TT 57: Poster: Superconductivity I

Time: Thursday 15:00–18:00 Location: P2/OG2

TT 57.1 Thu 15:00 P2/OG2

Influence of reduced dimensionality on the superconducting properties of ultrathin aluminum films — Werner M.J. van Weerdenburg[1], •Anand Kamlapure[1], Eirik Holm Fyhn[2], Xiaochun Huang[1], Niels P.E. van Mullekom[1], Manuel Steinbrecher[1], Peter Krogstrup[3], Jacob Linder[2], and Alexander A. Khajetoorians[1] — [1]Institute for Molecules and Materials, Radboud University, 6525 AJ Nijmegen, the Netherlands — [2]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [3]NNF Quantum Computing Programme, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

Study of superconductivity (SC) in lower dimensional systems is vital to devices involving multilayers and heterostructures for future quantum information applications. In this work, using scanning tunneling microscopy/spectroscopy, we study SC in ultrathin epitaxial Al films on Si(111) as we approach the 2D limit. With reducing thickness, we observe enhancement of SC where critical temperature and gap size shows threefold enhancement. In addition, we characterize the vortex structure in presence of strong Zeeman fields and find evidence for extended vortices showing paramagnetic Meissner effect originating from triplet pairing contributions. These results illustrate two striking influences of reduced dimensionality and present a new platform to study SC in presence of large magnetic fields. Reference: arXiv:2210.10645(2022).

TT 57.2 Thu 15:00 P2/OG2

Demonstration of 300 mm CMOS-compatible superconducting HfN and ZrN thin films — •Roman Potjan[1,3], Raik Hoffmann[1], Marcus Wislicenus[1], Benjamin Lilienthal-Uhlig[1], and J. Wosnitza[2,3] — [1]Fraunhofer Institute for Photonic Microsystems (IPMS), Center Nanoelectronic Technologies (CNT), Dresden, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [3]Institut für Festkörper- und Materialphysik, TU Dresden, Germany

The increasing interest in quantum computing is pushing the development of new superconducting materials for semiconductor fab process technology. However, these are often facing CMOS process incompatibility. In contrast to common CMOS materials such as TiN and TaN, reports on the superconductivity of other suitable transition-metal nitrides are scarce, despite potential superiority. Hence, we demonstrate fully CMOS-compatible fabrication of HfN and ZrN thin films on state-of-the-art 300 mm semiconductor process technology, employing reactive DC magnetron sputtering on silicon wafers. Mechanical stress, thickness, and roughness measurements of the thin films imply process compatibility. Material phase and stoichiometry in bulk and interfaces are investigated by structural analysis. HfN and ZrN exhibit transitions into the superconducting state with critical temperature up to 5.1 and 6.1 K, respectively. A decrease in critical temperature with decreasing film thickness indicates geometric limitations and proximity effects of the interfaces. The results prepare a scalable application of HfN and ZrN in quantum computing and related applications.

TT 57.3 Thu 15:00 P2/OG2

Unraveling Charge Transfer to Understand Superconductivity in MgB_2 — •Simon Marotzke[1,2], Jan Oliver Schunck[1,3], Amina Alic[4], Octave Duros[4], Moritz Hoesch[1], Alessandro Nicolaou[5], Gheorghe Sorin Chiuzbaian[4], and Martin Beye[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [3]Universität Hamburg, Hamburg, Germany — [4]Sorbonne Université, Paris, France — [5]Synchrotron SOLEIL, Saint-Aubin, France

Magnesium diboride (MgB_2) holds the world-record for the highest transition temperature ($T_C = 39$ K) in a conventional Bardeen-Cooper-Schrieffer (BCS)-type, i.e., phonon-mediated, superconductor. The undoped electron configuration of MgB_2 is still disputed as contradicting results on the appearance of charge transfer upon crossing T_C have been reported. To settle this question, we conducted high-resolution resonant X-ray emission spectroscopy (XES) as well as X-ray absorption spectroscopy (XAS) measurements around the boron K-edge at the SEXTANTS beamline at the synchrotron SOLEIL. In order to investigate the charge transfer between in-plane and out-of-plane states, we varied the polarization of the incoming photons as well as the incidence and emission angle. We report on differences in the spectral intensity for both the absorption and emission spectra upon crossing T_C to be first indications of changes in the density of the boron $2p$ states. Complementary density of states calculations showing good agreement with the experimental data were performed.

TT 57.4 Thu 15:00 P2/OG2

Strain device for *in-situ* uniaxial strain measurements of strongly correlated electron materials in scanning tunneling microscopy — •Carolina A. Marques[1], Danyang Liu[1], Alexander Steppke[1,2], and Fabian D. Natterer[1] — [1]University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland — [2]Paul Scherrer Institut Forschungsstrasse 111 5232 Villigen PSI Switzerland

Uniaxial strain is an effective way to tune the properties of strongly correlated electron systems without introducing disorder. One seminal example is the doubling of the critical temperature of Sr_2RuO_4.

Strain devices for the *in-situ* application of strain have been used in several different measurement techniques: transport, specific heat, angle-resolved photoemission spectroscopy, muon spin relaxation, and neutron scattering measurements. Here, we describe the design and construction of a strain device compatible with a scanning tunneling microscope. Our piezo-element based strain-cell is temperature compensated and enables the continuous tuning of strain, allowing to monitor local strain response. It opens up the possibility to locally track changes to the low-energy electronic states as a function of strain, giving insight into the underlying physical mechanisms.

TT 57.5 Thu 15:00 P2/OG2

Magnon dispersion of $SrRuO_3$ studied by inelastic neutron scattering experiments — Kevin Jenni[1], •Akshay Tewari[1], Stefan Kunkemöller[1], Agustinus Agung Nugroho[2], Russell Ewings[3], Yvan Sidis[4], Astrid Schneidewind[5], Paul Steffens[6], and Markus Braden[1] — [1]*II*. Phys. Institut, Universität zu Köln — [2]Institut Teknologi Bandung, Bandung 40132, Indonesia — [3]ISIS Pulsed Neutron and Muon Source, United Kingdom — [4]Laboratoire Léon Brillouin, Gif-sur-Yvette CEDEX, France — [5]Jülich Centre for Neutron Science (JCNS), Garching, Germany — [6]Institut Laue Langevin, Grenoble, France

Weyl points in the ferromagnetic state in $SrRuO_3$ not only determine anomalous magnetotransport properties but also modify the spin dynamics leading to a peculiar temperature dependence of both the spin gap and of the stiffness in the ferromagnetic state [1]. In contrast the magnon chirality in $SrRuO_3$ remains normal, i.e. right handed [2]. To extend the analysis of the magnon dispersion we performed inelastic neutron scattering experiments with the time-of-flight technique as well as with polarization analysis. The magnon dispersion can be followed to about 30 meV and there is no indication for a crossover into a Stoner continuum. There is evidence for additional coupling beyond just the nearest neighbors. In addition magnon excitations exhibit pronounced broadening that further increases upon heating possibly related to the strong coupling between ferromagnetism and conductivity in $SrRuO_3$.

[1] K. Jenni et al. Phys. Rev. Lett. **123**, 17202 (2019). [2] K. Jenni et al. Phys. Rev. B. **105**, L180408 (2022).

TT 57.6 Thu 15:00 P2/OG2

Screening in a two-band model for infinite-layer nickelate — •Tharathep Plienbumrung[1,2], Maria Daghofer[1,2], Michael Schmid[3], and Andrzej M. Oles[4,5] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology, University of Stuttgart, Stuttgart, Germany — [3]Waseda Research Institute for Science and Engineering, Waseda University, Tokyo, Japan — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany — [5]Institute of Theoretical Physics, Jagiellonian University, Kraków, Poland

Considering two-band model for infinite-layered nickelates, containing d- and s-like orbitals, on two-dimensional lattice. The extended nature of the s-like orbital leads to less electronic correlation. We thus parameterize the electronic correlations of the s-like orbital by introducing *screening parameter*. With exact diagonalization, we calculate the pairing symmetries and other electronic properties of the two-band model on two-dimensional lattice. We find that the screening strength of the s-like band plays an important role in the electronic properties of the two-band model. Interestingly, depending on the screening strength of s-like band, we find both d- and s-wave pairing symmetries within the two-band model. In strong screening, the d-wave pairing is found while the s-wave pairing is formed in the weak screening regime. The phase diagram of the two-band model for different ratio of J/U is also presented.

TT 57.7 Thu 15:00 P2/OG2

Magnetic and thermoelectric properties of Bi-substituted $La_{0.95-x}Bi_xSr_{0.05}CoO_3$ — •Divya Prakash Dubey and Ratnamala Chatterjee — IIT Delhi Hauz Khas New Delhi 110016 India

We present the results of a comprehensive investigation of electric and thermal transport properties of polycrystalline Bi substituted $La_{0.95-x}Bi_xSr_{0.05}CoO_3$ for x=0,0.1 and 0.2 (LBSCO-0, 1 & 2). The electrical resistivity reflects the semiconducting nature with interesting n-type to p-type transition 52K for LBSCO-1 and LBSCO-2 samples. The substitution of higher atomic weight elements Bi at La site drastically affects overall thermal conductivity by reducing the lattice contribution (κ 0.12W/m-K at T= 50K) and also enhance the Seebeck coefficient (S 354 μV/K). The increase in the resistivity and Seebeck coefficient for Bi-substituted system is related to the decrease in the available charge carrier concentration (5.12 10^{20} cm^3). The phonon mediated charge transport via phonon drag effect below 50K and a large increment in ZT 0.17 at RT for LBSCO-2 composition has been observed that is 1-order larger to pristine undoped LBSCO-0 and even higher to the other existing cobaltite*s-based thermoelectric choice.

TT 57.8 Thu 15:00 P2/OG2

High pressure T-P phase diagram of $2H$-TaSe$_2$ — •Yuliia Tymoshenko[1], Xingchen Shen[1], Amir-Abbas Haghighirad[1], Tom Lacmann[1], Gaston Garbarino[2], and Frank Weber[1] — [1]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [2]European Synchrotron Radiation Facility, 71 avenue des Martyrs, CS 40220, Grenoble 38043, France

Many layered materials featuring charge-density waves (CDW), a modulation of the electronic density of states, acquire a superconducting ground state often associated with a quantum critical point (QCP) of the CDW order. Although $2H$ polymorph of tantalum diselenide ($2H$-TaSe$_2$) with a layered hexagonal crystal structure is one of the most studied CDW systems, to the best of our knowlege, previous studies of the phase diagram have not been carried out at pressures sufficient to suppress the CDW order at low temperatures. We investigated the CDW phase diagram in its most crucial but still unexplored area and determined the CDW quantum critical point in $2H$-TaSe$_2$ under pressure via high-resolution synchrotron x-ray diffraction (XRD). Its position together with previously published resistivity measurements and our recent ambient-pressure study of the soft phonon mode at the CDW transition enable us to argue that this compound likely has a CDW quantum critical point closely connected to the emergent superconducting phase. This can serve as a textbook example where both phases are mediated by the same mechanism, electron-phonon coupling of the CDW soft phonon mode.

TT 57.9 Thu 15:00 P2/OG2

Clarifying the origin of CDW and finding the routes to superconductivity in 1T-TiSe$_2$ — •Andrii Kuibarov[1], Alexander Fedorov[1,2], Rui Lou[1,2], Yuliia Shemerliuk[1], Oleksandr Suvorov[1], Saicharan Aswartham[1], Bastian Rubrecht[1], Dmitry Efremov[1], Helmuth Berger[3], Bernd Büchner[1], and Sergey Borisenko[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II — [3]Institute of Condensed Matter Physics, Ecole Polytechnique Fédérale de Lausanne

The relationship between charge density waves (CDW) and superconductivity was always one of the important questions of solid-state physics. Even though they are often observed on the phase diagram next to each other, it is still unknown whether CDW competes or cooperates with superconductivity. Utilizing the photon energy-dependent ARPES we investigate the 3D electronic structure of well-known CDW-bearing material TiSe$_2$, superconductor Cu$_x$TiSe$_2$, and TiSeS. Our results suggest that neither Mott nor the excitonic insulator model is applicable to the electronic structure of TiSe$_2$. In contrast to the generally accepted model, we find a crucial agreement with the conventional band structure calculations, which predict the absence of the energy gap in this material.

Additionally, we perform temperature-dependent ARPES studies and show that the CDW phase remains in doped superconducting samples Cu$_x$TiSe$_2$. On the basis of the obtained results, we propose a mechanism for both CDW and superconductivity TiSe$_2$ family.

TT 57.10 Thu 15:00 P2/OG2

Nematic susceptibility in heavily hole-doped iron based superconductors — •Franz Eckelt[1], Xiaochen Hong[1], Vilmos Kocsis[2], Vadim Grinenko[2], Chul-Ho Lee[3], Bernd Büchner[2], and Christian Hess[1] — [1]Bergische Universität Wuppertal, 42097 Wuppertal, Germany — [2]Leibniz-Institute for Solide State and Materials Research (IFW-Dresden), 01069 Dresden, Germany — [3]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan

We investigate the elastoresistivity of the 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 [100] direction during cooling for all samples studied so far. We discuss our findings in terms of nematic fluctuations and Fermi surface effects in the vicinity of a Lifshitz transition.

TT 57.11 Thu 15:00 P2/OG2

Towards topological superconductivity on the surface of LiFeAs — •Luise Merkwitz[1], Andrii Kuibarov[1], Rui Lou[1,2], Alexander Fedorov[1,2], Sabine Wurmehl[1], Saicharan Aswartham[1], Igor Morozov[1], Bernd Büchner[1], and Sergey Borisenko[1] — [1]Leibniz-Institute for Solid State Research, IFW-Dresden, D-01171 Dresden, Germany — [2]Helmholtz-Zentrum Berlin, BESSY, D-12489 Berlin, Germany

Realisation of topological superconductivity is theoretically possible in iron-based superconductors, where the s-wave pairing in the bulk can induce superconductivity of the topological surface states. The detection of the latter by angle-resolved photoemission spectroscopy (ARPES) in LiFeAs and FeSeTe systems is questionable since the bulk-originated dispersions can mimic the Dirac crossing and inverted gap is expected to be very small (of the order of 5 meV). The only feasible possibility to detect topological surface states in such a small gap is to bring it to the Fermi level where the scattering is minimal. We have synthesized differently doped $LiFe_{1-x}Y_xAs$ (Y=Co, V) crystals and performed synchrotron-based ARPES studies to map k_z-dispersion in detail. Our results demonstrate the principal possibility of tuning the binding energy of the inverted gap in these systems and point to the optimal composition where this binding energy is close to zero. In addition, our results reveal considerable renormalization anisotropy of the Fe d-states never detected earlier.

TT 57.12 Thu 15:00 P2/OG2

The superconducting symmetries of CeRh$_2$As$_2$ — •Fabian Jakubczyk[1,2], Julia M. Link[1,2], and Carsten Timm[1,2] — [1]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

Multiphase unconventional superconductivity is a rare phenomenon, which has recently been discovered in the tetragonal but locally noncentrosymmetric heavy-fermion compound CeRh$_2$As$_2$. Here, the transition between two distinct superconducting phases occurs as a function of magnetic field applied along the c axis and the formation of superconductivity takes place around $T_{SCI} = 0.26$ K. At $\mu_0 H^* \approx 4$ T the superconductor changes from a low-field to a high-field state with a large critical field of $\mu_0 H_{c2} = 14$ T. However, for in-plane fields only the low-field phase appears, with $\mu_0 H_{c2} = 2$ T. Recent As-NQR experiments further increased the variety of intriguing phenomena in this material, for they detected the onset of antiferromagnetism within the superconducting low-field phase, i.e. at $T_N < T_{SCI}$. In order to study the coexistence and interplay of the potential superconducting and magnetic phases, as well as the effect of an external magnetic field, we conduct a symmetry analysis followed by the construction of a Landau-type energy functional. Thereby we can give a statement about the probable symmetries of the superconducting states.

TT 57.13 Thu 15:00 P2/OG2

Flat bands of surface states in chiral symmetric superconductors — •Clara Johanna Lapp[1,2], Julia M. Link[1,2], and Carsten Timm[1,2] — [1]Institute of Theoretical Physics, Technische Universität Dresden, 01069 Dresden, Germany — [2]Würzburg-Dresden Cluster of

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Nodal noncentrosymmetric superconductors can support flat bands of zero-energy surface states in part of their surface Brillouin zone if they obey time-reversal symmetry. These bands are protected by a winding number that relies on chiral symmetry, which in these systems is realized as the product of time-reversal and particle-hole symmetry. We examine which symmetry conditions a model must obey such that a winding number is well defined and can be nonzero. In particular, time-reversal symmetric Bogoliubov-de Gennes Hamiltonians which conserve one spin component can be interpreted as chiral symmetric in each of the spin-blocks and exhibit a nonzero winding number that protects zero energy surface modes. Moreover, we classify which types of sublattice symmetry lead to nonzero winding numbers.

TT 57.14 Thu 15:00 P2/OG2

Eliashberg theory calculations for magnetically mediated superconductivity — •Ran Tao and Malte Grosche — Department of Physics, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

Computational modelling for realistic material parameters can speed up the search for new unconventional superconductors.
We have implemented calculations of the superconducting transition temperature in Eliashberg theory for spin fluctuation mediated superconductivity and validated them by reproducing previously published results in simple systems (e.g. [1]). Next, our code has been extended to a minimal model for iron-based superconductors, namely a 2D compensated metal with varying Fermi surface volume and interaction strength. Developing this approach further in the spirit of the UppSC code (e.g. [2]), numerical calculations are used to investigate the effects of applied field and to assist the discovery of new unconventional superconductors by surveying large numbers of candidate materials.

[1] P. Monthoux and G. G. Lonzarich, Phys. Rev. B 59, 14598 (1999)
[2] A. Aperis, P. Maldonado, and P. M. Oppeneer, Phys. Rev. B 92, 054516 (2015)

TT 57.15 Thu 15:00 P2/OG2

Yu-Shiba-Rusinov states in unconventional superconductors — •Michael Hein[1], Wolfgang Belzig[1], and Juan Carlos Cuevas[2] — [1]Universität Konstanz, Konstanz, Germany — [2]Universidad Autónoma de Madrid, Madrid, Spain

Recently there has been a huge effort to investigate individual magnetic impurities on superconducting surfaces in the context of scanning tunneling microscopy (STM) [1]. These STM-based experiments have enabled to elucidate the properties of the in-gap superconducting bound states known as Yu-Shiba-Rusinov states. These bound states are a key signature of the interplay between magnetism and superconductivity at the atomic scale and, in turn, they lead to a strong local modification of the superconducting state. In this regard, we present here our theoretical efforts to understand the physics of YSR states in the context of unconventional superconductivity, with special attention to the so-called Ising superconductors. We show that the study of YSR states can provide a very valuable way to reveal the underlying properties of unconventional superconductors.

[1] B. W. Heinrich, J. I. Pascual, and K. J. Franke, Prog. Surf. Sci. 93, 1 (2018)

TT 57.16 Thu 15:00 P2/OG2

RKKY interaction in non-centrosymmetric superconductors — •Finja Tietjen and Jacob Linder — Department of Physics, Center for Quantum Spintronics, Norwegian University of Science and Technology, 7491, Trondheim, Norway

Recent advances in experimental studies have raised interest in how spin interactions are manifested in unconventional superconductors, which can potentially be used for spintronic devices. In particular, superconducting triplet states featuring spin-polarized Cooper pairs are expected to qualitatively alter spin interaction compared to non-superconducting materials.

We consider the RKKY-interaction between two impurity spins in a non-centrosymmetric superconductor. Such superconductors feature antisymmetric spin-orbit coupling and, generally, coexisting singlet and triplet Cooper pairs. The RKKY-interaction is treated perturbatively with a Schrieffer-Wolff transformation within the Bogoliubov-de Gennes framework. Exact numerical studies complement the analytical approach and show local decreases in the total superconducting gap as well as a change in local density of states at impurity sites. The RKKY interaction is affected by the superconductor and the corresponding change in the ground-state spin configuration is also clearly visible. We expect that the spin configuration can thus be externally controlled by entering or leaving the superconducting state.

Ongoing studies on the exact dependencies as well as advances in the analytical approach promise further insights closer to the conference date.

TT 57.17 Thu 15:00 P2/OG2

Analytical parquet renormalization group for multipocket systems — •Nora Taufertshöfer, Matteo Dürrnagel, and Ronny Thomale — Theoretische Physik I, Universität Würzburg

Materials with multi-pocket fermiology may exhibit unconventional superconductivity which arises from inter-pocket scattering. Studying this problem in the weak coupling regime by renormalization group (RG) methods requires a perturbative expansion in each flow step.

As electronically driven instabilities are predominantly governed by states close to the Fermi surface, the RG analysis can be restricted to a few distinct momentum channels between the Fermi pockets. The parquet RG [1] embeds the truncation of the flow equations into a rigorous analytical scheme to investigate superconductivity and its interplay with various competing phases. Within this framework we discuss the relevance of nematic fluctuations in a 2D model for GaAs/AlAs heterostructures, which may host the possibility for gate-tunable unconventional superconductivity [2].

[1] S. Maiti and A. V. Chubukov, Phys. Rev. B **82**, 214515 (2010)
[2] A. V. Chubukov and S. A. Kivelson, Phys. Rev. B **96**, 174514 (2017)

TT 57.18 Thu 15:00 P2/OG2

Higgs mode in superconductors with Rashba spin-orbit coupling — •Tobias Kuhn and Björn Sothmann — Fakultät für Physi, Universität Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany

When a superconductor is periodically driven by electromagnetic radiation, the superconducting order parameter shows radial oscillation with twice the driving frequency. This so called Higgs mode can be excited resonantly when the driving frequency equals the absolute value of the order parameter. Here, we study Higgs modes for superconductors with Rashba spin-orbit coupling using two methods. We discuss the resonance condition by analyzing the dynamics of Anderson pseudospins. In addition, we use Floquet Green's functions to generalize the pseudospin approach and discuss the impact of spin-orbit coupling on the order parameter dynamics.

TT 57.19 Thu 15:00 P2/OG2

Order-parameter evolution in the FFLO phase — •H. Kühne[1], S. Molatta[1], T. Kotte[1], D. Opherden[1], G. Koutroulakis[2], J.A. Schlueter[3,4], G. Zwicknagl[5], S.E. Brown[6], and J. Wosnitza[1,7] — [1]Hochfeld-Magnetlabor Dresden, HZDR — [2]UC Santa Barbara, USA — [3]ANL, Argonne, USA — [4]NSF, Alexandria, USA — [5]IMP, TU Braunschweig — [6]UC Los Angeles, USA — [7]IFMP, TU Dresden

The Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state represents a general concept of pairing in multi-component Fermi liquids with strong population imbalance. In the superconducting FFLO state, the spin polarization varies as the modulus of the spatially modulated superconducting gap amplitude, and, thus, its modulation amplitude represents the order parameter. Indeed, NMR experiments of the organic superconductors β''-$(ET)_2SF_5CH_2CF_2SO_3$ and κ-$(ET)_2Cu(NCS)_2$ showed the emergence of inhomogeneous line broadening, stemming from the spatially modulated spin polarization. We report on our studies of the temperature-dependent order parameter of the superconducting FFLO state. For that, we utilize ^{13}C NMR spectroscopy of β''-$(ET)_2SF_5CH_2CF_2SO_3$. From a comparison of the NMR spectra to a comprehensive modeling, we determine the evolution of the local spin-polarization modulation amplitude upon condensation of the FFLO state. Further, the modeling allows to quantify the decrease of the average spin polarization, stemming from the spin-singlet coupling of the superconducting electron pairs.

TT 57.20 Thu 15:00 P2/OG2

Comparison of window-type and cross-type Nb/Al-AlO$_x$/Nb Josephson tunnel junctions — •Fabienne Bauer[1], Martin Neidig[1], Christian Enss[2], and Sebastian Kempf[1] — [1]Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology

— [2]Kirchhoff Institute of Physics, Heidelberg University

Josephson tunnel junctions (JJs) are the heart of numerous superconducting electronic devices such as SQUIDs, qubits or parametric amplifiers. Out of the multitude of junction variants, Nb/Al-AlO_x/Nb junctions have somehow become the state of the art as they are resilient to thermal cycling and additionally show a very high junction quality and reproducibility of characteristic junction properties. Against this background, we present two anodization-free fabrication processes for Nb/Al-AlO_x/Nb Josephson junctions. One is a variant of the selective niobium etching process (SNEP) for fabricating window-type junctions. The second is a process for producing self-aligning, low-capacitance cross-type Josephson junctions. For comparing both processes, we comprehensively characterized fabricated junctions by studying resonance phenomena in unshunted dc-SQUIDs to determine the intrinsic junction capacitance and determined characteristic junction figures of merit. We show that both of our processes yield very high quality JJs. However, our cross-type Josephson junctions turn out not only to greatly simplify the fabrication process and to provide much lower junction capacitance, but also to show a greatly improved homogeneity of critical current density distribution as determined by analysing the magnetic field dependence of the critical current.

TT 57.21 Thu 15:00 P2/OG2

Process optimisation for the fabrication of cross-type Nb/Al-AlO_x/Nb Josephson junctions — •A. Stoll, F. Bauer, L. Münch, D. Hengstler, A. Ferring-Siebert, F. Krämer, N. Kahne, D. Mazibrada, A. Fleischmann, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany.

Josephson tunnel junctions (JJs) are the basic element of many superconducting electronic devices such as qubits or superconducting quantum interference devices (SQUIDs). Since many applications demand a large number of Josephson junctions, a reliable wafer-scale fabrication process yielding JJs with a reproducible and uniform high quality is required. Very often window-type JJs are used, in which the JJ area is defined by openings in an insulating layer. The size of the JJ is thus limited by the alignment accuracy, therfore causing the need for low critical current densities j_c and in turn long oxidation times. The transition to cross-type JJs is motivated by reducing the junction area as well as parasitic capacities, and in turn suppressing or completely removing parasitic effects, e.g. LC-resonances, with the additional benefit of simplistic and time efficient fabrication steps. We present how we optimised and retained the quality of our cross-type Nb/Al-AlO_x/Nb junctions, for which quality checks of our in-house sputter-deposited niobium films and oxidized aluminium layers were carried out, including the measurement of the critical temperature T_c, stress of the niobium film and junction specific quality features. The parameters for the magnetron sputtering, like the Ar-pressure and power of the sputtering source, were optimised accordingly.

TT 57.22 Thu 15:00 P2/OG2

Realization of He-FIB induced Josephson junction THz detectors in YBCO thin films — •Kenny Fohmann, Christoph Schmid, Eric Dorsch, Edward Goldobin, Dieter Koelle, and Reinhold Kleiner — Physikalisches Institut, Center for Quantum Science (CQ) and LISA$^+$, Universität Tübingen, Germany

We designed and fabricated ultrawideband thin-film antennas from the high-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ (YBCO) partially covered with Au. By using a focused He ion beam (He-FIB) we "draw" a Josephson Junction (JJ) [1] into the microbridge footpoint of the spiral antenna. Under microwave irradiation the JJ exhibits Shapiro steps in the $I-V$ characteristic.

We report on design optimization. This includes improved matching of the impedances of the antenna and the JJ in an ultrawide frequency band by using a logarithmic periodic antenna. Moreover, we performed simulations using CST Studio-Suite to improve the coupling of a plane-wave signal to the antenna.

To characterize the antennas, we compare the excitation of the JJ embedded in a simple linear YBCO bridge (~ 1 mm) with the one embedded in the footpoint of the antenna, for frequencies up to 40 GHz. The ultimate goal of such an antenna with a YBCO JJ is to detect the radiation from a BSCCO-mesa (placed on another chip nearby) in the frequency range $\gtrsim 0.5$ THz. The latest measurements will be presented.

[1] B. Müller et al., Phys. Rev. Appl. **11**, 044082 (2019)

TT 57.23 Thu 15:00 P2/OG2

Investigation and optimization of $YBa_2Cu_3O_{7-\delta}$ Josephson junctions written with a focused He ion beam — •Christoph Schmid[1], Max Karrer[1], Katja Wurster[1], Moritz Meichsner[1], Isabelle Vandermoeten[1], Noor Hasan[1], Ramón Manzorro[2,3], Javier Pablo-Navarro[2,3], Cesar Magen[2,3], Dieter Koelle[1], Reinhold Kleiner[1], and Edward Goldobin[1] — [1]Physikalisches Institut, Center for Quantum Science and LISA$^+$, Universität Tübingen, Germany — [2]Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza, Spain — [3]Laboratorio de Microscopías Avanzadas (LMA), Universidad de Zaragoza, Spain

We use a focused He Ion Beam (He-FIB) to "write" Josephson barriers across $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin-film bridges. Such Josephson junctions (JJs) exhibit RCSJ-like I–V characteristics, and the dependence of critical current vs. magnetic field resembles a Fraunhofer pattern [1]. Scanning transmission electron microscopy (STEM) shows that He-FIB irradiation modifies locally (~ 10 nm) the YBCO crystal structure that can partially heal with time. Electric transport measurements provide the evolution of the JJ parameters with time or thermal annealing. Those reveal barrier recovery processes and show how to stabilize the JJ parameters on short time scales. Furthermore, we investigated the interaction of two and more JJs placed close to each other and biased in series. Using a multi-terminal arrangement we found some unexpected behavior that will be discussed. Several approaches to synchronize arrays of He-FIB written JJs are investigated.

[1] B. Müller et al., Phys. Rev. Applied **11**, 044082 (2019)

TT 57.24 Thu 15:00 P2/OG2

On-chip driving of a phase-slip junction for dual Shapiro steps — •David Scheer and Fabian Hassler — JARA Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany

A single Josephson junction in the phase-slip regime exhibits Bloch oscillations that relate current to frequency if supplied with a DC voltage-bias. If additionally an AC-drive is applied to the junction, the Bloch oscillations can synchronize with the driving frequency. This leads to the emergence of dual Shapiro steps with constant current in the IV-curve of the junction with the current determined by the driving frequency. An AC-drive in the required frequency regime of $>$ 10GHz is challenging to implement experimentally without detrimental effects due to stray capacitances. We investigate the use of a Josephson junction with a DC-bias as an on-chip AC-voltage source. We discuss the relevant coupling parameters between the oscillations caused by the DC-Josephson effect and the Bloch oscillations as well as the back action of the Bloch oscillations on the Josephson oscillations. We identify the regime in which the back action is minimized in order to obtain a steady voltage source to create dual Shapiro steps.

TT 57.25 Thu 15:00 P2/OG2

MOCCA: A 4k-pixel molecule camera for the position and energy resolved detection of neutral molecule fragments — •Daniel Kreuzberger[1], Christian Enss[1], Andreas Fleischmann[1], Lisa Gamer[2], Loredana Gastaldo[1], Christopher Jakob[2], Ansgar Lowack[1], Oldřich Novotny[2], Andreas Reifenberger[1], Dennis Schulz[1], and Andreas Wolf[2] — [1]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 incident particles on the detector, even with multiple particles hitting the detector simultaneously.

We present a new read-out scheme which uses only 32 SQUID channels for the 4096 pixels of the detector as well as some new fabrication details including copper-filled through-wafer vias to heat-sink the detector to the wafer backside. In addition we present the results of first characterization measurements.

TT 57.26 Thu 15:00 P2/OG2

Towards large-area 256-pixel MMC arrays for high resolution X-ray spectroscopy — •Andreas Abeln, Steffen Allgeier, Axel Brunold, Lars Eisenmann, Daniel Hengstler, Lukas Münch, Alexander Orlow, Andreas Fleischmann, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University

Metallic Magnetic Calorimeters (MMCs) are energy-dispersive cryogenic particle detectors. Operated temperatures below 50 mK, they provide very good energy resolution, high quantum efficiency as well as linearity over a large energy range. In many precision experiments on 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. For a cost-effective read-out of a growing number of detector channels we investigate different multiplexing techniques.
In this contribution we present the design of a novel 16×16 pixel MMC array. The pixels provide a total active area of $4\,\mathrm{mm}\times4\,\mathrm{mm}$ 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 $\Delta\mathrm{E} = 1.4\,\mathrm{eV}$ (FWHM) at an operating temperature of 20 mK. We give an overview about the microfabrication process and focus on the challenging task of producing through wafer vias to heat sink the MMC pixels to the wafer backside. These vias are realized by holes etched through the silicon substrate and subsequently lined with gold to achieve high thermal coupling between detector pixels and the cryostat.

TT 57.27 Thu 15:00 P2/OG2

A dedicated 2-dimensional array of metallic magnetic microcalorimeters to resolve the 29.18 keV doublet of ^{229}Th — •A. Brunold, A. Abeln, S. Allgeier, J. Geist, D. Hengstler, A. Orlow, L. Gastaldo, A. Fleischmann, and C. Enss — Heidelberg University

The isotope ^{229}Th has the nuclear isomer state with the lowest presently known excitation energy, which possibly allows to connect the fields of nuclear and atomic physics with the potential application as a nuclear clock. In order to excite this very narrow transition with a laser a precise knowledge of the transition energy is needed. Recently the isomer energy (8.338 ± 0.024) eV [Kraemer et al., arXiv:2209.10276, 2022] could be precisely determined. To get additional valuable insights, we will improve our recent high-resolution measurement [Sikorsky et al., PRL 125, 2020] of the γ-spectrum following the α-decay of ^{233}U. This decay results in excited ^{229}Th with a nuclear state at 29.18 keV. Resolving the doublet, that results from subsequent de-excitation to the ground and isomer state, respectively, would allow an independent measurement of the isomer energy and the branching ratio of these transitions. To resolve this doublet, we develop a 2D detector array consisting of 8×8 metallic magnetic calorimeters (MMCs). MMCs are operated at millikelvin temperatures and convert the energy of a single incident γ-ray photon into a temperature pulse which is measured by a paramagnetic temperature sensor. The detector array features an active detection area of $4\,\mathrm{mm}^2$, a stopping power of 63.2% for 30 keV photons and an energy resolution below 3 eV (FWHM).

TT 57.28 Thu 15:00 P2/OG2

X-ray spectroscopy of U^{90+} ions with a 64-pixel metallic magnetic calorimeter array — •A. Orlow[1], S. Allgeier[1], A. Abeln[1], A. Brunold[1], M. Friedrich[1], A. Gumberidze[2], D. Hengstler[1], F. M. Kröger[2,3,4], P. Kuntz[1], A. Fleischmann[1], M. Lestinsky[2], E. B. Menz[2,3,4], Ph. Pfäfflein[2,3,4], U. Spillmann[2], B. Zhu[4], G. Weber[2,3,4], Th. Stöhlker[2,3,4], and C. Enss[1] — [1]KIP, Heidelberg University — [2]GSI/FAIR, Darmstadt — [3]IOQ, Jena University — [4]HI Jena

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+} at CRYRING@FAIR 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 $1\,\mathrm{cm}^2$ and a stopping power of 40 % at 100 keV. Four on-chip thermometers allow to correct for temperature drifts and to achieve an energy resolution of 40 eV at 60 keV. We show preliminary X-ray spectra of the recent U^{90+} beamtime. Due to the small rate of emitted X-rays, a good supression of background radiation is mandatory, which was ensured by a coincidence measurement with a particle detector. To increase the stopping power to above 60 % at 100 keV we develop a new maXs-100 detector with $100\,\mu$m thick absorbers.