TT 16: Poster Session Superconductivity, Cryogenic Particle Detectors, Cryotechnique

Time: Monday 15:00–19:00 Location: P2/EG

TT 16.1 Mon 15:00 P2/EG

Superconducting granular aluminum films grown at cryogenic condition — •Alessandro D'Arnese, Martin Dressel, and Marc Scheffler — 1.Physikalisches Institut, Universität Stuttgart, Germany

Superconducting domes have been observed in many superconductors, raising questions of the driving mechanisms influencing T_c. One such material is granular aluminum, which is composed of aluminum nanograins coupled through thin insulating oxide layers. Granular aluminum has two decisive microscopic length scales: the grain size and the barrier thickness. These govern the fundamental energy scales for superconductivity, namely the superconducting energy gap and the superfluid stiffness, which can be determined with low-frequency optical spectroscopy [1].

In this work we developed a new evaporation setup for the growth of thin granular aluminum films at cryogenic temperatures. Controlling substrate temperature and oxygen pressure allows us to tune grain size and barrier thickness. Towards this goal, we implemented a bath cryostat to reach liquid-helium temperatures for the substrate. This project focuses on growth, characterization, and optimization of granular aluminum films. We also present DC and microwave data as a way of characterizing films and their superconducting energy scales.

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

TT 16.2 Mon 15:00 P2/EG

Terahertz electrodynamics of low-temperature-grown granular aluminum — •Mehmet Ali Nebioglu, Alessandro D'Arnese, Martin Dressel, and Marc Scheffler — 1.Physikalisches Institut, Universität Stuttgart, Germany

Granular aluminum exhibits superconducting properties that can be tuned by its microscopic structure, in particular the size of the aluminum grains and the thickness of the aluminum-oxide barriers that separate the grains. This makes granular aluminum interesting for both fundamental studies of relevant superconducting energy scales and for applications. Terahertz (THz) spectroscopy is a powerful tool to study these energies via the frequency-dependent response of superconducting films that can be probed in transmission measurements, and it also gives access to superconducting collective modes [1, 2].

We study the THz response of granular aluminum films that are grown at cryogenic temperatures (down to the ^{4}He regime) and thus can exhibit substantial enhancement of T_c compared to room-temperature-grown films. We present the complex optical conductivity and we determine superconducting energy gap and superfluid stiffness. We compare these results to BCS predictions and to previous studies on granular aluminum films grown at higher temperatures [1, 3].

[1] Uwe S. Pracht *et al.*, Phys. Rev. B **93**, 100503 (2016).
[2] Uwe S. Pracht *et al.*, Phys. Rev. B **96**, 094514 (2017).
[3] Aviv Glezer Moshe *et al.*, Phys. Rev. B **99**, 224503 (2019).

TT 16.3 Mon 15:00 P2/EG

Scanning tunneling spectroscopy on disordered superconductors — •Martina Trahms[1], Idan Tamir[1], Franzisca Gorniaczyk[2], Marc Westig[1], Karl Jacobs[3], Dan Shahar[2], and Katharina J. Franke[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany. — [2]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot 7610001, Israel. — [3]I. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany.

In some materials superconductivity co-exists with a certain amount of disorder. The true microscopic nature of disordered superconductors remains unknown [1]. These systems have mainly been investigated in transport experiments which average over the macroscopic sample area. More recently, scanning tunneling microscopy/spectroscopy (STM/STS) measurements revealed large spatial fluctuations of the superconducting gap, indicating a local modification of the ground-state [2]. Here, we will present preliminary results of high resolution STM measurements enabled by utilizing superconducting tips. We study thin films of amorphous InO and polycrystalline NbN as well as a 400 nm TiN sample. We observe local gap variations on the nanometer length scale and resolve a number of in-gap states showing high fluctuations both in energy and spatial distribution.

[1] P. W. Anderson, J. Phys. Chem. Solids **11**, 26-30 (1959).
[2] B. Sacépé *et al.*, Phys. Rev. Lett. **101**, 157006 (2008).

TT 16.4 Mon 15:00 P2/EG

Probing the dielectric properties of disordered thin-films with microwave resonators — •Nikolaj Ebensperger[1], Benjamin Sacépé[2], Martin Dressel[1], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut Néel, CNRS Grenoble, France

Weakly superconducting materials are of high interest for a multitude of recent studies. Yet probing the fundamental properties of these often highly disordered or granular materials is challenging and experiments are not easily performed. Specifically the insulating state terminating superconductivity in highly disordered amorphous indium oxide poses various theoretical and experimental challenges. A body of work indeed showed that the charge carriers in it are localized Cooper pairs. The electrodynamic response in this regime can offer important insight, but it is difficult to probe. In this study we present measurements of the dielectric properties of very highly disordered, insulating indium oxide films. We detail the experimental design of our microwave-resonator device as a discrete frequency probe in the GHz-range up to 20 GHz in an operable temperature range down to mK temperatures. Additionally we apply this method to a variety of different insulating/dielectric films with varying thickness and compare to simulations and theory [1].

[1] Rev. Sci. Instr. **90**, 114701 (2019)

TT 16.5 Mon 15:00 P2/EG

High-Pressure Magnetic Measurements of 2H-NbSe$_2$ — •Israel Osmond and Sven Friedemann — HH Wills Laboratory, University of Bristol, UK

With superconductivity often found in the vicinity of ordered states such as charge density waves (CDW) and antiferromagnetism, the ability to tune materials through these states serves as a vital tool in exploring the interplay of these phases with superconductivity. For characterizing a given superconductor, magnetic measurements provide a non-invasive method of studying vortex dynamics and measuring critical temperatures and fields.

Likewise, pressure measurements serve as a continuous tuning parameter across many of these phases. As such, the application of pressure provides a method to both access novel structures not available at ambient pressure, and to explore the competition between phases such as the CDW and superconducting order. This work develops current pressure cell technology compatible with commercial SQUID magnetometers, with both piston cylinder and gemstone anvil type cells.

Previous research into 2H-NbSe$_2$ has shown multiband superconductivity, CDW ordering, and the existence of a quantum critical point beneath the superconducting state. Here, we use the aforementioned pressure cells for magnetic susceptibility measurements, mapping the behaviour of the lower critical field and T_c with pressure and temperature. These provide insight into the multiband nature of superconductivity in this material, and provide evidence for a competition between the CDW and superconducting phases.

TT 16.6 Mon 15:00 P2/EG

Superconductivity in $[(\mathrm{SnSe})_{1+\delta}]_m[\mathrm{NbSe}_2]_n$ ferecrystals — •Olivio Chiatti[1], Klara Mihov[1], Martina Trahms[1], Theodor Griffin[1], Corinna Grosse[1], Danielle Hamann[2], Kyle Hite[2], Matty B. Alemayehu[2], David C. Johnson[2], and Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Solid State Chemistry, Inorganic Chemistry, Electrochemistry and Materials Science, University of Oregon, Eugene, OR 97403-1253, U.S.A.

The electrical properties of layered superconducting thin films have recently received a lot of attention. The ferecrystals are multilayers grown with atomic layer precision, but without an epitaxial relationship between the layers in growth direction. In this work, the ferecrystals are composed of a superconducting transition metal dichalgonide (NbSe$_2$) stacked repeatedly with a metal monochalgogenide (SnSe), which provides a model system for layered superconductors [1]. We examine ferecrystals with $n = 1$ and varying m, which show a superconducting phase below a critical temperature. The Ginzburg-Landau coherence lengths are determined from the critical magnetic fields and give information about the coupling between the superconducting $NbSe_2$ monolayers [2]. In addition, we discuss the conductivity corrections above the critical temperature due to quantum effects and superconducting fluctuations.

[1] C. Grosse *et al.*, Cryst. Res. Technol. **52**, 1700126 (2017)
[2] M. Trahms *et al.*, Supercond. Sci. Technol. **31**, 065006 (2018)

TT 16.7 Mon 15:00 P2/EG

Universal behavior of the IMS domain formation in superconducting niobium: Neutron scattering and molecular dynamics simulations — •Abdel Al-Falou[1,2], Alexander Backs[1,2], Michael Schulz[1,2], Alexei Vagov[3], Peter Böni[2], and Sebastian Mühlbauer[2] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]Technische Universität München, Garching, Germany — [3]Physikalisches Institut, Universität Bayreuth, Germany

In the intermediate mixed state (IMS) of type-II/1 superconductors, vortex lattice and Meissner state domains coexist due to a partial vortex attraction. Recently, we performed a systematic study on the domain formation in the IMS for Nb samples of varying purity [1,2]. Due to the wide range of length scales in the IMS, we combined several neutron based techniques with bulk magnetization measurements. We find a preferred vortex spacing a_{VL} in the IMS, independent of the external magnetic field. The temperature dependence of a_{VL} shows a universal behavior, related to the superconducting penetration depth and the sample purity. An elusive key feature so far is the domain morphology in bulk samples. Hence, we use molecular dynamics simulations on a 2D system of vortices as a complementary method, where the vortex interaction is given by extended Ginzburg-Landau theory [3]. In the simulations, we follow a field cooling path analogous to our experiments. The resulting morphology of the IMS depends on several parameters, e.g. the cooling rate or pinning strength. The results can be directly compared to neutron scattering data by Fourier transformation.

TT 16.8 Mon 15:00 P2/EG

Nernst Effect and Thermal Conductivity in Nd doped $La_{1.81}Sr_{0.19}$ CuO_4 — •Sanaz Shokri[1], Christoph Wuttke[1], Federico Caglieris[1], Koushik Karmakar[1], Andrey Malyuk[1], Silvia Seiro[1], Christian Hess[1,2], and Bernd Büchner[1,2,3] — [1]IFW , Dresden, Germany — [2]Centre for Transport and Devices, TU dresden, Germany — [3]Institut für Festkörper Physik, TU Dresden, Germany

The interrelation of superconductivity, stripe correlations, and pseudogap in cuprate superconductors is an unresolved issue for rationalizing the physics of these materials. Here we focus on the thermal conductivity κ and the Nernst coefficient ν of $La_{2-y-x}Nd_ySr_xCuO_4$ at x=0.19, which is a prototype cuprate superconductor with a hole concentration close to p $\approx$ 0.18, below which pseudogap are considered to emerge in various physical properties [1]. Additionally, the Nd doping is understood to play an essential role for the appearance of stripe correlations [2]. Our data reveal a striking non-monotonic evolution of both ν and κ as a function of y. The data will be discussed in terms of the impact of Nd-doping on the buckling of the CuO_2 planes.

[1] O. Cyr-Choiniere et al., PRL 97, 064502(2017)
[2] J. Tranquada et al., Nature, 375, 561 (1994)

TT 16.9 Mon 15:00 P2/EG

Pump–probe spectroscopy of iron pnictides under high pressures — •Ivan Fotev[1,2], Harald Schneider[1], Manfred Helm[1,2], Bernd Büchner[2,3], Saicharan Aswartham[3], and Alexej Pashkin[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]TU Dresden, Germany — [3]Leibniz Institute for Solid State and Materials Research, Dresden, Germany

Iron pnictides are very susceptible to external pressure and can become superconducting (SC) at several GPa. Their rich temperature-pressure phase diagram contains a spin-density wave (SDW) phase next to the superconducting dome. Furthermore, it is thought that in iron pnictides the SDW and SC phases may even coexist, and they exhibit a quantum phase transition close to absolute zero.

We investigate the ultrafast quasiparticle dynamics of parental iron pnictides, like $BaFe_2As_2$, at low temperatures and high pressures, by combining optical pump–probe spectroscopy with a diamond anvil cell. This approach potentially enables us to identify SDW, SC or metallic state through their characteristic quasiparticle lifetimes and, therefore, scan the phase diagram of the material and explore the coexistence/competition between of SDW and SC phases.

TT 16.10 Mon 15:00 P2/EG

Analysis of Electronic Properties from Magnetotransport Measurements on $Ba(Fe_{1-x}Ni_x)_2As_2$ Thin Films — •Ilia Shipulin[1], Aleena Anna Thomas[1,2], Stefan Richter[1,2], Kornelius Nielsch[1,2], and Ruben Hühne[1] — [1]Leibniz IFW Dresden, Institute for Metallic Materials, Dresden, Germany — [2]2 School of Sciences, TU Dresden, Dresden, Germany

Within the last years, significant progress was made in the field of single crystal growth of 122 based materials with isovalent, hole or electron doping, which made it possible to study the thermodynamic and transport properties of these compounds. At the same time, the preparation of high-quality epitaxial thin films of 122 materials resulted at least for the $BaFe_2As2_2$ based compounds in properties comparable to single crystals. Such films are of particular interest for the study of both fundamental and applied questions. Therefore, we focused our research on the two tasks: growing epitaxial thin films of $Ba(Fe_{1-x}Ni_x)_2As_2$ with different nickel concentrations by PLD method and studying the main electronic characteristics of the obtained Ba(Fe1-xNix)2As2 thin films. Based on the results of magnetotransport studies we estimated the density of electronic states at the Fermi level, the coefficient of electronic heat capacity and other electronic parameters of this compound and their dependence on the dopant concentration within the framework of the Ginzburg-Landau-Abrikosov-Gorkov theory. The comparison of the determined parameters with the measurement data of similar $Ba(Fe_{1-x}Ni_x)_2As_2$single crystals demonstrates a good agreement, which confirms the high quality of the obtained films.

TT 16.11 Mon 15:00 P2/EG

Superconductivity and quasi two dimensional magnetism in $EuRbFe_4As_4$ — •Noah Winterhalter-Stocker[1], Stefan Gorol[1], Stevan Arsenijevic[2], Yurii Skourski[2], Hans-Albrecht Krug von Nidda[3], Mamoun Hemmida[3], Dieter Ehlers[3], Anton Jesche[1], Veronika Fritsch[1], and Philipp Gegenwart[1] — [1]EP VI, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]EP V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

$EuRbFe_4As_4$ is a member of the new 1144 structure type of IBSCs, which contains parmagnetic Eu 4f moments. This structure is highly related to half doped 122 IBSCs. In contrast to the latter $EuRbFe_4As_4$ shows a superstructure with distinct Eu and Rb positions. The material shows a superconducting transition at $T_c = 36.8$ K and an onset of magnetic order of the Eu moments at $T_m = 15$ K [1]. We study the magnetic order and superconductivity by magnetization, magnetotransport and ESR measurements. Our analysis reveals the temperature dependence of the lower and upper critical fields. The ESR-measurements along with the magnetization data indicate the quasi two dimensional nature of the Eu magnetism. This becomes manifest in a Berezinsky-Kosterlitz-Thouless transition of the Eu, which was proposed by [2] and is confirmed by the ESR data.

[1] M. P. Smylie *et al.*, Phys. Rev. B **98**, 104503 (2018)
[2] K. Willa *et al.*, Phys. Rev. B **99**, 180502 (2019)

TT 16.12 Mon 15:00 P2/EG

Growth and characterisation of substitution variants of LaOFeAs single crystals — •Felix Anger[1], Anja Wolter-Giraud[1], Sebastian Gass[1], Hans-Joachim Grafe[1], Saicharan Aswartham[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]Leibniz Institute for Solid State and Materials Research, IFW, Dresden, Germany — [2]Institute of Solid State and Materials Physics, TU Dresden, Dresden, Germany

Facetted LaOFeAs single crystals with considerably growth in the crystallographic c direction were first prepared by R. Kappenberger et al. The growth process takes place via diffusion in solid state, the so-called Solid State Crystal Growth (SSCG) method. The single crystals are grown from a polycrystalline matrix by the introduction of NaAs as a liquid phase to aid the crystallization process.[1] Here, we present some additional experimental findings on the role of NaAs for the growth. Furthermore, we are aiming to grow novel series of crystals of substitution variants as, e.g., Co-doped SmOFeAs and $LaO_{1-x}F_xFeAs$. The crystals were characterized regarding their composition, structure and magnetic properties.

[1] R. Kappenberger et al., *Journal of Crystal Growth* **483**, 9-15 (2018).

TT 16.13 Mon 15:00 P2/EG

Charge density wave in Li doped NaFeAs — Jose M. Guevara[1], •Sven Hoffmann[1], Zhixiang Sun[1], Steffen Sykora[1], Yevhen Kushnirenko[1], Alexander Fedorov[1], Chanhee Kim[2], Aga Shahee[2], Dilipkumar Bhoi[2], Kee Hoon Kim[2], Saicharan Aswartham[1], Sergei Borisenko[1], Bernd Büchner[1], and Christian Hess[1] — [1]Leibniz-Institute for Solid State and Materials Research, IFW-Dresden, 01069 Dresden, Germany — [2]CeNSCMR, Department of Physics and Astronomy, Seoul National University, Seoul 151-747, South Korea

The hierarchy between superconductivity, magnetism and charge order remains as an indecipherable and breathtaking puzzle in solid state physics. Clarifying the role of these interaction is immensely important to understand the pairing mechanism of superconductivity in Iron-based superconductors. Here, we use SI-STS to visualize the atomic-scale electronic structure of $Na_{0.96}Li_{0.04}FeAs$. We find short range electronic order in the LDOS with a periodicity $\sim$ 8 nm. We use q-selective STS and angle-resolved photoemission to find a gap with value $2\Delta = 15$ meV and an appropriate nesting vector of $q_{2k_F} \sim 0.05\frac{\pi}{a_{Fe}}$ in the d_{yz} band at the Γ point, respectively. These observations are a clear signature of a band-selective charge density wave (CDW). We conjecture that the band-selective CDW is responsible for the change in the spin-fluctuations and therefore resulted in a different nematic state. We compared these findings with results for the parent compound NaFeAs.

TT 16.14 Mon 15:00 P2/EG

Electronic nematicity and thermal expansion in $FeSe_{1-x}S_x$ — •Liran Wang[1], Sven Sauerland[1], Dmitriy Chareev[2], Alexandre Vassiliev[2], Michael Merz[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics, Heidelberg University, Germany — [2]NRC Kurchatov institute, Moscow, Russie — [3]Institute for Solid State Physics, Karlsruhe Institute of Technology, Germany

We report the study on electronic nematicity in pure and sulfer doped FeSe high quality single crystals by means of thermal expansion and shear modulus measurements. Clear anomalies in the thermal expansivity are observed at both the magneto-structural and superconducting transition. By means of the three-point bending technique in the capacitance dilatometer, we obtain the nematic susceptibility from the shear modulus response. The shear modulus softens well above T_s implying a Curie-Weiss-like behaviour of the nematic susceptibility. Sulfur-doping suppresses T_s but no clear effect on T_c can be found. The evolution of the nematic phase as well as of nematic fluctuations is mapped out towards the superconducting regime. The relation between the nematic susceptibility and spin, structure and orbital degrees of freedom is discussed.

TT 16.15 Mon 15:00 P2/EG

Towards the study of uniaxial strain in epitaxial $FeSe_xTe_{1-x}$ films — •Aleena Anna Thomas[1,2], Thomas Doert[2], Kornelius Nielsch[1,2], and Ruben Hühne[1] — [1]Leibniz Institute for Metallic Materials, IFW Dresden, 01069 Dresden, Germany — [2]TU Dresden, 01062 Dresden, Germany

The discovery of high temperature superconductivity in layered iron-based material has ignited significant scientific interest in basic studies of their properties as well as for technological applications. Among them, iron selenide has the simplest crystal structure, in which superconductivity can be tuned either by strain or by doping. In particular, it has been reported in literature that the transition temperature can be increased by compressive substrate-induced biaxial strain in thin film. Our aim is to extend these investigations in order to study the correlation between uniaxial strain and critical temperature in thin films. In order to study such thin film in a uniaxial strain cell, we grew iron selenides on ultra-thin single crystalline substrates. Therefore, a thin Fe(Se,Te) seed layer was deposited on these substrates at 400 °C using pulsed laser deposition, followed by a homo-epitaxially grown Fe(Se,Te) film at 300 °C. All films are highly textured and show a maximum superconducting transition temperature of 21 K, 19 K and 17 K on CaF_2, $SrTiO_3$ and MgO, respectively. These thin films will be studied to infer the influence of uniaxial strain on the superconducting transition in FeSe materials using the aid of uniaxial strain cell.

TT 16.16 Mon 15:00 P2/EG

FIB-Fabricated Micro-Resonators to Probe Symmetry Breaking in Unconventional Superconductors — •Amelia Estry[1], Carsten Putzke[1], Chunyu Guo[1], Markus König[2], and Philip J. W. Moll[1] — [1]Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Determining the broken symmetries in the strongly correlated states of unconventional superconductors is critical to their understanding. I will present a measurement technique currently being developed to probe symmetry breaking by examining the elastic moduli in crystalline micro-resonators in their competing ground states. We use Focused Ion Beam (FIB) micro-machining to cut cantilevers with well-defined geometry and crystallographic direction directly out of high-quality single crystals. The hundred-nanometer resolution of FIB fabrication leads to well-defined boundary conditions for the simulation of the elastic problem. We propose to explore symmetries by studying the resonance frequencies of cantilevers with different crystallographic orientations and complex shapes. The proximity of the pseudogap in cuprates and nematicity in pnictides to superconductivity raises the question of their interplay and possible common origin. Particularly, the pseudogap is debated to be either a crossover of energy scales or a distinct thermodynamic phase. With this novel approach we aim to identify the symmetries in the pseudogap, probing current theoretical predictions.

TT 16.17 Mon 15:00 P2/EG

Angular-dependent specific heat of the organic superconductor κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ — •T. Reimann[1], H. Kühne[1], J. A. Schlueter[2], and J. Wosnitza[1,3] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Division of Materials Research, National Science Foundation, Alexandria, VA 22314, USA — [3]Institut für Festkörper- und Materialphysik, TU Dresden, D-01062 Dresden, Germany

The layered organic superconductor κ-(BEDT-TTF)$_2$Cu(NCS)$_2$ ($T_c \approx 9.4$ K) has recently gained strong interest because macroscopic, such as specific heat and magnetic torque, as well as microscopic NMR studies indicate the formation of a Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state above the Pauli-limit of $B_P \approx 21$ T (For a recent review, see [1]). However, details about the nature of the phase transition remained controversial, since already a small off-alignment α of the superconducting layers to the magnetic field gives rise to orbital effects and reduces T_c considerably. Here, we present angular-resolved specific heat measurements in fields ranging from 0 to 22 T, covering the conventional superconducting as well as the FFLO state. For strictly parallel alignment, a sharpening of the superconducting transition accompanied by an upturn of $T_c(B)$ clearly hallmarks the FFLO state above B_P. However, for $0.5 \leq \alpha \leq 3.5$, pronounced first-order transitions appear slightly below T_c possibly indicating melting of the vortex lattice.

[1] J. Wosnitza, *Ann. Phys.* **530**, 1700282 (2018)

TT 16.18 Mon 15:00 P2/EG

Implementation of the full-potential relativistic KKR-BdG method — •Philipp Rüssmann[1], Phivos Mavropoulos[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Physics Department, National and Kapodistrian University of Athens, Greece

The realization of Majorana fermions in superconductor (SC)/topological insulator (TI) hybrid structures is a major international research challenge. Prerequisite is the understanding and optimization of SC/TI interface, which can in principle be achieved through the predictive power of density functional theory. However, treating superconductivity on this footing in complex systems, including defects, surfaces and interfaces, remains a major challenge. The Bogoliubov-de Gennes (BdG) method allows to combine the strengths of *ab initio* electronic structure calculations for the normal state with a simple description of the superconducting pairing interaction [1]. While taking care of the complexity of the normal state band structure, a material-specific semiphenomenological parameter can be introduced to allow the calculation of the BdG quasiparticle spectrum in the superconducting state. – Here, we present the implementation of the BdG method into our full-potential relativistic Korringa-Kohn-Rostoker Green function method [https://jukkr.fz-juelich.de], following Csire et al. [1]. We acknowledge financial support from DFG-Excellence Cluster ML4Q.

[1] G. Csire *et al.*, Phys. Rev. B **91**, 165142 (2015).

TT 16.19 Mon 15:00 P2/EG

Exact Diagonalization study of large Hubbard clusters — •Michael Danilov[1], Sergei Iskakov[2], Andrei Bagrov[3], Alexander Lichtenstein[1], and Mikhail Katsnelson[3] — [1]I. Institut für Theoretische Physik, Jungiusstr. 9, 20355 Hamburg, Germany —

[2]Department of Physics, University of Michigan, Ann Arbor, Michigan 48109, USA — [3]Institute for Molecules and Materials, Radboud University, 6525AJ Nijmengen, The Netherlands

Using efficient exact diagonalization scheme, we study electronic structure of 4x4 doped Hubbard cluster with realistic hopping parameters including next nearest neighbour hopping $t' = -0.3t$, which is optimal for superconducting cuprates.

To find possible candidates for superconducting regime we calculate the spectral function and network entanglement measures for different doping and Coulomb interaction.

TT 16.20 Mon 15:00 P2/EG

Josephson inductance of epitaxial Al-InAs-based Josephson junction arrays — •Christian Baumgartner[1], Linus Fresz[1], Lorenz Fuchs[1], Geoffrey Gardner[2,3], Michael Manfra[2,3], Nicola Paradiso[1], and Christoph Strunk[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, Germany — [2]Station Q Purdue, Purdue University, West Lafayette, Indiana 47907, USA — [3]Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907,USA

We study one-dimensional Josephson junction arrays (JJAs) in epitaxial Al/InAs/InGaAs heterostructures. Our measurement circuit allows us to measure simultaneously the Josephson inductance and the DC transport characteristics. Both are measured as a function of the magnetic field vector, temperature, gate voltage or direct current. We find that the critical current determined at the equilibrium from the Josephson inductance is significantly larger than the transport critical current. This latter is, in fact, determined by the weakest link, whereas the Josephson inductance is insensitive to defects in the JJA. Interestingly, the measurement of the Josephson inductance makes it possible to directly reconstruct part of the current-phase relation, and therefore deviations from the sinusoidal dependence. The present method offers a new approach to investigate the nature of topological Josephson junctions.

TT 16.21 Mon 15:00 P2/EG

Controllable Josephson Junctions by ferromagnetic Proximity Effect — •Lukas Kammermeier, Maik Kerstingskötter, Marcel Thalmann, Elke Scheer, and Torsten Pietsch — Universität Konstanz

Josephson junctions (JJ) belong to the most important superconducting devices in terms of applications. Thereby an active tuneability of the JJ's properties is highly desirable. Creating the JJ through local suppression of superconductivity due to the inverse proximity effect with ferromagnets, offers versatile control possibilities. The presented project aims at controlling the JJ by tayloring the ferromagnetic interface and its repsonse to magnetic fields and high frequency radiation to lay the ground for further control via spin pumping and spin injection. We show preliminary experimental results on the transport properties and the observation of fractional Shapiro steps in these types of junctions.

TT 16.22 Mon 15:00 P2/EG

Transport and ferromagnetic resonance in superconductor-ferromagnet junctions — •Andreas Bloch, Marcel Thalmann, Marcel Rudolf, Elke Scheer, and Torsten Pietsch — Physics Department, University of Konstanz, 78457 Konstanz, Germany

Hybrid superconductor nanostructures have the potential to overcome the limitations of conventional, dissipative electronic devices. We investigate novel spin and charge transport phenomena in superconductor (S) - ferromagnet (F) hybrid nanostructures under non-equilibrium conditions. We focus on ferromagnetic Josephson junctions (fJJs), where two S are separated by a F barrier. Theory predicts the possibility to generate long range triplet pairing in SF hybrid systems via a dynamic coupling of the electron spin to the magnetic resonance of the ferromagnet (FMR) [1]. We present here the first results of our project aiming at investigating experimentally this novel phenomenon. The samples under study are realized by electron beam and photo lithography. We use Al as S and Co or Py as F metal. A pre-patterned coplanar waveguide introduces microwaves (frequency up to 40 GHz) to the integrated SF contact to drive the FMR. The local and non-local current-voltage characteristics under irradiation will be discussed.

[1] S. Hikino et al., Supercond. Sci. Technol. **24**, 024008 (2011)

TT 16.23 Mon 15:00 P2/EG

Development of a fabrication process for nanoSQUIDs with three independent Nb layers — •Silke Wolter[1], Oliver Kieler[1], Thomas Weimann[1], Josepha Altmann[2], Sylke Bechstein[2], Jörn Beyer[2], Julian Linek[3], Reinhold Kleiner[3], and Dieter Koelle[3] — [1]Fachbereich Quantenelektronik, Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [2]Fachbereich Kryosensorik, Physikalisch-Technische Bundesanstalt (PTB), Berlin — [3]Physikalisches Institut and Center for Quantum Science (CQ) in LISA$^+$, Universität Tübingen

Nanometer-sized superconducting quantum interference devices, nanoSQUIDs (nSQs), offer high spatial resolution und high spin sensitivity approaching the order of $1\,\mu_B/\mathrm{Hz}^{1/2}$ (μ_B is the Bohr magneton), making them suitable for the detection of the magnetic states of magnetic nanoparticles. Our fabrication technology for nSQs with overdamped SNS (S: superconductor, N: normal conductor) trilayer Nb-HfTi-Nb Josephson junctions is based on the combination of electron beam lithography with chemical-mechanical polishing and magnetron sputtering on thermally oxidized Si wafers to produce dc nSQs with 100-nm-dimensions for Nb lines and junctions (down to 80 nm×80 nm). We extended the process from originally two to three independent Nb layers. This extension offers the possibility to increase the density of structures on the wafer and to realize superconducting vias to all Nb layers without the HfTi barrier. We present results on the yield of this process and measurements of nSQs characteristics.

This work was supported by the DFG (KI 698/3-2).

TT 16.24 Mon 15:00 P2/EG

Towards direct on-chip spectroscopy of the Bloch oscillations in a small Josephson junction — •Sergey Lotkhov — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

In our presentation, we address an experimental design which should make it possible to directly detect and to measure the linewidth of Bloch oscillations in a small Josephson junction. A dual experiment has been recently reported by our group [1] in respect to the Josephson radiation transmitted via a SQUID-tunable coplanar waveguide (CPW) to a photon-assisted tunneling (PAT) detector fabricated on the same on-chip. Single-photon-state readout has been demonstrated for the microwave frequencies around 80 GHz. In the new design, the source of oscillations is realized as a Bloch junction embedded into reactive high-impedance environment. The oscillations are coupled weakly to a sharp CPW resonant mode within the Bloch frequency range of 15-30 GHz. We discuss the experimental challenges and the promising solutions which we are about to deal with in the new experiments. In particular, we address our recent progress towards lower-threshold PAT detectors and highly transparent Bloch junctions. Furthermore, we will briefly overview the expected impact of the known stray mechanisms, like Landau-Zener tunneling or electron heating, on the oscillations linewidth for the scope of feasible parameters.

[1] S. V. Lotkhov et al., Appl. Phys. Lett. 115, 192601 (2019)

TT 16.25 Mon 15:00 P2/EG

Characterization of Nb/Al-AlO$_x$/Nb Josephson tunnel junctions suited for SQUID applications — •Fabienne Bauer, Dominik Zehender, Felix Herrmann, Constantin Schuster, Christian Enss, and Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Josephson tunnel junctions (JJs) are the basic element of many superconducting electronic devices such as qubits, Josephson voltage standards or superconducting quantum interference devices (SQUIDs). Since many recent applications strongly demand for circuits involving a large number of Josephson junctions, a reliable wafer-scale fabrication process yielding JJs with a reproducible and uniform high quality as well as a small parameter spread is required. To potentially readjust critical fabrication parameters, the quality of the fabricated JJs has to be continuously monitored.

In this contribution, we present our methods and approaches to characterize our home-made Nb/Al-AlO$_x$/Nb junctions which are utilized for SQUID applications. Current-voltage characteristics are recorded to check for the scaling of junction parameters like the critical current I_c with respect to the junction area and to extract different figures of merit such as the ratio of subgap to normal state resistance R_{sg}/R_N or the I_cR_N-product. To further check for the quality of the tunnel barrier, we measure the magnetic field dependence of I_c. In addition, we use unshunted SQUIDs to determine the intrinsic junction capacitance.

TT 16.26 Mon 15:00 P2/EG

Reducing the influence of SQUID Joule heating in dc-SQUIDs on the performance of cryogenic detectors — •Felix Herrmann, Matthäus Krantz, Anna Ferring-Siebert, Christian Enss, and Sebastian Kempf — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Metallic magnetic calorimeters (MMCs) are energy dispersive single particle detectors that are usually operated at temperatures below 50 mK. By making use of a paramagnetic temperature sensor absorbed energy is converted into a magnetic flux change which is measured by a dc-SQUID using a superconducting flux transformer.
In order to reduce parasitic inductances within the flux transformer, detector and SQUID should be placed in close vicinity. However, the Joule heat dissipated by the SQUID might negatively effect the detector temperature, thereby degrading the energy resolution. The energy dissipation of the SQUID is even more important in MMCs with direct sensor readout, a highly promising readout scheme to push the energy resolution in the sub-eV range. There, the paramagnetic sensor is placed directly on top of the SQUID loop, maximizing signal coupling while minimizing stray inductances.
In this contribution we discuss our recent efforts to reduce the influence of SQUID Joule heating on the performance of MMCs. In particular, we present a setup allowing to operate large detector arrays read out by conventional dc-SQUIDs, several means to reduce SQUID Joule heating e.g. by changing the shunt resistor geometry, as well as advanced heat sinking techniques using on-chip membranes.

TT 16.27 Mon 15:00 P2/EG

Metallic Magnetic Calorimeters for High Resolution X-Ray Spectroscopy of Highly Charged Ions — •M. Friedrich[1], S. Allgeier[1], M. Arndt[1], J. Geist[1], D. Hengstler[1], C. Schötz[1], S. Kempf[1], L. Gastaldo[1], A. Fleischmann[1], C. Enss[1], Ph. Pfäfflein[2], S. Trotsenko[2,3], T. Morgenroth[3], M.O. Herdrich[2], G. Weber[2], R. Märtin[2], and Th. Stöhlker[2,3,4] — [1]KIP, Heidelberg University — [2]HI Jena — [3]GSI Darmstadt — [4]IOQ, Jena University

Heavy Highly Charged Ions (HCIs) are promising candidates to test QED in extreme electromagnetic fields. Due to the high nuclear charge of such ions the electronic transitions are shifted to the X-ray regime, while the Lamb-Shift amounts to more than 0.1 % of the transition energies. Metallic magnetic calorimeters are energy dispersive X-ray detectors, which provide an extremely high energy resolution over a wide energy range as well as an excellent energy calibration. Thus, they are perfectly suited for high precision X-ray spectroscopy on HCIs in ion storage rings where photon flux is small and beam time is limited.
For an upcoming measurement on H-like U^{91+} at CRYRING@ESR we report on our newly developed, fabricated and characterised two-dimensional detector array maXs100 consisting of 64 pixels with a total detection area of 10x10 mm^2. An absorber thickness of 100 μm (50 μm) results in an expected energy resolution of $\Delta E_{\mathrm{FWHM}} \sim 38\,\mathrm{eV}(27\,\mathrm{eV})$. This detector is mounted on a side arm of a dilution refrigerator and will enable the determination of the 1s Lamb-Shift with sub-eV precision.

TT 16.28 Mon 15:00 P2/EG

Low Temperature MMC Detector Arrays for IAXO — •Daniel Unger, Andreas Abeln, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, and Daniel Hengstler — Kirchhoff Institute for Physics, Heidelberg University

The International Axion Observatory (IAXO) is searching for evidence of axions or axion-like particles generated in the Sun. A large magnet inside a helioscope pointing towards the Sun is used to generate the required magnetic field to convert solar axions into photons via the Primakoff effect. The expected photon spectrum considering only axion-photon coupling has a black body shape with its maximum at around 4 keV. Hence, X-ray detectors with high efficiency and low intrinsic background are necessary. Low temperature detectors based on metallic magnetic calorimeters (MMCs) fulfill these requirements.

We present the characterization of the first MMC detector setup developed for IAXO. This system consists of a two dimensional 64 pixel MMC array covering a detection area of 16 mm^2. Together with the SQUIDs necessary for the readout, the detector is mounted on a structure designed to be suitable for even larger MMC arrays. The performance of the detector array was investigated over a period of two months and will be discussed in terms of energy resolution, stability over time and background rate. To cope for different X-ray optics, a larger array covering an area of 1 cm^2 is at present under development.

The results, in particular the achieved low intrinsic background, demonstrate that two dimensional MMC arrays are a promising technology for IAXO.

TT 16.29 Mon 15:00 P2/EG

Large x-ray detector design for Baby-IAXO — •Andreas Abeln, Christian Enss, Andreas Fleischmann, Loredana Gastaldo, Daniel Hengstler, and Daniel Unger — Kirchhoff-Institute for Physics, Heidelberg University

Axions are promising candidates for cold Dark Matter as well as for solving the strong CP problem, their detection could shine light onto two important open questions in particle physics. The International AXion Observatory (IAXO) is an experiment designed for the validation of the existence of axion or axion-like particles (ALPs) produced in the Sun. IAXO is a fourth generation helioscope and will consist of a 20 m long magnet with field up to 6 T filling eight bores with diameter 60 cm. In this volume axion can be converted back to photons. Solar axions would produce a black body spectrum picking between 4 keV and 6 keV. The photons produced in the conversion volume are then focused onto high resolution and low background x-ray detectors. Metallic magnetic calorimeters (MMCs) have shown extremely good energy resolution and mainly unit quantum efficiency in the energy range of interest. First investigations have shown the possibility to reach very low level of undesired events.
We present the development of a new 2D MMC array characterized by 64 pixels covering an active surface of 1 cm^2. This absorber area perfectly contains the focal area of the x-ray optics foreseen to be used in Baby-IAXO, an intermediate stage of IAXO. The pixels are optimized to have high efficiency up to 10 keV. The expected energy resolution is 12 eV FWHM. We discuss the chip design and expected performance.

TT 16.30 Mon 15:00 P2/EG

dc-SQUID readout with intrinsic frequency-division multiplexing capability and high dynamic range — •Ludwig Hoibl, Daniel Richter, Andreas Fleischmann, Christian Enss, and Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Direct-current superconducting quantum interference devices (dc-SQUIDs) are extraordinarily sensitive flux-to-voltage converters. Due to their periodic flux-to-voltage characteristic, the linear flux range is rather small. For this reason, a flux locked loop (FLL) circuit is typically used to linearize the output signal. However, FLL operation often sets a practical limit for the realization of multi-channel SQUID systems since feedback wires have to be routed to each SQUID. There is hence a great need for SQUID based multi-channel readout techniques, providing a linear input-output signal relation.
In this contribution, we present a frequency-division multiplexing (FDM) readout technique with linear input-output signal relation and simultaneously a large dynamic range. It is based on flux-ramp modulation and hence relies on converting the input signal into a phase shift of the flux-to-voltage SQUID characteristic which is continuously measured by applying a periodic, sawtooth-shaped flux signal to the SQUID. We introduce the basic concept of our multiplexing technique and discuss the performance of a home-made four channel multiplexer device. Moreover, we present the status and performance of a custom-made readout electronics as well as potential applications in detector readout.

TT 16.31 Mon 15:00 P2/EG

Microwave SQUID multiplexer based on lumped element resonators — •Constantin Schuster, Mathias Wegner, Felix Ahrens, Daniel Richter, Christian Enss, and Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

To our present knowledge, microwave SQUID multiplexing is the most promising technique for reading out large detector arrays consisting of hundreds or even thousands of metallic magnetic calorimeters. Here, a non-hysteretic rf-SQUID is used to convert the detector signal into a phase or amplitude change of a superconducting microwave resonator for frequency encoding. So far, quarterwave transmission line resonators have been used exclusively, which somehow suffer from rather large lateral dimensions, severe sensitivity to frequency noise due to atomic tunneling systems as well as a challenging frequency control considering fabrication inaccuracies.

In this contribution we will present a microwave SQUID multiplexer (LEMUX) which is based on lumped element resonators and allows for a significantly increased channel density on the chip as well as the possibility for trimming the resonance frequency. We introduce our LEMUX design with a new generation of optimised rf-SQUIDs, discuss the achieved device performance and compare it to existing microwave SQUID multiplexers based on transmission line resonators.

TT 16.32 Mon 15:00 P2/EG

Investigation of the influence of nuclear spins and hydrogen absorbates on low-frequency excess flux noise — •Fabian Kaap, Anna Ferring-Siebert, Christian Enss, and Sebastian Kempf — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

The performance of superconducting quantum devices (SQDs) such as SQUIDs or qubits often suffers from low frequency excess flux noise (LFEFN). It is widely accepted that spin fluctuations at the surface of the superconductor, e.g. caused by adsorbed oxygen or hydrogen, is one of many sources of LFEFN. Recent works also suggest that spin fluctuations inside the bulk superconductor, e.g. due to nuclear spins, could give rise to LFEFN. However, there have been no experimental proofs or hints confirming or excluding these predictions so far.

In this contribution, we first present a chemical method to load hydrogen inside Nb layers in a controllable manner. We then discuss if and how LFEFN depends on hydrogen loading present in the bulk of the SQUID loop. Finally, we discuss our experimental approach to investigate the influence of device material on the LFEFN to ultimately reveal whether or not nuclear spins is another source of LFEFN. Within this context, we compare measurements on dc-SQUIDs with SQUID-washer made of Al to our conventional Nb-based SQUIDs.

TT 16.33 Mon 15:00 P2/EG

Spatially resolved SQUID-NMR measurement instrumentation for investigation of superfluid ^{3}He-thin-films — •Josepha Altmann[1], Sylke Bechstein[1], Joern Beyer[1], Oliver Kieler[2], Silke Wolter[2], Andrew Casey[3], and John Saunders[3] — [1]7.6 Kryosensorik, Physikalisch-Technische Bundesanstalt Berlin — [2]2.4 Quantenelektronik, Physikalisch-Technische Bundesanstalt Braunschweig — [3]Department of Physics, Royal Holloway University of London

Superfluid ^{3}He stands out as an unique and sophisticated condensed matter system. At the Royal Holloway University of London the different phases of ^{3}He-thin-films with heights varying from 100 nm up to 1100 nm are investigated to study the topological effects of the superfluid. To measure the phase diagram nuclear magnetic resonance (NMR) spectroscopy is used. In our setup, a Superconducting Quantum Interference Device (SQUID), designed as a current sensor, measures the NMR signal. To specify the location of the NMR signal, spatially resolving pick-up-coils are employed with dimensions ranging from 10 μm to 400 μm. Concurrently, coil inductances from about 20 nH up to 20 μH are needed to match well to the input circuit of SQUID current sensors. Electron beam lithography (EBL) enables the fabrication of superconducting planar structures with sub-μm-dimensions and thus a high ratio of inductance to coil size. We present the design, EBL-based fabrication and characterization of fine-pitch superconducting Nb-coils with line widths of 200 nm and their foreseen application in spatially resolved NMR on superfluid ^{3}He-thin-films.

TT 16.34 Mon 15:00 P2/EG

Optimized geometry for a compact 3D quantum memory — •Julia Lamprich[1,2], Stephan Trattnig[1,2], Yuki Nojiri[1,2,3], Qiming Chen[1,2,3], Stephan Pogozarek[1,2], Michael Renger[1,2,3], Kirill Fedorov[1,2,3], Achim Marx[1,2,3], Matti Partanen[1,3], Frank Deppe[1,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany

Quantum memories are of high relevance in the context of quantum computing and quantum communication. In view of the tremendous publicly-funded and commercial efforts to build scalable architectures based on superconducting quantum circuits, 3D cavities are promising candidates for a quantum memory. Recently, a compact layout exploiting the multimode structure of a rectangular 3D cavity has been demonstrated [1]. As an alternative to an improved operation mode of this device with optimal control strategies [2], we discuss an optimization of the cavity geometry here. Our results are promising with respect to key properties such as storage time and scalability.

We acknowledge support by the Germany's Excellence Strategy EXC-2111-390814868, Elite Network of Bavaria through the program ExQM, and the European Union via the Quantum Flagship project QMiCS (Grant No. 820505).

[1] E. Xie et al., Appl. Phys. Lett. 112, 202601 (2018).
[2] Sh. Machnes et al., Phys. Rev. Lett. 120, 150401 (2018)

TT 16.35 Mon 15:00 P2/EG

Quantum key distribution with squeezed displaced microwave states — •Florian. Fesquet[1,2], Kirill.G. Fedorov[1,2], Stefan. Pogorzalek[1,2], Michael. Renger[1,2], Qi-Ming. Chen[1,2], Yuki. Nojiri[1,2], Matti. Partanen[1], Achim. Marx[1], Frank. Deppe[1,2,3], and Rudolf. Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany

Quantum key distribution (QKD) is a technique to secretly communicate a key string between two parties. For continuous variables, the security can be achieved using properties of quantum mechanics, notably the non-commutativity of variables. We investigate a prepare-and-measure continuous-variables QKD protocol based on single-mode squeezed displaced microwave states to communicate a Gaussian modulated key. We theoretically investigate the secrecy and secret key rate of the protocol with an eavesdropper. It is shown that depending on the additional noise induced by the eavesdropper, the protocol is proven to be secure at the cost of an increased signal-to-noise ratio. Additionally, we show preliminary experimental results of the protocol in the microwave regime.

We acknowledge support by the Germany's Excellence Strategy EXC-2111-390814868, Elite Network of Bavaria through the program ExQM, and the European Union via the Quantum Flagship project QMiCS (GrantNo.820505).

TT 16.36 Mon 15:00 P2/EG

Optimized superconducting NbN resonators for hybrid quantum systems in strong magnetic field — •Thomas Koch[1], Kiril Borisov[1,2], Dennis Rieger[1], Christoph Sürgers[1], Patrick Winkel[1], Ioan Pop[1,2], and Wolfgang Wernsdorfer[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe — [2]Institute of Nanotechnology, Karlsruher Institut für Technologie, Karlsruhe

Superconductors are utilized as highly precise detectors for magnetometry, superconducting qubits and other hybrid quantum systems. Our goal is superconducting NbN microwave resonators with high magnetic field stability and high quality factors at single photon regime. Therefore, we optimized deposition conditions and patterning geometries and achieved high critical temperature ($\approx$ 15 K), high critical fields ($>$ 9 T), reduced susceptibility to vortex dynamics and high kinetic inductance (L $\approx$ 80 pH/square) in thin (10 nm) NbN films. We extracted quality factor and resonance frequency of stripline NbN resonators by microwave reflection in parallel and perpendicular field up to 1 T at 20 mK. Initial results on the realization of a hybrid quantum system with a NbN resonator as a read-out sensor will be presented as well.

TT 16.37 Mon 15:00 P2/EG

Low temperature suppression of the critical current in nanoscale Josephson junction parallel arrays — •Konrad Dapper[1], Lukas Powalla[1,2], Yannick Schön[1], Micha Wildermuth[1], Hannes Rotzinger[1,3], and Alexey V. Ustinov[1,4] — [1]Institue of physics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Institut für Festköperphysik, Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Russian Quantum Center, National University of Science and Technology MISIS, Moscow, Russia

We investigate the dynamics of fluxoids in parallel arrays of discrete, nanoscale Josephson junctions (JJPA) in the quantum regime where both charging and Josephson energy exceed the thermal energy. One mayor problem of these circuits is the confinement of current vortices in the array, since the small size of the Josephson junctions also leads to a vortex size typically much larger than the array length. To overcome this issue, we place additional Josephson junctions as kinetic inductance elements to each individual plaquette. Special care has also been taken to ensure a homogeneous biasing scheme of the array and a high impedance environment. The arrays are analyzed with transport measurements, in particular, we perform switching current measurements at various milli-Kelvin temperatures. We present data, which show a critical current suppression below temperatures of 600 mK, which indicates an influence of non-thermal quasiparticles and / or quantum phase slips.

TT 16.38 Mon 15:00 P2/EG

Microwave environment design for compact arrays of granular aluminum fluxonium qubits — •Patrick Paluch[1,2], Martin Spiecker[2], Daria Gusenkova[2], Ivan Takmakov[2], Francesco Valenti[2], Patrick Winkel[2], Dennis Rieger[2], and Ioan Pop[1,2] — [1]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [2]Physikalisches Institut, Karlsruhe Institute of Technology, 76137 Karlsruhe, Germany

Fluxonium qubits employing the high kinetic inductance of granular aluminum (grAl) have recently been implemented, demonstrating state-of-the-art coherence time [1]. In superconducting qubit design, the use of 3D waveguides is generally advantageous in reducing dielectric losses; however, it can limit the availability of in-situ magnetic flux lines. Moreover, given the localized nature of the fluxonium qubit mode, with the junction capacitance dominating, the advantages of 3D waveguides can be debated. Here we present a fast-flux tunable grAl fluxonium design in a coplanar waveguide geometry, surrounded by a normal metal ground plane, potentially decreasing the number of quasiparticles in the system [2] and avoiding flux trapping.

[1] Grünhaupt and Spiecker et al., Nat. Mater. 18, 816-819 (2019)
[2] Henriques and Valenti et al., Appl. Phys. Lett. 115, 212601 (2019)

TT 16.39 Mon 15:00 P2/EG

Two-level-systems spectroscopy in Transmon qubits. — •Serhii Volosheniuk[1], Alexander Bilmes[1], Alexey V. Ustinov[1,2], and Jürgen Lisenfeld[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe 76131, Germany — [2]Russian Quantum Center, National University of science and Technology MISIS, Moscow 1190449, Russia

Despite the announcement of achieving quantum supremacy, we are still far away from a superconducting quantum processor. One of the principal causes is low qubit fidelity due to parasitic material defects. These act like two-level-systems (TLS) which limit qubit coherence and create environmental fluctuations.

To understand how TLS are forming during sample fabrication, we seek information on their location in a given qubit circuit. For this, TLS are tuned with applied elastic strain and dc electric fields, allowing us to distinguish defects in Josephson junction tunnel barriers from those at film interfaces[1,2].

Here we present our latest results and ideas on TLS spectroscopy with E-field tuning in qubits. One goal is to obtain two-dimensional maps of defect locations in the vicinity of the qubits Josephson junctions to elucidate and mitigate the role of junction lithography on defect formation.

[1] J. Lisenfeld et al., npj Quantum Inf 5, 105 (2019)
[2] A. Bilmes et al., arXiv:1911.08246 (2019)

TT 16.40 Mon 15:00 P2/EG

Dielectric Low Temperature Properties of Printed Circuit Boards made of FR4 — •Andreas Rall, Benedikt Frey, Andreas Schaller, Andreas Fleischmann, Andreas Reiser, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, D-69120 Heidelberg

Printed circuit boards (PCB) are commonly used in electronic devices and are increasingly utilized in various low temperature applications. In many cases standard FR4 is used, which is a laminate of glass-fibers (alumino-borosilicate glass) and brominated epoxy resin. Little is known about its low temperature properties. We present dielectric measurements of FR4 down to a few millikelvin temperatures, where we use the material as dielectric sample of a plate capacitor in a superconducting LC-resonator at MHz frequencies.

The observed behavior can be well understood in terms of atomic two-level tunneling systems, that are known to dominate the low temperature properties of amorphous solids. The material shows a good thermalisation with the cryogenic environment even at the lowest measured temperatures. Measurements of the sample's temperature with a thermometer directly mounted on the sample can confirm this good thermalisation.

TT 16.41 Mon 15:00 P2/EG

Investigating the Non-equilibrium Dynamics of two-level systems at Low Temperatures — •Marcel Haas, Andreas Reiser, Andreas Fleischmann, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University, 69120 Heidelberg

The dielectric loss of amorphous materials along with noise and decoherence is the major limiting factor in many applications like superconducting circuits, Josephson junctions and quantum computing. It is mainly determined by atomic tunneling systems described by quantum mechanical two-level systems (TLS) leading to a broad distribution of low-energy excitations in the sample. The spontaneous phonon emission of an excited TLS gives rise to a relaxation time T_1 and the interaction between TLSs with their thermally excited surrounding induces a dephasing timescale T_2. These effects mainly determine the measurable dielectric loss in the observed material, which we ascertain by measuring the quality factor of a bridge type superconducting LC-resonator. The dielectric medium in between the capacitor plates is a sputter deposited $a\text{-}SiO_2$ film. A variation of the Rabi-frequency through the electric field strength of the drive can thereby change the transition probability of the TLSs and thus the influence of loss generating effects. The experimental setup additionally allows the application of a DC to AC electric bias field across the capacitance. This enables us to manipulate the occupation difference of the TLSs by shoving new unexcited TLSs through resonance which restores the influence of decoherence. We present first measurements at a frequency of 1 GHz performed with a microfabricated superconducting resonator.

TT 16.42 Mon 15:00 P2/EG

Machine learning for quantum chemistry with quantum computers — •Tomislav Piskor[1,2], Sebastian Zanker[1], Thilo Mast[1], Peter Schmitteckert[1], Frank Wilhelm-Mauch[2], and Michael Marthaler[1] — [1]HQS Quantum Simulations GmbH, Haid-und-Neu-Straße 7, 76131 Karlsruhe — [2]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

Simulating chemical systems is a major field of interest not only for the pharma and chemistry, but also for the automotive industry. One such example is the simulation of functional groups of a large molecule or proteine, which can be useful for QM/MM methods. In order to get the exact ground state of the functional group, we can use quantum computers in the future. However, every call to a quantum computer will be relatively expensive, making high-throughput simulations with quantum computers unfeasible.

To bypass this, we propose the following scheme: a few single point calculations are determined with the quantum computer and then extended to more conformations with machine learning methods. We use sGDML (symmetric gradient domain machine learning), where the atomic coordinates of the molecules are given as the input and the corresponding forces as the output. A modified Gaussian kernel is then used in order to obtain the trained force fields and by performing an integration with respect to the atomic coordinates one gets the potential energy surface. This routine was tested on molecules such as enediyne and malonaldehyde, where we observe very good results not only for the force field, but also energy predictions.

TT 16.43 Mon 15:00 P2/EG

Influence of the nuclear quadrupolar interactions in periodically driven quantum dots — •Iris Kleinjohann and Frithjof Anders — Lehrstuhl für Theoretische Physik II, Technische Universität Dortmund, 44227 Dortmund

Periodic optical driving of the electron spin in singly charged semiconductor quantum dots generates a spin polarization and induces a synchronization of the spin dynamics with the driving frequency. An external magnetic field perpendicular to the optical axis results in the Larmor precession of electron and nuclear spins of the quantum dot ensemble. While the electron spin precession adjusts to the periodicity of optical pumping, the synchronization is transmitted to the surrounding nuclear spins via hyperfine interaction generating a non-equilibrium distribution of the Overhauser field. We describe the spin dynamics by a central spin model and employ a Lindblad equation for the time evolution between optical pulses. Due to the growth process of the quantum dot sample a strain occurs in the quantum dots entailing quadrupolar interactions in the nuclear spin bath. We extend the central spin model to include these interactions and show that the influence on the synchronization with the periodic driving depends strongly on the parameters of the quadrupolar interactions.

TT 16.44 Mon 15:00 P2/EG

Effect of an RKKY interaction between electron spins in different quantum dots on their spin dynamics — •Kira Deltenre and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

Two-colored pump-probe experiments on self-assembled InGaAs quantum dots with spectrally narrow pump pulses allow to excite disjunct subsets of quantum dots. The observed correlations between the spin polarizations of the subsets suggest an interaction between the electron spins in the different quantum dots (Spatzek et al., Phys. Rev. Lett. **107**, 137402 (2011)). The observed phase shift between the measured ellipticities depends on the time delay between the two differently colored pump pulses. For our simulation, we assume an RKKY interaction transmitted via the wetting layer of the sample. The calculations of the spin dynamics are based on the central spin model. A semiclassical approach enables a simulation of a large number of quantum dots ($Q > 1000$). The extracted time dependent phase shifts are qualitatively similar to the experimental data for a specific set of parameters entering the distance dependent RKKY interaction strength.

TT 16.45 Mon 15:00 P2/EG

Bose condensation of squeezed light — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics-UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

Light with an effective chemical potential and no mass is shown to possess a general phase-transition curve to Bose-Einstein condensation. This limiting density and temperature range is found by the diverging in-medium potential range of effective interaction. While usually the absorption and emission with Dye molecules is considered, here it is proposed that squeezing can create also such an effective chemical potential. The equivalence of squeezed light with a complex Bogoliubov transformation of interacting Bose system with finite lifetime is established with the help of which an effective gap is deduced. This gap phase creates a finite condensate in agreement with the general limiting density and temperature range. The phase diagram for condensation is presented due to squeezing and the appearance of two gaps is discussed. Phys. Rev. B 99 (2019) 205124

TT 16.46 Mon 15:00 P2/EG

A sustainable sub-Kelvin cooling technology for quantum electronics — •Klaus Eibensteiner[1,2], Jan Spallek[1], Alexander Regnat[1], Tomek Schulz[1], Felix Rucker[1], Nico Huber[1,2], Carolina Burger[1,2], Anh Tong[1,2], and Christian Pfleiderer[2] — [1]kiutra GmbH, München, Germany — [2]Physik-Department, Technische Universität München, Germany

Cooling devices providing temperatures well below 1 K are a key prerequisite for basic research and quantum technologies. Commercially available cooling solutions typically require either the rare and costly helium isotope helium-3 or provide cooling only for a limited period of time. Here we present a compact demagnetization refrigerator for the cryogen-free, continuous generation of sub-Kelvin temperatures based on prevalent and affordable solid-state cooling media.

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Development and characterization of a small scale two-stage pulse tube cryocooler — •Bernd Schmidt[1,2], Jack-André Schmidt[1,2], Jens Falter[2], Günter Thummes[1,2], and André Schirmeisen[1,2] — [1]Justus-Liebig Universität Gießen, Germany — [2]TransMIT GmbH, Gießen, Germany

Small scale pulse tube cryocoolers with input powers < 2 kW are a valuable alternative for liquid Helium cryostats, especially for long time measurements. In this input power regime, Helium compressors with air cooling and single phase power supply are commercially available, lowering the requirements for the measuring environment. Also, since pulse tube cryocoolers are closed cycle systems, the refilling of cryogen is not needed, leading to long running intervals of up to several years and less usage of Helium gas, which is consistently suffering of shortages [1].

In this poster, we present the development process of a new 4 K two-stage pulse tube cryocooler with an input power of about 1 kW [2]. The cryocooler reaches temperatures of < 2.5 K and provides a cooling power of > 70 mW at liquid Helium temperature. The cryocooler was simulated using Sage and Regen simulation environments. Afterwards it was fabricated, tested and optimized using a SHI CNA-11 Helium compressor with about 1 kW input power. A cooling load map was measured to characterize the system.

[1] Halperin, William P., Nature Physics 10.7 (2014): 467.
[2] Schmidt, B., et al., Cryogenics 88 (2017): 129-131.

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Construction of mK-scanning tunneling microscope combined with electron spin resonance technique — •Won-Jun Jang[1,2], Jinkyung Kim[1,2], Thi Hong Hong[1,2], Denis Krylov[1,2], and Andreas Heinrich[1,2] — [1]Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul 03760, Republic of Korea — [2]Ewha Womans University, Seoul 03760, Republic of Korea

For a well-defined energy resolution of STM combined with electron spin resonance (ESR) technique, the lowering the effective temperature is necessary. Here we present technical efforts for the construction of mK-STM with the lowest effective temperature under ESR measurement. To reduce the effective temperature, we need to be lower a base temperature of inner conductor of RF signal lines, RF noises and the eddy current effect by external vibration. We achieved 10 mK using the dilution refrigerator (Janis research) with STM supporting structures made by SiPCu. We applied the thermal anchoring structure for RF signal lines. To reduce RF noises, we are planning to use RF filter at each signal line. To prevent the external vibration, we designed the pendulum structure for the circulation line for mixture gas and two vibration isolation stages. And also, we applied the slit structure to reduce the eddy current. Finally, we will introduce our effective temperature by the measurement of superconducting gap.