hengstler[1], A. Reifenberger[1], L. Gastaldo[1], P. Martini[3], S. Rosén[3], H. Zettergren[3], O. Novotný[2], H. T. Schmidt[3], and C. Enss[1] — [1]Kirchhoff Institute for Physics, Heidelberg University — [2]Max Planck Institute for Nuclear Physics, Heidelberg — [3]Department of Physics, Stockholm University

The MOCCA detector is a high-resolution camera for neutral molecule fragments with kinetic energies in the keV range. It features several thousand pixels based on metallic magnetic calorimeters and is read out using SQUIDs. To reconstruct the kinematics of electron-ion and ion-ion reactions, MOCCA measures both the energy and the impact position of molecular fragments incident on the detector, even with multiple particles hitting the detector simultaneously. The latest fabricated version is currently being deployed at the Cryogenic Storage Ring (CSR) at the Max Planck Institute for Nuclear Physics in Heidelberg, where molecular ions are stored and prepared in their rotational and vibrational ground states, allowing detailed studies of electron-ion interactions. We present plans for integrating the 11.5k-pixel MOCCA-Quattro detector system into the Double ElectroStatic Ion Ring ExpEriment (DESIREE) at Stockholm University, which enables mutual neutralization of ions at extremely small relative velocities. This will significantly enhance studies of neutralization processes in complex molecules prepared in their quantum ground state.

TT 22.32 Mon 18:00 P1

Towards reproducible Transition Edge Sensors for rare event searches — •Kilian Heim[1], Godehard Angloher[1], Laci Andricek[2], Mukund Bharadwaj[1], Dieter Hauff[3], Bernd Liebig[2], Gerhard Liemann[2], Jelena Ninkovic[2], Karoline Schäffner[1,3], Kumrie Shera[1], Raimund Strauss[3], Philipp Wasser[3], and Lutz Ziegele[1] — [1]Max-Planck-Institut für Physik — [2]Max-Planck Halbleiterlabor — [3]Technische Universität München

One approach to the search for dark matter is the use of scintillating crystals, such as sodium iodide (NaI), operated at cryogenic temperatures, as implemented by the COSINUS experiment. The readout of the signal, generated upon a nuclear recoil in a NaI crystal, relies on tungsten based transition edge sensors (TESs). These sensors consist of thin (~200 nm) tungsten films that are operated in the transition between the normal and superconducting state.

The transition temperature of such thin tungsten films depends on a multitude of factors, including grain size, stress level, and film impurities. However, for COSINUS, and next-generation rare event searches, the ability to mass-produce sensors with a consistent transition temperature of ~15 mK is crucial. Achieving this necessitates a solid understanding of the factors influencing the transition temperature as well as a precise control of these parameters during the fabrication process.

This contribution presents the first steps taken towards the establishment of a reproducible TES fabrication process as well as future measures to achieve consistent transition temperatures.

TT 22.33 Mon 18:00 P1

In-situ thermometry of Holmium in $LiYF_4$ crystals with Erbium as a probe — •Julia Latour[1,2,3], Cesare Mattiroli[2], Matthias Althammer[3,1], Nadezhda Kukharchyk[3,1,4], and Henrik M. Rønnow[2] — [1]Technische Universität München — [2]École Polytechnique Fédérale de Lausanne — [3]Walther-Meißner-Institut für Tieftemperaturforschung — [4]Munich Center for Quantum Science and Technology

Measurements of sample temperatures in cryogenic environments are, in most cases, performed using resistance thermometers. Such measurements, however, do not allow for determining the actual temperature inside optical crystals, such as $LiYF_4$, due to thermal boundary resistance and thermal-conductivity mismatches between the sample, mounting plate, and sensor. These limitations can be overcome by employing an in-situ spin-temperature measurement technique based on the analysis of changes in the hyperfine energy-level populations of fast-thermalizing, highly coherent electron spin systems. In this work, we investigate mixed ensembles of Holmium and Erbium ions diluted in a $LiYF_4$ host for in-situ spin thermometry. To this end, we monitored the relative changes in the absorption spectra of $LiYF_4$ with 0.1% and 1% Ho doping and 0.005% Er co-doping in the magnetic fields of 0–5 T over the temperature range of 0.1–1 K. We compare the thermometry results for the lower- and higher-doped samples to estimate the impact of ion-ion interactions. Samples doped with only Holmium and Erbium are similarly probed to serve as temperature references.

TT 22.34 Mon 18:00 P1

Fast calibration and performance verification of RuO_2 chip thermometers down to 20 mK utilizing adiabatic demagnetization refrigeration in the PPMS. — •Jorginho Villar Guerrero, Philipp Gegenwart, Christian Heil, and Tim Treu — University Augsburg

Access to temperatures in the millikelvin (mK) range is essential for the research and development of quantum technologies. Calibrated low-temperature sensors are expensive and only available with long lead times. We focus on the fast calibration of cheap Ruthenium Oxide (RuO_2) thick-film resistor chips that are widely used in the automotive industry and are therefore readily available. Upon cooling to below 4 K, they show a pronounced rise of the resistance, which follows variable-range hopping and can be used for low-temperature thermometry down to 20 mK [1]. The thermometers feature a low mass and consequently a low specific heat. Their small size allows mounting them on small contact surfaces. For calibration and performance tests down to mK temperatures, we utilize adiabatic demagnetization of frustrated oxide quantum magnets in the Quantum Design Physical Property Measurement System [2]. We present a miniaturized thermometer calibration setup with reduced response time and minimal self-heating for use down to 20 mK. We report measurements against secondary thermometers with traceable calibration as well as verification with superconducting transitions of Rh-Ir alloy.

[1] R. W. Willekers et al., Cryogenics 30, Issue 4, 1990
[2] T. Treu et al., J. Phys. Condens. Matter 37, 013001 (2025)

TT 22.35 Mon 18:00 P1

Optimizing the Energy Resolution of Calorimetric Low Temperature Detectors (CLTDs) by Reducing Mechanical Vibrations of the Cryogenic Setup — •Elias Eisenschmidt[1,3], Hardy Weisweiler[1], Andre Schirmeisen[2,3], Jack-Andre Schmidt[2,3], and Saskia Kraft-Bermuth[1] — [1]Technische Hochschule Mittelhessen, D-35390 Giessen, Germany — [2]Justus-Liebig-Universität Giessen, D-35392 Giessen, Germay — [3]TransMIT GmbH, D-35392 Giessen, Germany

A CLTD consists of an absorber whose temperature can be measured with a thermometer. Due to the careful consideration of absorber*s heat capacity and thermal coupling, the temperature increase of the absorber due to the impact of a particle can be directly related to the energy of said particle [1],

One limit to the energy resolution is electronic noise which is partly due to vibrations. In this study, the required low temperature is reached using a Pulse Tube Cooler (PTC) for precooling and a pumped 4He pot on a second stage. The CLTD*s energy resolution is noticeably influenced by mechanical vibrations. In this work, measurements and FEM simulations of vibrations at different cold finger designs are correlated to the energy resolution of heavy ion CLTDs obtained from alpha particles.

[1] P. Egelhof and S. Kraft-Bermuth, Prog. Part. Nucl. Phys. 132, 104031 (2023)
DOI:10.1016/j.ppnp.2023.104031.

TT 22.36 Mon 18:00 P1

Optimization of a Single-Stage GM-Type Cooler for Large Thermal Masses — Miriam Reif[3], •Jan Ole Sonnenberger[1,2], Bernd Schmidt[2,3], Jack-André Schmidt[2], and André Schirmeisen[2,3] — [1]Technische Hochschule Mittelhessen, Friedberg, Germany — [2]TransMIT GmbH, Giessen, Germany — [3]Instiute of Applied Physics, Justus-Liebig University, Giessen, Germany

The demands placed on cooling systems are constantly increasing, which is why they are becoming larger resulting in more overall mass, yet are still expected to cool as quickly as existing systems. Therefore, the systems must be optimized to cool larger masses.[1] A single-stage cooler is ideal for pre-cooling, which is why a single-stage GM-type PTS power cooler was tested as part of the investigation. The performance data of the system was recorded and analyzed under various operating conditions. Based on these measurements, a cooling curve was measured and optimized varying the operating frequency to determine the optimal operating point of the system.

Another another test was then carried out with an attached thermal load in the form of 42 kg of copper to investigate the cooling behavior under increased mass. Once the mass had cooled down without optimization, the cooling time was reduced by around 25% based on the data gained from the previous experiments. These tests provide deeper insight into the performance and optimization of the single-stage GM-type power cooler.

[1] Snodgrass et al., Nat Commun 15, 3386 (2024)

TT 22.37 Mon 18:00 P1

Purification of liquid Helium with a heat flush purifier in a dry cryostat — •Franziska Hömke and for the DELight Collaboration — Kirchhoff-Institute for Physics, 69120 Heidelberg, INF 227, Germany

The Direct search Experiment for Light dark matter (DELight) aims to search for dark matter by probing elastic scattering interactions of light dark matter particles with helium atoms in liquid helium. The helium is cooled to low millikelvin temperatures within a $^3He/^4He$ dilution refrigerator. At these temperatures ^4He is in its superfluid phase, enabling a long mean free path for the phonons and rotons produced in the scattering events. However, ^3He impurities drastically limit the mean free path and hinder the ballistic propagation of the phonons and rotons. To achieve a sufficiently large mean free path, the ^3He concentration in the helium must be reduced by at least three orders of magnitude from the natural concentration.

A heat flush purifier makes use of the unique properties of superfluid ^4He to remove ^3He and other impurities via a temperature gradient. It can be operated in continuous flow and will be integrated into the helium filling circuit of the cell. In wet cryostats, these devices were able to achieve the desired ^3He concentration in ^4He within a single cycle, but no implementations in dry cryostats have yet been described.

This contribution presents the ongoing developments in the design and optimization of a heat flush purifier for the DELight cell.