TT 11: Superconductivity: Poster

Time: Monday 15:00–18:00 Location: P4

TT 11.1 Mon 15:00 P4

Chiral and nematic superconductivity in monolayer $NbSe_2$ — •Anton Bleibaum[1], Julian Siegl[1], Wen Wan[2], Marcin Kurpas[3], John Schliemann[1], Miguel M. Ugeda[2,4,5], Magdalena Marganska[1], and Milena Grifoni[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93053 Regensburg, Germany — [2]Donostia International Physics Center, Paseo Manuel de Lardizábal 4, 20018 San Sebastián, Spain — [3]Institute of Physics, University of Silesia in Katowice, 41-500 Chorzów, Poland — [4]Centro de Física de Materiales, Paseo Manuel de Lardizábal 5, 20018 San Sebastián, Spain — [5]Ikerbasque, Basque Foundation for Science, Bilbao 48013, Spain

Superconductivity emerges when there is an effective attractive electron-electron interaction. As proposed by Kohn and Luttinger in 1965, screening of the Coulomb interaction can give rise to long-range Friedel oscillations providing regions of attractive interaction which allow for Cooper pairing. In $NbSe_2$, Coulomb repulsion is sufficient to induce superconductivity, when accounting for screening on the triangular lattice. Using momentum resolved gap equations, we find two quasi-degenerate nematic solutions near the critical temperature T_c. In agreement with tunneling spectroscopy experiments, a complex linear combination forms a fully gaped chiral phase well below T_c. When we allow for an in-plane magnetic field, we find an equal spin pairing component.

TT 11.2 Mon 15:00 P4

Exfoliation and STM/STS Investigations of Monolayer $NbSe_2$ S/F Systems — •Tiark Tiwary[1], Marcel Strohmeier[1], Elke Scheer[1], and Angelo Di Bernardo[1,2] — [1]University of Konstanz, 78457 Konstanz, Germany — [2]University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano (SA), Italy

Two dimensional materials have become of great interest in the recent years, because of their promise to enable novel electronic functionality by choosing suitable material combinations. A typical feature of 2D superconductors is their anisotropy of the critical field which is most pronounced in the monolayer limit. To understand more about the behaviour of Ising superconductivity in monolayer $NbSe_2$, STM/STS measurements were performed. To this end, gold-assisted exfoliation was used to obtain large monolayer on a Ti/Au surface. The measurements largely confirmed the previous reports [1, 2] on monolayer $NbSe_2$. To develop devices for superconducting spintronics, the interplay between a ferromagnet and monolayer $NbSe_2$ is investigated. Multiple techniques to gain $NbSe_2$ monolayer were explored. The exfoliation of small monolayers on a Co surface could be achieved.

[1] Wan et al., Adv. Mater. 34, 2206078 (2022);
[2] Kuzmanović et al., Phys. Rev. B **106**, 184514 (2022).

TT 11.3 Mon 15:00 P4

Cavity Mediated Control on Study of Transient THz Field on Superconductors — Angela Montanaro, Giacomo Jarc, •Nitesh Khatiwada, and Daniele Fausti — Friedrich-Alexander-Universität Erlangen-Nürnberg

Cavity QED has emerged as a new stimulus for studying phase transition in quantum materials. A recent study[1] demonstrating changes in critical temperature for metal insulator phase transition mediated by cavity electrodynamics in 1T-TaS_2 has inspired us to investigate cavity mediated phase transition in superconductors.

[1] Nature 622, 487 (2023).

TT 11.4 Mon 15:00 P4

THz spectroscopy on superconducting ZrN thin films — •Ozan Saritas[1], Frederik Bolle[1], Martin Dressel[1], Roman Potjan[2], Marcus Wislicenus[2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Fraunhofer Institute for Photonic Microsystems (IPMS), Center Nanoelectronic Technologies (CNT), Dresden, Germany

The recent large-scale preparation of superconducting ZrN thin films is of interest for potential quantum technology applications [1]. Therefore, here we use THz frequency domain spectroscopy to investigate the superconducting electrodynamics of ZrN thin films, with thickness between 20 nm and 50 nm, grown on 300 mm-standard silicon substrates. We have measured the transmission and phase shift of THz radiation passing through the ZrN films, and we have obtained the frequency-dependent dielectric function. We thus acquired characteristic material quantities such as the temperature-dependent superconducting energy gap $2\Delta(T)$ and superfluid density $n_s(T)$. With decreasing thickness, there is a clear trend towards a lower critical temperature T_c, a reduced $2\Delta(T=0)$, and a lower $n_s(T=0)$. While the overall behavior is similar to BCS predictions, thinner films exhibit values for the ratio $2\Delta(T=0)/(k_BT_c)$ that deviate more from the canonical value.

Additionally, a novel analysis of the temperature-dependent shift of Fabry-Perot transmission resonance frequencies of superconducting thin-film samples was performed.

[1] R. Potjan *et al*, Appl. Phys. Lett. **123**, 172602 (2023)

TT 11.5 Mon 15:00 P4

Terahertz investigations on superconducting nitride thin films — •Yayi Lin[1], Frederik Bolle[1], Janine Lorenz[2], Marcello Guardascione[2], Marc Neis[2], Thomas J. Smart[2], Martin Dressel[1], Rami Barends[2], Pavel Bushev[2], F. Stefan Tautz[2], Felix Lüpke[2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich, Jülich, Germany

In recent years, superconducting nitride thin films have garnered significant attention, for example for applications in quantum electronics. Due to the wide range of accessible kinetic inductance, high critical temperature, and correspondingly large energy gap, these materials are readily utilized in microwave resonators, low-temperature amplifiers, and quantum circuits.

We use terahertz (THz) spectroscopy to probe the electrodynamics of superconducting NbTiN ($T_c > 10$ K) and TiN ($T_c > 3$ K) thin films at frequencies below and above their superconducting energy gaps. We combine THz frequency-domain spectroscopy and THz time-domain spectroscopy to cover the frequency range from 100 GHz to 3 THz. We present key properties of several nitride thin films such as critical temperature (T_c), complex optical conductivity ($\hat{\sigma}$), energy gap (2Δ), superfluid density (n_s), and kinetic inductance (L_k). Of particular interest is the absolute value of the superconducting energy gap, which allows comparison with other spectroscopic techniques and predictions based on BCS theory.

TT 11.6 Mon 15:00 P4

Nanoscale Characterization of Defects in Superconducting Nitrides — •Janine Lorenz[1,2,3], Amin Karimi[1], Yorgo Hadad[1], Rami Barends[1], F. Stefan Tautz[1,2,3], and Felix Lüpke[1,4] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [2]Jülich Aachen Research Alliance (JARA) - Fundamentals of Future Information Technology, Germany — [3]Institut für Experimentalphysik IV A, RWTH Aachen Universität, Germany — [4]II. Physikalisches Institut, Universität zu Köln, Germany

Due to their elevated critical temperature and high kinetic inductance, Nitride supercondcutors are promising candidates for microwave resonators and low-noise amplifiers that are essential for useful quantum computing. We aim to improve structural and superconducting properties of our 11 nm NbTiN thin films grown by sputter deposition. By implementing a post-deposition thermal annealing protocol in Nitrogen/Hydrogen gas atmosphere we achieve an increase in critical temperature from initially 11.5 K to 18 K. In this work, we apply scanning probe techniques to investigate surface superconductivity and defects that appear as Yu-Shiba-Rusinov states of treated and untreated thin films.

TT 11.7 Mon 15:00 P4

Superconductivity of Reduced Indium Tin Oxide — •Luca Hofmeister, Jan Pusskeiler, Gabriele Untereiner, Martin Dressel, and Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, Deutschland

Indium tin oxide (ITO) is a transparent semiconductor commonly used in photovoltaics and flat screen displays. It is possible to induce low temperature superconductivity in ITO via electrochemical reduction in a NaCl solution. [1,2]

We reduced multiple ITO samples at a constant reduction current and measured the temperature dependence of their two-point resistance with a microwave Corbino spectrometer. Depending on the reduction time, the T_c ranges from 2.2 K to 3.7 K, forming a superconducting dome.

Reduction induces a color change of the ITO, which loses some of its transparency for increasing reduction times. Nevertheless, ITO retains some transparency even after very long reduction, thereby making ITO a candidate for usage as a transparent superconducter.

[1] A. E. Aliev *et al.*, Appl. Phys. Lett. **101**, 252603 (2012);
[2] E. Batson *et al.*, Supercond. Sci. Technol. **36**, 055009 (2023).

TT 11.8 Mon 15:00 P4

Structural properties of $YBa_2Cu_3O_7$ thin film nanopatterns generated by focused He-ion-beam irradiation — •Robin Hutt[1], Cesar Magen[2], Christoph Schmid[1], Jan Ullmann[1], Simon Koch[1], Javier Pablo-Navarro[2], Ross Carter[1], Paul Zimmermann[1], Frank Schreiber[1], Dieter Koelle[1], Reinhold Kleiner[1], Ivan Zaluzhnyy[1], and Edward Goldobin[1] — [1]Universität Tübingen, Germany — [2]INMA, Universidad de Zaragoza - CSIC, Spain

Irradiation of a $YBa_2Cu_3O_7$ (YBCO) thin film with a focused He ion beam (He-FIB) with spot size $\lesssim 10$ nm changes its properties on the nanoscale. A moderate irradiation dose D supresses the critical temperature T_c locally, thus allowing us to "draw", e.g., Josephson barriers, while a high D destroys (amorphizes) the crystal locally, letting us create highly resistive walls (edges of devices and holes) in one fabrication run. We report on the irradiation of YBCO thin films by He-FIB using single lines and rectangular areas with different doses and investigate the result using transmission electron microscopy (TEM). We visualize the crossover to amorphization at the critical dose D_c and the growth of the amorphous track width with D. Using a simple model, we obtain the value of D_c and FIB spot size with a good accuracy. In the areas irradiated by $D < D_c$ we use strain analysis of the TEM images to detect subtle changes in the crystal structure. This is complemented by spatially-resolved X-ray diffraction data that indicate the swelling of the film in c-direction in irradiated regions. Finally, these observations are correlated with electric transport properties of irradiated areas.

TT 11.9 Mon 15:00 P4

$YBa_2Cu_3O_7$ thin films on Si substrates for SQUID-on-lever scanning probe microscopy — •Simon Koch, Alexander Koller, Christoph Schmid, Reinhold Kleiner, and Dieter Koelle — Physikalisches Institut, Center for Quantum Science (CQ) and LISA$^+$, Universität Tübingen, Germany

Scanning SQUID microscopy (SSM) is a powerful technique for imaging magnetic fields or dissipation processes. The use of the high-T_c cuprate superconductor $YBa_2Cu_3O_7$ (YBCO) combined with custom made Si atomic force microscopy (AFM) cantilevers could enable SSM in the Tesla range and at temperatures up to ~ 80 K with high spatial resolution. However, YBCO has a complex crystal structure and a small coherence length, which leads to a high sensitivity to defects on the atomic scale. High quality YBCO films can only be obtained by epitaxial growth on lattice-matched substrates. Therefore, the challenge with this approch is the integration of YBCO thin films on Si wafers. In recent years, epitaxial $SrTiO_3$ (STO) with perovskite crystal structure has been realized on Silicon [1] and epitaxial STO-on-Si commercial substrates are now available. STO is lattice-matched to YBCO, and therefore provides an ideal starting point for the project.

We present our process for the fabrication of YBCO thin films on STO-on-Si substrates, based on pulsed laser deposition (PLD) and discuss the optimization of growth conditions. We further present our preliminary results regarding film quality and electrical characterization of fabricated structures.

[1] Abel *et al.*, Nature Mater. **18**, 42-47 (2019).

TT 11.10 Mon 15:00 P4

Disorder dependent properties of superconductors — •Marvin Zibula and Götz Seibold — Institut für Physik B-TU Cottbus-Senftenberg, Erich-Weinert Straße 1, 03046 Cottbus

We study the properties of disordered superconductors within the attractive Hubbard model and a disorder potential which interpolates between diluted impurities and Anderson-type disorder with a random potential at each lattice site. In the latter case, we reproduce the results from Ghosal et al. [1], corresponding to the formation of superconducting islands that are not correlated to the underlying charge distribution. However, such a correlation becomes effective upon reducing the impurity concentration. Our results are important for recent optical experiments related to the nonlinear first harmonic response which are more compatible with the diluted model.

[1] A.Ghosal, M.Randeria, N.Trivedi, Phys.Rev.B 65, 014501 (2001)

TT 11.11 Mon 15:00 P4

Influence of strong correlations on impurity-induced TRSB in a (s+id)-wave superconductor — •Marius Paul and Götz Seibold — BTU Cottbus

In numerical simulations of the extended Hubbard model with nearest-neighbor attraction, which is an actively investigated model for high-Tc-superconductors, there has been made observations of time reversal symmetry breaking in the form of loop currents in the last few years [1,2]. Those loop currents emerge mainly in the vicinity of an $s + id$-state when nonmagnetic disorder is present in the superconductor. While previous work has focused on the investigation of this phenomenon within the Bogoljubov-de Gennes approximation, we will discuss here the influence electronic correlations on the stability of the loop currents. This is accomplished via the time-dependent Gutzwiller approximation extended towards the inclusion of pairing correlations.

[1] Z.-X.Li, S. Kivelson, D.-H.Lee, npj Quantum Mater. 6, 12 (2021).
[2] C.N.Breiø, P.J.Hirschfeld, B.M.Andersen, PRB 105, 014504 (2022).

TT 11.12 Mon 15:00 P4

Constraints on the theoretical modeling of hole-doped La_2CuO_4 — •Qiwei Li, Xuejing Zhang, and Eva Pavarini — Peter Grünberg Institute-2, Forschungszentrum Jülich, Jülich, Germany

The low-energy electronic properties of hole-doped La_2CuO_4 are believed to be well captured by the single-band Hubbard model describing x^2-y^2 electrons. This finds support, e.g., on Fermi surface and angle resolved photoemission experiments. Here we show that this imposes constraints on the microscopic description of the system.

TT 11.13 Mon 15:00 P4

Nonlinear THz-spectroscopy of $PdCoO_2$ and LBCO: Probing c-axis dynamics and collective excitations — •Shuhan Wang[1], Tim Priessnitz[2], Min-Jae Kim[1,2], Liwen Feng[1,2], Gideok Kim[2], Bernhard Keimer[2], and Stefan Kaiser[1,2] — [1]TUD Dresden University of Technology, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Layered quantum materials offer a unique platform for studying anisotropic transport and collective excitations. Using THz-High-Harmonics Generation, we investigate the c-axis responses of $PdCoO_2$ and $La_{2-x}Ba_x CuO_4$ (LBCO) grown on offcut substrates. $PdCoO_2$ shows exceptionally large THz second harmonic and third harmonic generation [1] while LBCO shows distinct features linked the superconducting Higgs response and the Josephson plasma resonance. We will discuss the features referenced to the linear response of these systems measures with THz time domain spectroscopy.

[1] T. Priessnitz et al., arXiv:2409.07872

TT 11.14 Mon 15:00 P4

Higgs collective mode in superconductors: in- and out-of equilibrium — •Sida Tian[1], Rafael Haenel[1,2], and Dirk Manske[1] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart — [2]Quantum Matter Institute, University of British Columbia, Vancouver V6T 1Z4, Canada

Collective modes in superconductors encode rich information about the superconducting state. Experimentally probing them requires THz lasers that push the system away from equilibrium. We present a theory of non-equilibrium response based on Keldysh formalism, and introduce a recent developed experimental technique of Non-equilibrium Antistokes Raman Scattering. We further comment on the influence of higher-order fluctuations to collective modes, which will change the collective mode mass. This implies that in circumstances where quantum corrections become relevant such as strong coupling, the Higgs mode will move inside the pair breaking gap.

TT 11.15 Mon 15:00 P4

Nematic susceptibility in heavily hole-doped iron based superconductors — •Franz Eckelt[1], Xiaochen Hong[2], Vilmos Kocsis[3], Vadim Grinenko[4], Bernd Büchner[2], Christian Hess[1], Chul-Ho Lee[5], and Kunihiro Kihou[5] — [1]Bergische Universität Wuppertal, 42097 Wuppertal, Germany — [2]College of Physics and Center of Quantum Materials and Devices, Chongqing University, 401331 Chongqing, China — [3]Leibnitz-Institut for Solide State and Materials Research, 01069 Dresden, Germansy — [4]Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai 201210, China — [5]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, 305-8568, Japan

We investigate the elastoresistivity of heavily hole doped iron-based superconductor $Ba_{1-x}K_xFe_2As_2$ in the range x=0.68-0.98 using a piezoelectric measurement technique. We observe a divergent increase in elastoresistance along the [110] direction during cooling for all samples the amplitude of which possesses a strong non-montonic doping dependence. We discuss our results in terms of nematic fluctuations, Fermi surface effects near a Lifshitz transition, and a potential orbital-selective Mott transition.

TT 11.16 Mon 15:00 P4

The Search for 1144 Phases under Pressure — •Leonard Essich, Kristin Kliemt, and Cornelius Krellner — Institute of Physics, Goethe University Frankfurt, Germany

Alternative stacking of 122 Fe-based pnictides has enabled the synthesis of the 1144 phase ABFe$_4$As$_4$ (A = alkali, B = alkaline earth). Examples include $CaKFe_4As_4$, where a *half-collapsed* tetragonal phase emerges under pressure, and $EuRbFe_4As_4$ or $EuCsFe_4As_4$, where Eu magnetism coexists with superconductivity [1,2]. Theoretical studies predict the stability of further 1144 Fe-arsenides and an extension to phosphides (AB(TM)$_4$P$_4$ where TM = Fe, Ru, Co, or Ni). Notably, $CaKRu_4P_4$ has been successfully synthesised [1]. This work investigates the synthesis of other 1144 phases under high-pressure conditions, designed to support the incorporation of smaller phosphorus atoms on arsenic lattice positions. Multi-anvil presses offer precise pressure and temperature control, large sample sizes, and adaptable setups for crystal growth research. In this contribution, we present the capabilities of a multi-anvil press, the challenges encountered during sample preparation, and outline the pathway to synthesising 1144 phases. A Walker-type module, previously utilized in our laboratory, contains a 6-8 anvil configuration within a steel cylinder [3]. The choice of pressure-transmitting medium and internal configuration is crucial to achieving the desired outcome in these experiments.

[1] B. Q. Song *et al.*, Phys. Rev. Materials **5**, 094802 (2021)
[2] U. S. Kaluarachchi *et al.*, Phys. Rev. B **96**, 140501 (2017)
[3] A. A. Haghighirad *et al.*, Cryst. Growth Des. **8**, 1961 (2008)

TT 11.17 Mon 15:00 P4

Two-Gap Superconductivity in the Noncentrosymmetric La_3Se_4 — f košuth[1,2], n potomová[2], z pribulová[1], j kacmarcík[1], •m naskar[3], d s inosov[3], s ash[4], a k ganguli[5], j soltýs[6], v cambel[6], p szabó[1], and p samuely[1] — [1]Centre of Low Temperature Physics, Institute of Experimental Physics, Slovak Academy of Sciences, SK04001 Košice, Slovakia — [2]Centre of Low Temperature Physics, Faculty of Science, P. J. Šafárik University, SK-04001 Košice, Slovakia — [3]Institut für Festkörper und Materialphysik, Technische Universität Dresden, D-01069 Dresden, Germany — [4]Institute for Solid State Research, Leibniz IFW Dresden, D-01069 Dresden, Germany — [5]Department of Chemistry, Indian Institute of Technology Delhi, New Delhi 110016, India — [6]Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava SK84104, Slovakia

Point-contact Andreev reflection spectroscopy at low temperatures and high magnetic field has been carried out on the noncentrosymmetric superconductor La_3Se_4 (T_c = 8 K). Two superconducting energy gaps Δ_1 and Δ_2, with $2\Delta_1/k_BT_c = 5.8$ and $2\Delta_2/k_BT_c = 2.3$, are directly observed in certain spectra. The effects of temperature and magnetic fields help to distinguish a two-gap structure, even in the more common spectra where only a single gap is visible at low temperatures, indicated by a pair of maxima around zero bias. The presence of two-gap superconductivity, consistent with the results from point-contact Andreev reflection spectroscopy, is further confirmed by heat capacity and Hall probe magnetization measurements.

TT 11.18 Mon 15:00 P4

Positive Evidence for Bogoliubov-Fermi Surfaces in Al/InAs Hybrids — •Simon Feyrer[1], Ignacio Lobato[1], Vjeko Dimic[1], Michael Prager[1], Dominique Bougeard[1], Matthias Kronseder[1], Giorgio Biasiol[4], Carlos Balseiro[2], Liliana Arrachea[2], Marco Aprili[3], Christoph Strunk[1], and Leandro Tosi[1,2] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [2]Centro Atomico Bariloche, Comision Nacional de Energia Atomica, Argentina — [3]Laboratoire: Physic des Solides, Université Paris-Saclay, France — [4]IOM CNR, Laboratorio TASC, Area Science Park Basovizza, Trieste, Italy

We present measurements of a lumped element microwave resonator made out of hybrid Al/InAs superconductor/semiconductor 2D heterostructures. In our device, the inductor is a narrow wire taylored in the material, dominating the kinetic inductance contribution. The resonance frequency depends on temperature, on power and strongly on in-plane magnetic field. We have observed a change of behavior as the magnetic field becomes larger than B*, consistent with a contribution of the superconducting 2DEG in the InAs affected by the spin-orbit coupling [1]. Using resonators with different geometries we discuss the correlation between the observed anisotropy and the crystal orientation.

[1] D. Phan et al., Phys. Rev. Lett. 128, 107701 (2022).

TT 11.19 Mon 15:00 P4

Proximity induced superconductivity in non-collinear antiferromagnets (NCAFMs) — •Anshuman Padhi[1], Prajwal Rigvedi Madhusudan Rao[1], Ajin Joy[2], Ajesh K Gopi[1], Jiho Yoon[1], Jae-Chun 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

Conversion of spin-singlet Cooper pairs to spin-polarised triplet Cooper pairs has been a significant achievement of proximity induced superconducting hybrids. But they often require multilayed stack of mismatched magnetisation interfacing the superconducting condensate, leading to lower tunability, less flexibility on the choice of materials and lesser densities of converted triplet Cooper pairs. Recently, usage of non-collinear antiferromagents have been shown to host long-ranged supercurrents and owing to their atomic distribution of spins in a Kagome lattice are a prime candidate for triplet superconductivity. In this study we aim to fundamentally understand the proximity effect into two-phases of a Mn-based antiperovskite, by analysing the field-dependence of the critical temperature of the superconducting thin-film interfacing them. The unique spin-texture of such materials, with broken inversion symmetry and the presence of uncompensated moments too, can lead to interesting physics w.r.t. the Andreev levels. Thus we fabricate S/I/NCAFM tunneling devices and perform electrical tunneling measurements to study the probable Andreev levels and the impact of the spin-states on them. This exploratory work aims at a deeper level of understanding of Cooper pair interactions in NCAFMs.

TT 11.20 Mon 15:00 P4

Interaction of supercurrents in multiterminal graphene Josephson junctions — •Paul Maier, Romain Danneau, and Detlef Beckmann — Institut für Quantenmaterialien und Technologien, Karlsruher Institut für Technologie

Topological states are predicted to exist in the Andreev bound state spectrum of multiterminal Josephson junction with four or more terminals [1]. Superconductor graphene hybrid structures are especially suitable to realize such devices due to the gate tunability of graphene and the low contact resistance necessary to form Andreev bound states. Understanding the distribution of supercurrent in graphene multiterminal Josephson junctions is one step in the search for these states. We report on the experimental investigation of transport in a four-terminal graphene Josephson junction. We observe magnetic interference patterns in two-terminal measurements and critical current contours in multiterminal measurements, and compare the results to theoretical simulations.

[1] R.-P. Riwar et al., Nat. Commun. 7, 11167 (2016).

TT 11.21 Mon 15:00 P4

Control of Andreev Reflection via a Single-Molecule Orbital — •Lorenz Meyer[1], Jose L. Lado[2], Nicolas Néel[1], and Jörg Kröger[1] — [1]Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany — [2]Department of Applied Physics, Aalto University, 02150 Espoo, Finland

Charge transport across a single-molecule junction fabricated from a normal-metal tip, a phthalocyanine, and a conventional superconductor in a scanning tunneling microscope is explored as a function of the gradually closed vacuum gap. The phthalocyanine (2H-Pc) molecule and its pyrrolic-hydrogen-abstracted derivative (Pc) exhibit vastly different behavior. Andreev reflection across the 2H-Pc contact exhibits a temporary enhancement that diminishes with increasing conductance. The hybridization of 2H-Pc with the tip at contact formation gives rise to a molecular magnetic moment that is Kondo-screened in the tip. In contrast, the single-Pc junction lacks Andreev reflection in the same conductance range. Spectroscopy experiments and supporting nonequilibrium Green function calculations highlight the importance of a molecular orbital close to the Fermi energy for rationalizing the observations.

Funding by the DFG through KR 2912/18-1 and KR 2912/21-1 is acknowledged.

TT 11.22 Mon 15:00 P4

Real-space mapping of Yu-Shiba-Rusinov states around magnetic defects on superconducting surfaces — •Raffaele Aliberti[1,2], Samir Lounis[1,4], Philipp Rüssmann[1,3], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany — [2]RWTH Aachen, Aachen, Germany — [3]Institute for Theoretical Physics and Astrophysics, University of Würzburg, Würzburg, Germany — [4]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

Interfacing magnetic impurities with superconductors generally gives rise to Yu-Shiba-Rusinov (YSR) bound states. Using first-principles, we study the case of Mn impurities deposited on a superconducting Ta (110) surface. We explore both the orbital nature and amplitude of the induced YSR states while investigating their spatial extent, which is characterized by an oscillatory and anisotropic behavior as function of distance with respect to the Mn impurities.In particular, we study the interplay of intrinsic electronic structure properties of the hosting superconductor and that of the impurities, which impacts the resulting "cloud" of YSR states.

We employ the Kohn-Sham Bogoliubov-de Gennes method within the all-electron full-potential relativistic Korringa-Kohn-Rostoker Green function method [1] interfaced with the AiiDA infrastructure for high-throughput automation [2].

TT 11.23 Mon 15:00 P4

Stochastic resonance realized with a superconducting magnetic impurity state — •Philipp Maier[1], Björn Kubala[1,2], Joachim Ankerhold[1], and Ciprian Padurariu[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University — [2]German Aerospace Center (DLR), Ulm

The phenomenon of stochastic resonance was originally studied in the context of climatic changes and has since been observed in a variety of systems, both classical and quantum. Here, we employ this phenomenon to infer the rates of tunneling processes in the course of quantum electronic transport [1,2]. We theoretically investigate the emergence of stochastic resonance in superconducting junctions, focusing on a system where one electrode hosts a Yu-Shiba-Rusinov state – a discrete bound state within the superconducting gap induced by the magnetic exchange interaction between a magnetic impurity and its superconducting host. Applying the framework of full counting statistics, we demonstrate that stochastic resonance manifests as the reduction of the Fano factor and a resonance of the tunneling current. The frequency of the resonance reveals information about the rate of microscopic electronic processes, e.g. the process responsible for quasiparticle-occupation parity breaking.

[1] M. Hänze et al., Sci. Adv. 7 (2021)
[2] T. Wagner et al., Nat. Phys. 15 (2019)

TT 11.24 Mon 15:00 P4

Dynamical simulations of single photon detection in superconducting nanowires — •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 use a Python simulation package py-TDGL [1] based on modified Ginzburg-Landau theory [2] to simulate the dynamics of the superconducting condensate in a thin nanowire during the detection of a single-photon. The detection event is modeled phenomenologically as a hot-spot formation: the photon is modeled as an initially localized increase in the electronic temperature, with a Gaussian spatial profile that diffuses outwards while also dissipating in time. Our simulations successfully reproduce the characteristic time-dependent voltage peaks measured in superconducting nanowire single-photon detectors, while providing an accompanying movie-like dynamics of the superconducting order parameter. We propose a method to enhance the prominence of the voltage peaks by optimizing the applied DC current and the intensity of an externally-applied perpendicular magnetic field, with the goal of enabling the detection of single-photons in a broader frequency spectrum.

[1] L.Bishop-Van Horn, Comput.Phys.Commun**291**, 108799 (2023).
[2] L. Kramer, R. J. Watts-Tobin, Phys. Rev. Lett. **40**, 1041 (1978).

TT 11.25 Mon 15:00 P4

Simulations of heating effects in dual Shapiro step circuits — •Matthias Meiring, Fabian Kaap, Sergey Lotkhov, and Lukas Grünhaupt — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

So-called dual Shapiro steps are quantised current steps separated by $2ef$, with e the elementary charge and f the rf drive frequency. They have recently gained renewed interest due to successful experimental demonstrations [1,2,3]. These dual Shapiro steps could bear the potential for a novel quantum current standard. Our measurements of dual Shapiro steps in an $Al/AlO_x/Al$ dc-SQUID connected to a circuit made of high-kinetic-inductance granular aluminium and high-ohmic oxidised titanium revealed an electron temperature, which is substantially higher compared to the case without rf drive. We evaluate thermal heating phenomena in the measured chip layout and present adapted circuit designs, which should reduce heating effects and enhance the step size. Achieving this will lead to more prominent dual Shapiro steps and could thus pave the way to a new quantum current standard based on superconducting circuits.

[1] R.S.Shaikhaidarov et al., Nature 608 (2022).
[2] N. Crescini et al., Nat. Phys. 19 (2023).
[3] F. Kaap et al., Nat. Commun. 15 (2024).

TT 11.26 Mon 15:00 P4

Broadband kinetic inductance of high impedance superconductors — •Jan Pusskeiler[1], Martin Dressel[1], Thomas Valentin[2], Ameya Nambisan[2], Simon Geisert[2], Ioan Pop[1,2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart — [2]Physikalisches Institut and IQMT, KIT

Kinetic inductance quantifies the intrinsic phase-shifted electrodynamics of superconductors and lies at the heart of superconducting quantum electronics operating at microwave frequencies. Determining the complex impedance Z of disordered and granular superconductors in a frequency range from 10 kHz to 20 GHz using a broadband Corbino reflectometer allows direct observation of the kinetic inductance as a linear contribution to the reactance, $\mathrm{Im}(Z) = L_{\mathrm{kin}} \cdot \omega$. By obtaining the broadband kinetic inductance at temperatures deep in the superconducting state, from 1.15 K up to the critical temperature T_c, we can extrapolate the zero-temperature kinetic inductance.

We study granular aluminum as a high-kinetic inductance superconductor featuring a superconducting dome in the low-temperature phase diagram as a function of normal-state resistivity ρ_{dc}. We report kinetic inductances ranging from 20 pH/sq to 2 nH/sq for granular aluminum thin films with resistivities between 120 $\mu\Omega$cm and 6100 $\mu\Omega$cm. We calculate the superfluid stiffness and observe a $1/\rho_{\mathrm{dc}}$ dependance, as also reported in [1]. Furthermore, we observe absorption features that we interpret as signatures of collective modes of the superfluid condensate.

[1] U. S. Pracht *et al.*, Phys. Rev. B **93**, 100503(R) (2016)

TT 11.27 Mon 15:00 P4

Characterization of photoresists for deep UV direct writing lithography — •Niels Fiedler[1], Andreas Reifenberger[1], Lukas Münch[1], Alexander Stoll[1], Ludwig Hoibl[2], Andreas Fleischmann[1], and Christian Enss[1] — [1]Kirchhoff Institute for Physics, Heidelberg University — [2]Heidelberg Instruments Mikrotechnik GmbH

Photoresists are integral to the precise pattern transfer processes required for fabricating micro- and nanoscale devices. The structuring of photoresists with optical maskless lithography systems has proven to be extremely versatile and efficient in research and development. Within the framework of the SuperLSI project, Heidelberg Instruments is developing a maskless lithographic platform incorporating a 266 nm Deep UV optical system, designed to achieve patterning resolutions as fine as 200 nm. Identification and thorough characterization of photoresists compatible with the lithographic platform is required. We focus on the performance of a positive (DuPont UV5-0.6) and negative (micro resist technology ma-N 2405) photoresist for the fabrication of superconducting sub-500 nm features. Structural fidelity, etch resistance, and developer compatibility with superconducting materials, such as niobium and aluminum, are evaluated. Achieving reduced linewidths advances quantum sensors like SQUIDs by enabling smaller Josephson junctions (JJs). Initial results for cross-type JJs with areas below 1 μm^2 highlight the potential of optical maskless lithography for flexible wafer-scale fabrication of superconducting devices.

TT 11.28 Mon 15:00 P4

Chemical-mechanical polishing process for the fabrication of cross-type Nb/Al-AlOx/Nb Josephson tunnel junctions — •A. Stoll, N. Fiedler, L. Münch, D. Hengstler, A. Reifenberger, A. Fleischmann, and C. Enss — KIP, Heidelberg University

Josephson tunnel junctions (JJs) are the basic elements of many superconducting electronic devices such as qubits or superconducting quantum interference devices (SQUIDs). Since many applications demand numerous JJs, a reliable wafer-scale fabrication process yielding reproducible, high-quality junctions is essential.
We present the microfabrication process of cross-type Nb/Al-AlOx/Nb Josephson tunnel junctions, emphasizing chemical-mechanical polishing (CMP) for planarization within SiO_2. A layer of SiO_2 is deposited over the structured trilayer, and CMP is used to polish away excess SiO_2, resulting in a planar, smooth, and uniform surface that enhances the accuracy and reliability of the junctions. Quality checks were conducted on junctions of various sizes, as well as the influence of support-like structures around junctions, to evaluate performance and scalability. Electrical characterizations demonstrate high-quality superconducting properties, validating the efficacy of CMP in the planarization of Josephson junction trilayers
This method enhances the scalability and integration of Josephson junctions in complex superconducting circuits, contributing to advancements in quantum computing and superconducting electronics.

TT 11.29 Mon 15:00 P4

High-quality niobium Josephson junctions for superconducting mm-wave qubits — •Urs Strobel[1], Benedict Rothmund[1], Lucas Radke[1], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut (PHI), Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Institut for Quantum Materials and Technologies (IQMT), Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

Millimeter-wave quantum circuits require a superconductor with an energy gap above 100 GHz , which exceeds the energy gap of the widely used aluminum. Niobium offers much more suitable properties in this frequency range. Implemented in thin film technology on low loss substrates, high quality niobium Josephson junctions should complement the capacitors and inductors required for quantum circuits. We have developed Nb/Al-AlO_x/Nb trilayer Josephson junctions suitable for quantum circuits and characterized them at cryogenic temperatures. We present dc and mm-wave measurement data obtained with these junctions. In addition, we discuss design considerations for prospective mm-wave transmon qubits.

TT 11.30 Mon 15:00 P4

Building a Quantum Wheatstone Bridge — •Thilo Krumrey[1], Alex Kreuzer[1], Hossam Tohamy[1], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]IQMT, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

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 present circuit simulations results based on the proposed design and compare them with measurements of the circuit at mK temperatures.
[1] K. Poulsen *et al.*, PRL **128**, 240401 (2022).
[2] F. Yan *et al.*, arXiv:2006.04130v1.

TT 11.31 Mon 15:00 P4

Charge Sensitivity of a Quantum Phase Slip Transistor — •Marius Frohn[1], Jan Nicolas Voss[1], Hannes Rotzinger[1,2], and Alexey Ustinov[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Institut für Quantenmaterialien und Technologien (IQMT), Karlrsruher Institut für Technologie, Karlsruhe, Germany

Superconducting quantum phase slip (QPS) devices are high-impedance circuits that are promising for quantum sensing applications or the realisation of a current standard. For example, the QPS transistor is a dual circuit to the SQUID and is therefore sensitive to charge rather than flux. We study QPS transistors fabricated from two strongly coupled granular aluminium nanowires. This allows us to use intrinsic electromigration[1] to fine-tune the Coulomb blockade voltage in situ. The current-voltage characteristics at different gate biases and wire resistances provide insight into the charge sensitivity and operating range of the QPS transistor. We present the results of experiments on superconducting nanowire circuits at mK temperatures.
[1] J. N. Voss, Y. Schön, M. Wildermuth, D. Dorer, J. H. Cole, H. Rotzinger and A. V. Ustinov, ACS Nano **15** (2021)

TT 11.32 Mon 15:00 P4

Characterization of Nb Air Bridges for Superconducting Quantum Computing — •Amanda Scoles[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], Ivan Tsitsilin[1,2], David Bunch[1,2], Julius Feigl[1,2], Lea Richard[1,2], Vera Bader[1,2], Lasse Södergren[1,2], Christian Schneider[1,2], and Stefan Filipp[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany

Superconducting qubits are a promising platform for the realization of practical quantum computing. The short gate times, comparatively long lifetimes, and relatively straightforward fabrication process, when compared to other systems, indicate an encouraging future for superconducting quantum circuits. Nevertheless, further optimization of both the fabrication and calibration processes is necessary to fully realize the potential of this platform. In particular, there is a need to enhance qubit coherence, reliability and scalability, which are the current main limitations of this technology.

In this work we investigate Nb air bridges, which provide flexibility in routing of control lines and facilitate the scaling of qubit numbers in planar geometries. We investigate the optimal fabrication parameters in order to maximize the yield of such structures. Additionally, we assess the quality factors of superconducting resonators in the vicinity of air bridges as well as daisy chains of air bridges, to determine the additional loss induced by the air bridge process.

TT 11.33 Mon 15:00 P4

Chiral High-Fidelity State Transfer with Thouless Pumping in Superconducting Circuits — •Lukas Vetter[1,2], Federico Roy[1,2], Jacquelin Luneau[1,2], João H Romeiro[1,2], Max Werninghaus[1,2], Christian MF Schneider[1,2], Peter Rabl[1,2], and Stefan Filipp[1,2] — [1]Technical University of Munich, TUM School of Natural Scienes, Department of Physics — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften

Efficient and robust techniques for state transfer and entanglement generation are vital for the progress of quantum technologies. Thouless pumping enables the topologically protected chiral transfer of excitations in quantum systems, however, dispersion during the protocol leads to losses in transfer fidelity. Here, we introduce a protocol for high-fidelity state transfer based on Thouless Pumping with Bloch Oscillations to suppress dispersion. Our protocol enables the transfer of single and multi-excitation Fock states and Bell states with high fidelity while being robust against perturbations of the Hamiltonian. We describe the effect of Bloch Oscillations using semi-classical equations of motion and show that changing the pumping cycle enables the generation of distant Bell pairs. We experimentally implement our results on a superconducting qubit device by realizing the pumping on a tunable coupler architecture. Our work paves the way for using Thouless pumping in quantum information processing, with applications in topologically robust entanglement generation and multi-qubit gates.

We acknowledge financial support from GeQCoS, MUNIQC-SC, MCQST, OpenSuperQPlus100, and the Munich Quantum Valley.

TT 11.34 Mon 15:00 P4

Vacuum Correlations in Superconducting Quantum Circuits — •Gesa Dünnweber[1,2,3] and Peter Rabl[1,2,3] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

When the quantum vacuum is subjected to time-varying boundary conditions, its inherent fluctuations can be parametrically amplified to create photonic excitations. This phenomenon, known as the dynamical Casimir effect, has been experimentally realized in superconducting quantum devices. Building on these results, we theoretically investigate the correlations induced in such circuits by quantum vacuum interactions. In particular, we analyze a system featuring controlled time-dependence across multiple components and consider potential technological applications.

TT 11.35 Mon 15:00 P4

Gate tunable superconductivity in Al/STO hybrid structures — •Jay Schmidt, Simon Reinhardt, Matthias Kronseder, Nicola Paradiso, and Christoph Strunk — Deptartment of Exp. and Appl. Physics, University of Regensburg, Germany

We present a systematic study on the gate-tunable superconducting properties of Al thin films epitaxially deposited on STO substrates. As a quantum paraelectric, STO exhibits an exceptionally high $\varepsilon \approx 7000$, enabling substantial charge modulation at the Al/STO interface. Metal deposition on STO induces oxygen vacancy formation within the substrate, contributing double electron donors that create an interface 2DEG. Based on measurements of the Hall-effect we extract charge carrier densities in the Al/STO system that are comparable to those in pristine Al films and significantly surpass those observed in LAO/STO 2DEGs. This finding indicates that charge transport is predominantly mediated by Al carriers. $T_C(n)$ and $B_C(T,n)$ exhibit strong tunability under an applied gate voltage with variations up to 15% and 50%, respectively. Notably, the observed T_C values ($\approx$ 0.92 - 1.06 K) are lower than those of pristine Al thin films ($\approx$ 1.4 K) but exceed those of STO, suggesting a bilayer system of superconductors with distinct gap energies coupled through proximity effects. We further investigate the superfluid stiffness, which turns out to be also highly gate-tunable with variations up to 15%. These results underline the potential of Al/STO heterostructures as a versatile platform for studying tunable superconducting phenomena.

TT 11.36 Mon 15:00 P4

Design of a Gate Tunable $\lambda/4$ Josephson Parametric Amplifier in an Al/InAs Hybrid Superconductor/Semiconductor Heterostructure — •Vjeko Dimić[1], Simon Feyrer[1], Alexander Kirchner[1], Giorgio Biasiol[2], Christoph Strunk[1], and Leandro Tosi[1,3] — [1]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [2]CNR-Istituto Officina dei Materiali Laboratorio TASC, Italy — [3]Centro Atomico Bariloche, Comision Nacional de Energia Atomica, Argentina

We present the design of a Josephson parametric amplifier based on a distributed $\lambda/4$ microwave resonator fabricated on a hybrid Al/InAs heterostructure. The 2DEG hosted in the InAs is used to tailor SNS junctions which terminate the resonator and can be tuned using an electrostatic gate deposited on top [1]. We characterize the microwave response of $\lambda/4$ resonators, the losses and the tunability of the resonance frequency resulting from the gate modulation of the Josephson inductance. We show how amplification can be obtained by pumping the gate electrode at twice the resonance frequency.

[1] W. Strickland et al., Phys. Rev. Appl. 19, 034021 (2023).

TT 11.37 Mon 15:00 P4

Design of granular aluminum based kinetic inductance traveling wave parametric amplifiers — Daniel Valenzuela, Christoph Kissling, •Victor Gaydamachenko, Fabian Kaap, Sergey Lotkhov, and Lukas Grünhaupt — Physikalisch-Technische Bundensanstalt, Bundesallee 100, 38116 Braunschweig

Superconducting traveling wave parametric amplifiers (TWPA) are a key ingredient in readout chains, which benefit greatly from lowest possible added noise and several GHz of bandwidth. In the case of kinetic inductance based TWPAs (KI-TWPA), the non-linear kinetic inductance of disordered superconducting thin films is used to enable three- and four-wave mixing processes for signal amplification. A key challenge for the design of KI-TWPAs is to ensure an impedance of 50 Ohm. In addition, unwanted frequency conversion processes have to be phase mismatched, while those generating amplification need to be retained. We tackle both challenges using so-called artificial coplanar waveguides with a multiperiodic capacitance variation. Here, we discuss the design of granular aluminum (grAl) KI-TWPA, our fabrication and process, and show initial experimental results.

TT 11.38 Mon 15:00 P4

Advanced Josephson travelling wave parametric amplifyer analysis with non-linear circuit simulations — •Lars Aaron Anhalt[1,2,3], Daniil Bazulin[1,2], Gleb Krylov[1,2], Yongjie Yuan[4], Diego Contreras[1,2,3], Christian Gnandt[1,2,3], Michael Haider[4], Kirill Fedorov[1,2,5], and Stefan Filipp[1,2,5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]School of Natural Sciences, Technical University of Munich, 85748 Garching — [3]Ludwig-Maximilians-Universität in Munich, 80539 Munich — [4]TUM School of Computation, Information and Technology, Technical University of Munich, 85748 Garching — [5]Munich Center for Quantum Science and Technology, 80799 Munich

Broadband, quantum-limited microwave amplifiers are crucial for efficient and fast readout, which enables scaling of superconducting quantum processors. Josephson travelling wave parametric amplifiers (JTWPAs) are the most common solution in the field, providing amplification via copropagation of a pump tone with a signal in a nonlinear medium composed of Josephson junctions. Unwanted conversion processes, as well as stringent requirements on the fabrication processes, still pose challenges to their successful implementation. Here, we demonstrate how circuit simulation with WRSpice can help with the interpretation of experimental measurements of particular JTWPA designs and facilitate further improvements. Our simulations prove to be applicable to a wide range of circuit designs and varying parameters, reproducing competing conversion processes that go beyond analytical results from commonly used coupled mode equations.

TT 11.39 Mon 15:00 P4

Observing measurement-induced transitions in a transmon qudit — •Philippe Gigon[1,2], Zihao Wang[3], Benjamin D'Anjou[1], Alexandre Blais[1], and Machiel Blok[3] — [1]Université de Sherbrooke — [2]Walther-Meißner-Institut — [3]University of Rochester

Numerous experiments have shown that high-power dispersive transmon readout can lead to unexpected state transitions. Significant theoretical efforts have been made to describe these transitions using a simplified model, avoiding the need to account for the full Lindbladian dynamics of the coupled resonator-transmon system [1,2,3,4]. In this study, we employ a semi-classical effective drive model combined with Floquet theory and compare its predictions with experimental results from a transmon qudit. The high controllability and the readout capabilities of the qudit make it the perfect tool to study measurement-induced transitions. Our findings reveal that the semi-classical model accurately predicts critical photon numbers, identifies the states involved in the transitions, and quantifies the affected population.

[1] D. Sank et al., Phys. Rev. Lett. 117, 190503 (2016).
[2] M. Khezri et al., Phys. Rev. Appl. 20, 054008 (2023).
[3] R. Shillito et al., Phys. Rev. Appl. 18, 034031 (2022).
[4] M. F. Dumas et al., Phys. Rev. X 14, 041023 (2024).

TT 11.40 Mon 15:00 P4

Collective behavior of qubits coupled to a common waveguide — •Johannes Friedrich[1,2], Gerhard Huber[1,2], Joan Agustí[1,2], Gesa Dünnweber[1,2], Christian Schneider[1,2], and Stefan Filipp[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften

The behavior of multiple qubits coupled to a common waveguide cannot be understood as the additive behavior of single qubits. Since the waveguide can mediate an all-to-all interaction between qubits via propagating photons, collective radiant states, such as superradiant, subradiant, and twilight states, can be formed [1,2]. Using superconducting qubits offers control over multiple system parameters such as individual qubit frequency, coupling and spacing and enables the realization of 1D waveguides with large coupling to decoherence ratios, parameters difficult to achieve in atomic systems. Here, we explore parameter regimes beyond time and spatial uniform couplings, providing insights into designing quantum devices with controllable radiative properties.

We acknowledge financial support from GeQCoS, MUNIQC-SC, MCQST, OpenSuperQPlus100, the Munich Quantum Valley and the Deutsche Forschungsgemeinschaft.

[1] Y. Ke, et al., Phys. Rev. Lett. 123, 253601 (2019).
[2] B. Kannan et al., Nature 583 (2020).

TT 11.41 Mon 15:00 P4

Design of fluxonium qubits inductively coupled to granular aluminum based readout resonators — •Li-Wei Chang, Asen Georgiev, Fabian Kaap, Sergey Lotkhov, Mark Bieler, and Lukas Gruenhaupt — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The fluxonium qubit is a specific type of superconducting qubit, which has garnered significant interest due to its coherence time in the millisecond range, high gate fidelities on the order of 99.9%, and a large anharmonicity up to several GHz. Recent years have also seen a surge in material studies related to this type of qubit, with a particular focus on high kinetic inductance materials such as granular aluminum (grAl). Three basic components form a fluxonium qubit: a Josephson junction, a capacitor, and a so-called superinductor with an impedance larger than the resistance quantum $R_Q = \hbar/4e^2$. We discuss our circuit parameters chosen via numerical simulations to implement a fluxonium with a transition frequency of 0.6 GHz $\sim$ 12 GHz depending on the external magnetic field. To enable dispersive readout, we employ a granular aluminum based readout resonator. This configuration not only provides substantial inductance but also allows inductive coupling to the qubit. We present our methodology to design the circuit parameters, including the dispersive shift, quality factor, and T1 Purcell decay

TT 11.42 Mon 15:00 P4

Understanding loss channels in fluxonium qubits through high-impedance LC resonators — •Matthias Zetzl[1,2,3], Johannes Schirk[1,2,3], Florian Wallner[1,2,3], Ivan Tsitsilin[1,2,3], Niklas Bruckmoser[1,2,3], Christian Schneider[1,2,3], and Stefan Filipp[1,2,3] — [1]Walther-Meißner-Institut, Garching, Germany — [2]Technische Universität München, Munich, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Current quantum systems based on superconducting qubits are limited by their rate of information loss. Therefore, identifying and mitigating the sources of decoherence of individual qubits is key to improve the performance of these systems. Here, we investigate loss mechanisms in Josephson junction arrays, which are commonly used to implement protected qubits such as "fluxonium" or "zero-pi" qubits. To probe these loss channels, we characterize high-impedance lumped-element LC resonators, comprised of two charge islands connected by a Josephson junction array. While this architecture closely resembles that of "fluxonium" qubits, it allows for a more straightforward characterization by direct transmission measurements of the resonators. By extracting the internal quality factor of the resonators, we can assess the fabrication quality of the junctions in a fast and efficient way, providing a useful tool for all junction based components.

TT 11.43 Mon 15:00 P4

dc-SQUIDs with distributed lossy lines to damp LC resonances — •Nicolas Kahne, Anna Ferring-Siebert, Daniel Hengstler, Fabian Krämer, David Mazibrada, Lukas Münch, Alexander Stoll, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University

SQUIDs are sensitive superconducting magnetic flux to voltage converters, whose operation is based on the Josephson effect. In particular at mK temperatures this sensitivity can be degraded by LC-resonances in inductances and capacitances of different structures of the SQUID design. To damp the resonances and reduce their influence on the SQUID characteristics, lumped-element resistors are commonly placed into the SQUID circuitry, which need precise simulations to determine the appropriate resistance values and positions.

In this contribution we show results for a dc-SQUID with a new damping strategy, using lossy lines for the input coil and the feed lines. For the input coil we use a thin gold layer which is fabricated in a bilayer process underneath the superconducting coil. For the parallel pair feed lines, on the other hand, we damp inductively through large areas of gold on top which are galvanically decoupled by an insulating layer. We compare the different damping schemes for single dc-SQUIDs and two-stage dc-SQUID setups, regarding the resonance features in their SQUID characteristics and noise contributions. For future designs we also plan tests with SQUID-washers made of lossy lines.

TT 11.44 Mon 15:00 P4

Mapping Locations of Two Level Defects in Superconducting Quantum Circuits — •David Mazibrada[1], Johannes Schwenk[1], Jürgen Lisenfeld[1], Hannes Rotzinger[1,2], Philip Willke[1], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut, 76131 Karlsruhe, Germany — [2]Institut for Quantum Materials and Technologies, 76131 Karlsruhe, Germany

The development of superconducting quantum circuits has drawn attention to the study of microscopic two-level systems (TLS), as they are a source of decoherence and instability of qubits. Individual TLS can be manipulated using microwave signals, but their specific locations in quantum circuits remain largely unclear. We intend to manipulate the TLS using the electric field of an atomic force microscope tip [1]. This approach should allow us to gain insights into the microscopic nature of the TLS. We will present the assembled atomic force microscope setup and show characterisation data of quantum circuits measured at millikelvin temperatures.

[1] M. Hegedüs, et al., arXiv:2408.16660v1 (2024)

TT 11.45 Mon 15:00 P4

Fully tunable C-shunted Flux Qubits for TLS Research — •Benedikt Berlitz[1], Alexey V. Ustinov[1,2], and Jürgen Lisenfeld[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]IQMT, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Material defects forming two-level-systems (TLS) present a source of decoherence and unwanted degrees of freedom in superconducting quantum systems. The qubits in turn can be used as a tool to study the properties of TLS. We fabricated fully tunable, capacitively shunted superconducting flux qubits specifically to be used as TLS detectors, aiming for good coherence in a wide accessible qubit frequency range. The goal is to gather comparable data of many defects located within the same device. We describe design, fabrication and measurements of the fabricated samples. Studying TLS with these tools will enhance our understanding of the underlying physics of TLS in amorphous materials and hopefully reveal a path to achieving higher coherence with superconducting qubits.

TT 11.46 Mon 15:00 P4

Identification of Noise Sources in Superconducting Microstructures — •Markus Renger, Anton Jarecka, Daniel Hengstler, Matthew Herbst, David Mazibrada, Lukas Münch, Andreas Reifenberger, 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 different noise sources. Many noise sources are independent of the specific experimental set-up and transferable across many device categories such as qubits, SQUIDs, and superconducting detectors. We have constructed a stand-alone device with which we can analyze specific noise sources in a representative manner. This device consists of a Wheatstone-like bridge of four microfabricated superconducting inductors, two of which filled with sample material, and a pair of two-stage dc-SQUID read-out chains. We can use the method of cross-correlation, to derive the total noise contribution of our device, or AC-drive the Wheatstone bridge to measure the complex AC susceptibility 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 $f = 100\,\mathrm{kHz}$. We discuss the design of the experimental holder with excellent thermal coupling and shielding. We present the results of multiple measurements on thin films of SiO_2, Ag:Er, as well as Au:Er and perform a detailed comparison. In addition, we demonstrate our device's ability to probe the dynamics of magnetic moments in the sample material.

TT 11.47 Mon 15:00 P4

Dual Tone Spectroscopy of Atomic Tunneling Systems — •Jan Blickberndt, Anton Jarecka, Moritz Maur, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

Atomic Tunneling Systems (TSs) are intrinsic to disordered structures and thin films, inevitably impacting microstructured devices by causing noise and decoherence in all kinds of applications ranging from Josephson Junctions to cryogenic detector readout chains. Understanding the dynamics of these random fluctuators is essential to mitigate their deteriorative effects on superconducting quantum devices. To investigate the non-equilibrium dielectric behavior of TSs under electric bias, we developed a novel LC resonator setup based on a Wheatstone bridge design. This configuration features two resonance branches that share a common dielectric host material in their capacitors, thereby probing the exact same ensemble of TSs. By applying an external bias field via a cover electrode, we can modulate the energy states of the TSs, enabling their transition between the two resonance modes which allows us to explore ensemble properties as well as the non-linear dynamics of two-level systems. Our current experiments confirm the functionality of the device. To complement the experimental work, we developed a Monte Carlo simulation framework to validate and extend our findings.

TT 11.48 Mon 15:00 P4

Dynamic Control of Dielectric Loss in Amorphus Solids at Low Temperatures — •Marc Hyps, Christian Ständer, Jan Blickberndt, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

The main influence on the low temperature behaviour of amorphous solids is determined by atomic tunneling systems (TSs). TSs can be described by the phenomenological standard tunneling model (STM). The STM assums the TSs to be broadly distributed in their energy splitting. Experimental investigations of atomic tunneling systems gained recent interest due to their deteriorative effects in superconducting quantum devices, such as increased noise and decoherence.
We use newly designed and microfabricated superconducting LC-resonator to study the dielectric rf-response of an amorphous sample in the presence of an electric bias field. The bias field is applied via an electrode placed above the resonator chip wich modifies the energy splitting of the TSs. With this setup we are able to prove the non-equillibrium Landau-Zener dynamics with two different measurement protocols. Aditionally we apply two symetrically detuned pump tones. These resulted in an inversion of the population difference between ground and exited state, hence gain. Also an additional loss contribution was found, hinting towards a coupling to nuclear quadrupol moments.

TT 11.49 Mon 15:00 P4

Enhancement of Low Temperature Dielectric Loss through Vibrational Bias — •Jonathan Herbrich, Christian Ständer, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

At low temperatures low energy excitations are present in amourphous solids, due to atomic tunneling systems (TSs), leading to different properties compared to their crystalline counterparts. These TSs can be expressed as two level systems with a flatly distributed energy splitting. These properties are well described by the phenomenological standard tunneling modell (STM). Due to their negative influence like noise and decoherance on superconducting quantum devices, these TSs are a subject of recent investigations.
Lately we investigated the dielectric rf-response of an amourphous sample while slowly varying an electric bias field. A microfabricated superconducting LC-resonator, using the sample as a substrate, was used for these measurements. In recent measurements a mechanical strain field was used instead of the electric one. The field is applied by bending the sample with a piezoelectric actuator. As a result, the energy splitting of the TSs is modified, as these couple to the strain field via the deformation potential. Our measurements can be described in a framework based on Landau-Zener transition, origianally developed for the description of electrically biased resonators.

TT 11.50 Mon 15:00 P4

Superconducting Qubits for Measurements with Infrared Photons — •Jonathan Huschle[1], Markus Griedel[1,2], Hannes Rotzinger[1,2], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut (PHI), Karlsruhe Institut for Technology (KIT) — [2]Institut for Quanten Materials and Technologies (IQMT), Karlsruhe Institut for Technology (KIT)

In superconductors, the impact of photons with energy higher than the energy gap leads to breaking of Cooper pairs, which increases noise level and introduces additional dissipation at microwave frequencies. The coherence of superconducting qubits is particularly sensitive to this influence and can be used as a detector. In the qBriqs project, we develop a setup and measurement protocol for far-infrared photons and identify the influence of broken Cooper pairs using a modified transmon qubit[1]. Here, the capacitance of the qubit is reduced, resulting in an increased charge noise sensitivity. We present the qubit design and measurements at mK temperatures.

[1] B. G. Christensen *et al.*, Phys. Rev. B 100, 140503 (2019).

TT 11.51 Mon 15:00 P4

Round Robin of the European "Metrology for Superconducting Qubits" (MetSuperQ) Project — •Paul Kugler — KIT, Karlsruhe, Deutschland

Project presentation: The MetSuperQ project addresses the urgent need for metrology support in superconducting circuits, a leading technology for practical quantum computers. The qubit round robin aims to enhance qubit coherence times by studying external influences through round robin measurements at multiple institutes and laboratory settings. This initiative will demonstrate qubit readout and benchmarking, disentangle intrinsic from external sources of decoherence, and raise awareness about the reliability of qubit characterization. By closing the gap in metrology support, this project paves the way for fault-tolerant quantum computers and their scalability.

TT 11.52 Mon 15:00 P4

Quantum Secret Sharing in Multipartite Microwave Networks — •Karolina Weber[1,2], Wun Kwan Yam[1,2], Simon Gandorfer[1,2], Florian Fesquet[1,2], Kedar E. Honasoge[1,2], Maria-Teresa Handschuh[1,2], Achim Marx[1], Rudolf Gross[1,2,3], and Kirill G. Fedorov[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 Munich, Germany

Quantum secret sharing (QSS) is a quantum cryptography scheme that provides an unconditionally secure way to exchange information in multipartite networks. Here, information about a secret quantum state is shared with n receivers, where the original secret state can be reconstructed if and only if a sufficient number of receivers collaborate. The remaining receivers do not acquire enough information for reconstruction, thereby protecting the secret state from losses, noise, or malicious conspiracies. We experimentally implement the QSS protocol with coherent states in a microwave network with $n = 3$ parties using continuous-variable entanglement and analyze the achieved reconstruction fidelities for different scenarios. We observe that the reconstruction fidelity with 2 collaborating parties exceeds the no-cloning limit, thus, proving the unconditional security of the QSS protocol. Finally, we consider an extension of this experiment towards sharing of qubit states and its applications to blind quantum computing.

TT 11.53 Mon 15:00 P4

Simulation of Non-Markovian Waveguide QED Systems with Tensor-Network Techniques — •Ze Xu — Walther-Meißner-Institute

The coupling of atoms or other two-level emitters to the quantized electromagnetic field is typically modeled using a Markovian master equation, which accounts for both dissipative and coherent photon-mediated interactions. However, this description breaks down in extended optical networks or slow-light waveguides, where significant propagation delays lead to strongly retarded, i.e., non-Markovian, interactions between the emitters. This regime of light-matter interactions remains largely unexplored due to the complexity of modeling non-Markovian effects in a fully quantized framework. In this poster, I will discuss the application of tensor-network techniques for simulating non-Markovian waveguide QED systems with strongly driven emitters, focusing specifically on the case of so-called giant atoms under critical coupling conditions.

TT 11.54 Mon 15:00 P4

Evaluating Spin Ensembles Based on Phosphorus Donors for Quantum Memory Applications — •Andreas Dunaev[1,2], Patricia Oehrl[1,2], Rudolf Gross[1,2,3], and Hans Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]School of Natural Sciences, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Solid-state spin ensembles show great potential for applications in quantum memory devices due to their long coherence times and compatibility with superconducting quantum circuits [1]. Crucial requirements for the application as a memory platform are that the stored information can be accessed and the storage capacity can actively be reset [2]. Here, we discuss an electron spin ensemble of phosphorus donors in silicon coupled to a superconducting resonator in this context. In detail, we present the characterization of this coupled system and demonstrate the storage of classical pulses using a Hahn-echo pulse sequence at temperatures of 4K, moderate magnetic fields, and GHz frequencies. In addition, we introduce the concept of an active reset of the spin ensemble using infrared light. We compare our findings to an input-output model.

[1] A. Morello *et al.*, Adv. Quantum Technol. **3**, 2000005 (2020)
[2] J. O'Sullivan *et al.*, Phys. Rev. X **12**, 041014 (2022)

TT 11.55 Mon 15:00 P4

Remote Cooling of Spin-ensembles through a Spin-mechanical Hybrid Interface — •Wang Yang[1], Durga Dasari[1], and Joerg Wrachtrup[1,2] — [1]3. Physikalisches Institut, ZAQuant, University of Stuttgart, Allmandring 13, 70569 Stuttgart, Germany

— [2]Max Planck Institute for solid state research, Heisenbergstraße 1, 70569 Stuttgart, Germany

We present a protocol for the ground-state cooling of a tripartite hybrid quantum system, in which a macroscopic oscillator acts as a mediator between a single probe spin and a remote spin ensemble. In the presence of weak dispersive coupling between the spins and the oscillator, cooling of the oscillator and the ensemble spins can be achieved by exploiting the feedback from frequent measurements of the single probe spin. We explore the parameter regimes necessary to cool the ensemble, the oscillator, or both to their thermal ground states. This novel cooling protocol shows that, even with only weak dispersive coupling, energy transfer-like effects can be obtained by simply manipulating the probe spin. These results not only contribute to the development of a practical solution for cooling/polarizing large spin ensembles, but also provide a relatively simple means of tuning the dynamics of a hybrid system. The proposed protocol thus has broader implications for advancing various quantum technology applications, such as macroscopic quantum state generation and remote sensing.

TT 11.56 Mon 15:00 P4

Towards SQUID Optomechanical Devices based on $YBa_2Cu_3O_7$ — •Timo Märklin, Kenny Fohmann, Michael Schöllhorn, Mohamad El Kazouini, Christoph Schmid, Benedikt Wilde, Dieter Koelle, Reinhold Kleiner, and Daniel Bothner — Physikalisches Institut, Center for Quantum Science (CQ) and LISA$^+$, Universität Tübingen, Germany

Integrating a superconducting quantum interference device (SQUID) into a superconducting microwave resonator yields a circuit with a flux-tunable resonance frequency. By additionally releasing a part of the SQUID loop from the substrate such that it can oscillate mechanically, one obtains a SQUID optomechanical device in which microwave photons interact with phonons of the mechanical oscillator. If their interaction rate is sufficiently high, one can prepare non-classical states in the mechanical resonator which could build the foundation for experiments testing quantum gravity.

Today's standard material for superconducting frequency-tunable resonators is aluminum. However, the low critical field of aluminum in the range of some 10 mT severely limits the interaction rates achievable in SQUID optomechanical devices, as the interaction rate is directly proportional to an externally applied magnetic field. Therefore, we investigate the high-T_c superconductor $YBa_2Cu_3O_7$ (YBCO) regarding its suitability for SQUID optomechanics, since its high critical field beyond 10 T promises interaction rates higher than those achieved so far. This poster presents our recent progress along the path towards SQUID optomechanical devices based on YBCO.

TT 11.57 Mon 15:00 P4

Analysis of the Mechanical Properties of Nanomechanical String Resonators based on NbTiN — •Burak Bülbüloğlu[1,2], Korbinian Rubenbauer[1,2], Thomas Luschmann[1,2,3], Rudolf Gross[1,2,3], and Hans Huebl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]School of Natural Sciences, Technical University of Munich, Garching, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Opto- and electromechanical systems play an intricate part in the fields of quantum sensing and transduction. Aluminum (Al) is a popular material platform in the field of cavity-optomechanics due to its low internal loss rates at microwave frequencies and self-limiting oxide. However, the operation of Al is limited by its critical temperature ($T_c \approx 1.2\,K$ in the bulk). We explore Niobium Titanium Nitride (NbTiN) as an alternative candidate for opto- and electromechanical systems based on thin film technology. NbTiN has a T_c of up to $17\,K$ in bulk and can be used as a material for planar superconducting microwave quantum circuits. Moreover, it has a higher critical current density compared to Al and, thus, can support a larger photon number or microwave drive power. Here, we present doubly-clamped NbTiN nanomechanical string resonators and investigate their mechanical properties. We find stress levels on par with annealed Al, positioning NbTiN strings as a promising platform for the implementation of nano-electromechanical circuits operating at elevated temperatures.

TT 11.58 Mon 15:00 P4

Cavity Optomechanics with a Carbon Nanotube Nanomechanical Resonator — •Katrin Burkert, Akong Loh, Furkan Özyigit, Fabian Stadler, Anton Weber, Niklas Hüttner, and Andreas K. Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Carbon nanotubes (CNTs) are the smallest and lightest nanomechanical resonators. Suspended between Ti/Au electrodes and gated, they can act simultaneously as beam resonators with large Q and as quantum dots. We have realized optomechanical coupling of a SWCNT nanomechanical resonator to a microwave cavity and quantified it through optomechanically induced transparency measurements [1,2]. The nonlinearity of Coulomb blockade in the CNT was exploited to significantly enhance the coupling strength, reaching g_0 ∼100 Hz [1,2]; also back-action of the CNT on the microwave cavity has been demonstrated [1,2]. Ongoing work is directed towards strong coupling and ground state cooling of the nanomechanical resonator. This requires improvements of the microwave cavity [3] and the transfer assembly procedure. Suspended CNTs have been proposed as long-lived nanoelectromechanical qubits [4], a topic of high current research interest [5].

[1] S. Blien et al., Nat. Commun. 11, 1636 (2020).
[2] N. Hüttner et al., PR Appl. 20, 064019 (2023).
[3] N. Kellner et al., PSSB 260, 2300187 (2023).
[4] F. Pistolesi et al., PRX 11, 031027 (2021).
[5] Y. Yang et al., Science 386, 783 (2024).

TT 11.59 Mon 15:00 P4

Dissipative Microwave Optomechanics with a Carbon Nanotube — •Anton Weber, Katrin Burkert, Akong Loh, Niklas Hüttner, and Andreas K. Hüttel — Institut for Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany

High-frequency nanomechanical resonators are valuable for many measurement applications. We investigate a high quality factor mechanical resonator consisting of a suspended carbon nanotube. The nanotube is actuated by applying an external radiofrequency signal. Its motion can modulate its conductance, allowing for electrical detection [1]. In order to transfer this type of experiment from time-averged, dc measurement to fast GHz detection, the nanotube can be integrated into a microwave reflectometry setup at low temperature. A Quartz tuning-fork based carbon nanotube transfer is used to insert the bottom-up grown CNTs into the top-down designed circuit geometry [2]. The specific electronic and mechanical properties of CNTs require adaptation to the microwave circuit; a stub tuner, formed from coplanar waveguides (CPWs), is used for this purpose. They are particularly suitable for high impedance CNTs, as their resonant frequencies and impedance behavior can be precisely controlled by their geometry. The nanotube vibration modulates the signal reflection, effectively resulting in a dissipatively coupled microwave optomechanical system [3].

[1] G. A. Steele et al., Science 325, 5944 (2009).
[2] S. Blien et al., PSSB 255, 180018 (2018).
[3] F. Elste et al., Phys. Rev. Lett. 102, 207209 (2009).

TT 11.60 Mon 15:00 P4

Simulation model on the trigger time in superconducting single-photon detectors — •Tim Janocha, Someshvaran Udayakumar, Stefan Kaiser, and Riccardo Bassoli — Technische Universität Dresden, Dresden, Deutschland

Superconducting nanowire single-photon detectors (SNSPDs) are promising quantum communication devices due to their high efficiency, low dark count rates and minimal timing jitter. Here we present a simulation model on the trigger time between photon absorption and detection triggering. Within the framework of the proposed model, the influence of the photon energy, bias current, and strip width are investigated and their influence on the device performance is discussed.

TT 11.61 Mon 15:00 P4

Towards X-ray Spectroscopy with sub-eV Absolute Energy Calibration up to 100 keV — •A. Striebel, A. Abeln, A. Brunold, D. Kreuzberger, D. Unger, D. Hengstler, A. Reifenberger, A. Fleischmann, L. Gastaldo, and C. Enss — Kirchhoff Institute for Physics, Heidelberg University

Metallic magnetic calorimeters (MMCs) are energy-dispersive X-ray detectors which provide an excellent energy resolution over a large dynamic range combined with a very good linearity. MMCs convert the energy of each incident photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The resulting change of magnetisation is read out by a SQUID magnetometer.

To investigate electron transitions in U^{90+} within the framework of the SPARC collaboration, we developed the 2-dimensional maXs-100 detector array. It features 8x8 pixels with a detection area of 1 cm^2, an absorber thickness of 50 μm, a photo efficiency of 18 % at 100 keV, an energy resolution of 40 eV at 60 keV and was successfully operated in a recent beamtime at CRYRING@FAIR. To increase the photo efficiency to above 35 % at 100 keV we develop a new maXs-100 detector with 100 μm thick absorbers.

Currently, the absolute energy calibration is limited not by the detector itself, but by the Struck SIS3316 analog-to-digital converter. We present a technique to precisely determine the ADCs' non-linearity using an Analog Devices EVAL-ADMX1002B ultra low-distortion sine wave generator. This allows to correct for the non-linearity. We discuss the effect of this correction on actual MMC spectra.

TT 11.62 Mon 15:00 P4

Towards Large-Area 256-Pixel MMC Arrays for High Resolution X-ray Spectroscopy — •Andreas Abeln, Daniel Hengstler, 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 mm × 4 mm and are equipped with 5 μm 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 11.63 Mon 15:00 P4

MMC-Based Photon and Phonon Detector for Scintillating Crystals at mK Temperatures — •Ioana-Alexandra Nitu, Christian Enss, Andreas Fleischmann, Daniel Hengstler, Ashish Jadhav, Cagla Mahanoglu, Andreas Reifenberger, Christian Ritter, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg University

Scintillating crystals at mK temperatures are used in the search for neutrinoless double beta decay ($0\nu\beta\beta$) and Dark Matter, because they provide the means to discern the interaction of heavy particles, such as α particles, from light ones, such as electrons. The discrimination is achieved by measuring the temperature increase of the crystal and the emitted light simultaneously. This approach is used in the AMoRE experiment where $LiMoO_4$ crystals are employed to search for $0\nu\beta\beta$.

We present the design concept of an integrated photon and phonon (P2) detector, based on low temperature metallic magnetic calorimeters (MMCs). This detector is to be microfabricated on a 3-inch Si wafer; the central wafer area is used for the detection of the scintillation light, while the outer area contains three double-meander MMC detectors to monitor temperature changes in the crystal. We pursue the optimisation of the design and discuss the challenges in the microfabrication of the photon and phonon detector. Preliminary results are presented and compared to the expected performance.

TT 11.64 Mon 15:00 P4

MMC-based X-ray Detector for Transitions in light Muonic Atoms — •Peter Wiedemann, Andreas Abeln, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Daniel Hengstler, Daniel Kreuzberger, Andreas Reifenberger, Adrian Striebel, Daniel Unger, and Julian Wendel — for the QUARTET Collaboration, Kirchhoff Institute for Physics, Heidelberg University

High energy resolution X-ray spectroscopy of muonic atoms is used for the determination of charge nuclear radii. The QUARTET collaboration aims to improve the accuracy of nuclear charge radii of light elements from Li to Ne up to one order of magnitude by using Metallic Magnetic Calorimeter (MMC) arrays. These Detectors have already demonstrated excellent energy resolution and energy calibration with sub-ev prevision. We present the result obtained with the newly developed MMC array optimized to reach a quantum efficiency of 98% at 19 keV with 4 eV ΔE_{FWHM} We Discuss the performance achieved with this new MMC array at the light of precision X-ray spectroscopy of muonic lithium, beryllium and boron.

TT 11.65 Mon 15:00 P4

Towards Phonon Detection in Superfluid Helium with MMCs — •Axel Brunold, Andreas Fleischmann, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

The search for light dark matter requires innovative detection techniques that can probe weakly interacting particles with exceptional sensitivity. One promising approach involves studying elastic scattering interactions between dark matter particles and helium atoms at millikelvin temperatures.
As part of the "Direct search Experiment for Light dark matter", DELight, a pilot experiment is conducted to investigate the behavior of metallic magnetic calorimeters (MMCs) submerged in liquid helium. MMCs have previously demonstrated the capability to detect photons with high energy resolution and linearity; this experiment seeks to explore how these properties translate to the detection of phonons. In this setup, a small copper cell (300 ml) is cooled to below 1 K within a $^3He/^4He$ dilution refrigerator and filled with ^4He. The liquid helium level, while filling and later on operating the MMC, is monitored with an LC circuit-based level meter. At these millikelvin temperatures, ^4He is deep in its superfluid phase, enabling a long mean free path for phonons and rotons. A resistive heater is used to excite phonons, which are then collected by an MMC on a 5 mm x 5 mm silicon substrate. This contribution presents the setup and first results.

TT 11.66 Mon 15:00 P4

MOCCA: A 4k-pixel Molecule Camera for the Position and Energy Resolved Detection of Neutral Molecule Fragments — •Abdullah Özkara[1], Christian Enss[1], Andreas Fleischmann[1], Lisa Gamer[2], Loredana Gastaldo[1], Daniel Hengstler[1], Christopher Jakob[2], Daniel Kreuzberger[1], Ansgar Lowack[1], Oldřich Novotný[2], Andreas Reifenberger[1], Dennis Schulz[1], and Andreas Wolf[2] — [1]Kirchhoff Institute for Physics, Heidelberg University — [2]Max Planck Institute for Nuclear Physics, Heidelberg

The MOCCA detector is a 4k-pixel high-resolution molecule camera based on metallic magnetic calorimeters and read-out with SQUIDs that is able to detect neutral molecule fragments with keV kinetic energies. It will be deployed at the Cryogenic Storage Ring CSR at the Max Planck Institute for Nuclear Physics in Heidelberg, a storage ring built to prepare and store molecular ions in their rotational and vibrational ground states, enabling studies on electron-ion interactions. To reconstruct the reaction kinematics, MOCCA measures the energy and position of the molecule fragments incidenting on the detector, even with multiple particles hitting the detector simultaneously.
For readout, the signals of the 64 pixels of each row are added up and a triggered pixel is identified by its unique signal decay time. Two pixel rows are connected to the same SQUID with opposite polarity. This allows the use of only 32 SQUID channels to read out all 4094 pixels of the detector. We present an improved readout scheme using an exponential decay time spacing. In addition, we compare simulations of this scheme to measured data.

TT 11.67 Mon 15:00 P4

Characterization of Ti/Au Bilayer at mK — •Martin Schwendele, Chrsitain Enss, Andreas Fleischmann, Daniel Hengstler, Ashish Jadhav, Lukas Münch, Andreas Reifenberger, and Loredana Gastaldo — Kirchhoff Institute for Physics, Heidelberg University

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 calorimeteres (MMCs) and transition edge sensors (TESs).
We present the study of Ti/Au bilayers, typically used in TES as sensible material for MPTs. Films with different ratios between the superconducting layer and the normal conducting layers have been produced using sputtering technique. We discuss the dependence of the transition temperature as a function of the thickness ratio as well as the estimation of the penetration depth as a function of temperature.