TT 19: Superconductivity: Poster Session

Time: Monday 15:00–18:00 Location: Poster D

TT 19.1 Mon 15:00 Poster D

Superconductivity in the high-pressure phase of bismuth — •Philip A. C. Brown, Konstantin Semeniuk, and F. Malte Grosche — Department of Physics, Cavendish Laboratory, University of Cambridge, UK

At pressures above 27 kbar, elemental bismuth adopts a highly unusual incommensurate host-guest structure. This structure combines two distinct, interpenetrating crystal lattices and consequently lacks discrete translational symmetry. Although similar high pressure structures have been observed in other elements, their electronic properties have not been investigated in detail. The moderate pressure required to induce the host-guest phase in bismuth presents a favourable opportunity for comprehensive electrical transport studies.

The high-pressure host-guest phase of bismuth, termed Bi-III, is known to be superconducting with a transition temperature of around 7 K, but the details of its superconducting and normal state properties are comparatively little explored. We report resistivity and magnetisation measurements in the Bi-III phase in fields up to 9 T and temperatures down to 120 mK. We find evidence for a strikingly high critical field and an unusual temperature dependence of the resistivity above the superconducting transition. We discuss our findings in the context of theoretical descriptions of host-guest materials.

TT 19.2 Mon 15:00 Poster D

Co-sputtered MoRe as carbon nanotube growth-compatible superconductor — •Karl Götz, Stefan Blien, Peter Stiller, Ondrej Vavra, Thomas Mayer, Thomas Huber, Thomas Meier, Matthias Kronseder, Christoph Strunk, and Andreas Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93053 Regensburg, Germany

Molybdenum rhenium alloys exhibit superconducting transition temperatures up to 15 K as well as high critical current densities. In addition, the thin films are stable under typical carbon nanotube CVD growth conditions, i.e., a hydrogen/methane atmosphere at 900 °C, and form good contacts in nanotube overgrowth. This makes them predestined for experiments integrating "ultraclean" carbon nanotube devices into coplanar radiofrequency circuits, towards quantum nanoelectromechanics and information processing. MoRe thin films are deposited via co-sputtering of two separate targets. The resulting thin film composition and its controllability is verified via XPS spectroscopy both before and after undergoing nanotube growth conditions. The effects of the high temperature process on surface oxides, carbon content, superconducting critical temperature, magnetic field, and current are characterized. Selecting an optimized alloy composition, we define coplanar waveguide resonators, demonstrating resonant behaviour after CVD at $f \approx 3 \ldots 4$ GHz and up to $Q_\mathrm{i} \approx 5000$. Modelling device properties via Mattis-Bardeen theory combined with substrate two-level systems leads to good agreement with the data.

TT 19.3 Mon 15:00 Poster D

Magnetic field dependent microwave spectroscopy on superconducting Pb stripline resonators — •Nikolaj G. Ebensperger, Markus Thiemann, Martin Dressel, and Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569 Stuttgart, Germany

Planar superconducting resonators have multiple applications, e.g. in quantum information processing or spectroscopy on unconventional solids. Here, Pb can be used as a basis of microwave resonators with a critical temperature of 7.2 K and a critical magnetic field of 80 mT. It shows interesting behavior with residual normal conducting areas after entering the superconducting phase with applied external magnetic field.

We present a study of superconducting Pb microwave stripline resonators in variable external magnetic field up to 140 mT and a temperature range of 1.6 K to 6.5 K. We are able to determine the complex conductivity of Pb in variable magnetic field and we find striking similarities to measurements in variable temperature, like a coherence peak. The quality factor of the resonances shows strong hysteresis effects after exceeding the critical magnetic field, indicating residual normal conducting areas in the resonator persisting in the superconducting state. We are able to determine the critical magnetic field for a set of given temperatures both for the Pb resonator as well as a Sn sample placed on top of the underlying Pb resonator. These results demonstrate that Pb resonators can be applied for different spectroscopy studies in zero as well as finite magnetic field.

TT 19.4 Mon 15:00 Poster D

Microwave study of superconducting Sn films above and below percolation — •Manfred H. Beutel, Nikolaj G. Ebensperger, Markus Thiemann, Gabriele Untereiner, Martin Dressel, and Marc Scheffler — 1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70569, Germany

The electronic properties of superconducting Sn films ($T_c \approx 3.7$ K) change significantly when lowering the film thickness down to a few nm, in particular at the percolation threshold. The low energy electrodynamics of such Sn samples can be probed via microwave spectroscopy, e.g. with superconducting stripline resonators.

We have deposited Sn films by thermal evaporation, ranging in thickness between 38 nm and 842 nm, and we characterized their morphology by AFM. We use superconducting Pb stripline resonators to probe the microwave response of Sn films at temperatures from 7.5 K down to 1.5 K in a frequency range between 1 GHz and 20 GHz. The measured quality factor of the resonators decreases with increasing temperature due to increasing losses. As a function of the sample thickness we observe three regimes with significantly different properties: Samples below percolation exhibit dielectric properties with negligible losses, demonstrating that macroscopic current paths are required for appreciable dynamical conductivity of Sn at GHz frequencies. Thick Sn films, on the other hand, lead to low-loss resonances above and below T_c of Sn, but in an intermediate thickness regime, just above percolation, the metallic state of the Sn films is too lossy for resonator operation whereas the superconducting state only has low microwave losses.

TT 19.5 Mon 15:00 Poster D

Superconducting coplanar resonators with frequencies up to 50 GHz — •Markus Thiemann[1], Desirée Rausch[1], Martin Dressel[1], Daniel Bothner[2], Reinhold Kleiner[2], Dieter Koelle[2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart — [2]Physikalisches Institut and Center for Quantum Science in LISA$^+$,Universität Tübingen

Planar superconducting microwave resonators are widely used, e.g. in the field of quantum information technology, but usually at frequencies well below 20 GHz. Because of their high quality factor and therefore high sensitivity, superconducting planar resonators are very interesting probes for investigating the electronic properties of novel superconductors. The energy gap of superconductors with a $T_c < 1$ K lies within the GHz-regime. Hence, resonators covering a wide frequency range are desirable to perform measurements across the superconducting energy gap.

Therefore we have developed coplanar resonators, made of superconducting niobium ($T_c \approx 9.2$ K) on sapphire with operating frequencies up to 50 GHz. We show measurements performed on two different resonator designs with fundamental resonance frequencies of 2 GHz and 5 GHz, at ^{4}He temperatures. By measuring not only the fundamental mode, but also the higher harmonics, frequencies up to 50 GHz can be covered, showing quality factors exceeding 20000. To demonstrate the applicability of these resonators for spectroscopic measurements, we show measurements performed on bulk tin ($T_c \approx 3.7$ K), where the superconducting transition of tin can be observed up to 50 GHz.

TT 19.6 Mon 15:00 Poster D

Measuring the microwave response of superconducting Nb:STO and Ti at mK temperatures using superconducting resonators — •Markus Thiemann[1], Manfred Beutel[1], Martin Dressel[1], Evangelos Fillis-Tsirakis[2], Hans Boschker[2], Jochen Mannhart[2], and Marc Scheffler[1] — [1]1. Physikalisches Institut, Universität Stuttgart — [2]Max Planck Institute for Solid State Research, Stuttgart

Niobium doped $SrTiO_3$ is a superconductor, with the lowest charge carrier density among all superconductors. It shows a dome in the transition temperature as a function of doping concentration with a maximum $T_c \approx 0.3$ K . The superconducting dome may originate from the different bands being occupied depending on the doping level. The

low energy scales of the system, as indicated by the low T_c are within the GHz-regime. Therefore microwave measurements are a powerful technique to reveal the electronic properties of these superconductors.

We preformed microwave measurements on Nb:STO of different doping levels in a dilution refrigerator, using superconducting stripline resonators. Measurements were done in a temperature and frequency range from 40-400mK and 1-20GHz, covering the normal and superconducting states. For comparison we also measured the temperature dependence of the surface impedance of superconducting titanium ($T_c \approx 0.5$ K), which can be well described by the Mattis-Bardeen equations with a ratio $\frac{2\Delta}{k_B T_c} = 3.56$. Therefore titanium is an ideal reference sample representing a conventional BCS-superconductor.

TT 19.7 Mon 15:00 Poster D

Test for the presence of long-ranged Coulomb interactions in thin TiN films near the superconductor-insulator transition — •Klaus Kronfeldner[1], Tatyana Baturina[2], and Christoph Strunk[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]A. V. Rzhanov Institute of Semiconductor Physics SB RAS, Russia

We have measured the conductance of square shaped TiN films on the superconducting and the insulating side of the superconductor/insulator transition. The conductance shows thermally activated behaviour with an activation energy $k_B T_0(L) \propto \ln L$, with L being the lateral size of the squares. Such behavior is consistent with 2D long-ranged Coulomb interactions with a large electrostatic screening length $\Lambda \simeq 200\,\mu$m [1]. To independently test whether long ranged Coulomb interactions can be responsible for the observed size dependence we compare $R(T, B)$ of a large TiN film in the critical region with and without a screening Pd layer in a distance $t \approx 60$ nm to the TiN film. The screening Pd-layer is expected to reduce the activation energy from $\propto \ln[\min(L, \Lambda)]$ to $\propto \ln(t)$ and the thermally activated resistance in films with $L \gtrsim \Lambda$ by the large number $\Lambda/t \simeq 3000$. In contrast, our experiment showed no significant reduction of $R(T)$ and T_0. This suggests that the measured size dependent conductance of our TiN film is not related to long-ranged Coulomb interactions.

[1] M. V. Fistul, V. M. Vinokur, and T. I. Baturina, PRL **100**, 086805 (2008).

TT 19.8 Mon 15:00 Poster D

The Polar Kerr Effect in Superconductors — •Joshua Robbins, James F. Annett, and Martin Gradhand — University of Bristol, United Kingdom

The polar Kerr effect is an optical phenomenon which arises in states with broken time-reversal symmetry. This effect has recently been observed in a series of unconventional superconductors, including the layered perovskite compound Sr_2RuO_4[1]. Confirmation of a Kerr signal below T_c supports the hypothesis of chiral p-wave superconductivity in this material. However, the nature of the unconventional superconducting state remains a source of controversy.

Here, we present calculations for the chiral superconducting state including spin-orbit coupling (SOC) by extending the three dimensional, multiband model considered previously [2]. SOC was found to induce strong mixing of the orbital characters within the bandstructure. This mixing is essential for the existence of the polar Kerr effect and the large increase due to SOC has a significant influence on the frequency dependence of the predicted Kerr signal.

We will extend and apply the model to other unconventional superconductors which have displayed the Kerr effect in recent years [3]. This will allow a detailed study of the symmetry properties of these systems and will provide valuable insight into the pairing mechanism of superconductors.

[1] J. Xia *et al.*, PRL **97**, 167002 (2006)
[2] M. Gradhand *et al.*, PRB., **88**, 094504 (2013)
[3] A. Kapitulnik *et al.*, NJP **11**, 055060 (2009)

TT 19.9 Mon 15:00 Poster D

Spin susceptibility and magnetic instability in Spin-Orbit Coupled system of Sr_2RuO_4 — Sergio Cobo[1], Ilya Eremin[2], and •Alireza Akbari[1] — [1]Asia Pacific Center for Theoretical Physics, Pohang, Gyeongbuk 790-784, Korea — [2]Theoretische Physik III, Ruhr-Universität Bochum - D-44780, Bochum, Germany

Although the Stronthium Ruthenate compound has been known for more than two decades, there are some major features, which still remain unknown. Mainly, it is still not clear what is the Cooper pairing mechanism and why it can be a triplet superconductor. These features turn out to be even more striking when considering the similarity of its crystal structure and that of the high-T_c cuprates. We analyzed the magnetic response of Sr_2RuO_4 under the presence of a strong spin-orbit coupling interaction. We found very remarkable anisotropies in the different components of the spin susceptibility. This finding strongly suggest that the Cooper instability may be driven by magnetic fluctuations and that spin orbit coupling is much more important than expected in this regard. Furthermore, we think there must be a relation between this interesting behavior and the fact that the stronthium ruthenate chooses the triplet-pairing channel when reaching the superconducting state.

TT 19.10 Mon 15:00 Poster D

Quasiparticle interference in heavy fermion superconductors: role of the slab geometry — •Fabian Lambert[1], Alireza Akbari[3,4], Peter Thalmeier[5], and Ilya Eremin[1,2] — [1]Institute für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Germany — [2]Institute of Physics, Kazan (Volga Region) Federal University, 420008 Kazan, Russian Federation — [3]Asia Pacific Center for Theoretical Physics (APCTP) — [4]Department of Physics, and Max Planck POSTECH Center for Complex Phase Materials, POSTECH, Pohang 790-784, Korea — [5]Max Planck Institute for the Chemical Physics of Solids, D-01187 Dresden, Germany

We analyze theoretically the quasiparticle interference in the heavy fermion superconductors $CeCoIn_5$ and UPt_3 as a direct method to investigate the gap symmetry. In contrast to the prior attempts that computed QPI patterns for some effective two-dimensional models or by perfoming calculations for varous k_z cuts and then averaging the final result, we perfom the calculations for the three-dimensional models in the slab geometry and investigate possible effects of the finite sample size, topology, and surface termination. Comparing with the results of prior analysis of the bulk system we can conclude on the importance of the possible surface states for determining the QPI pattern.

TT 19.11 Mon 15:00 Poster D

Magnetic properties of $La_{2-x}Sr_xCuO_4$: LDA+(C)DMFT study — •Amin Kiani and Eva Pavarini — Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

High temperature superconductivity in hole-doped cuprates is one of the most intriguing phenomena discovered in strongly correlated materials. In the normal phase, hole-doping causes the gradual destruction of antiferromagnetism and, in some cases, the appearance of incommensurate magnetic instabilities. In this work we study the magnetic properties of one of the representative family of materials, $La_{2-x}Sr_xCuO_4$. We calculate the static lattice spin susceptibility $\chi(\mathbf{q}, T)$ by using the local density approximations+dynamical mean field theory (LDA+DMFT) approach and the local vertex approximation. We discuss the results as a function of doping in the interval $0 \leq x \leq 0.4$ and investigate the non-local effects on $\chi(\mathbf{q}, T)$ via the cellular DMFT (CDMFT) approach.

TT 19.12 Mon 15:00 Poster D

Overgrowth of cracks in $YBa_2Cu_3O_{6+\delta}$-thin films grown on $SrTiO_3$- and Al_2O_3-substrates — •Kai Ackermann, Jens Hänisch, and Bernhard Holzapfel — Institut für Technische Physik, Karlsruher Institut für Technologie, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen

High temperature superconducting materials like REBCO-thin films offer a wide range of applications like superconducting transformers, cables, coils or fault current limiters. Although the number of applications is increasing the REBCO-coated conductor length is still limited due to substrate and thin film fabrication defects. In order to improve the manufacturing processes of REBCO-coated conductors the growth behavior of REBCO-thin films on defective or broken substrate surfaces has to be understood. Therefore we investigated the structural and electronic properties of YBCO-thin films grown on cracked $SrTiO_3$- and Al_2O_3-substrates. The YBCO-films were prepared by using metalorganic (MOD) and pulsed laser deposition (PLD). Structural and electronic properties of the YBCO-films were investigated by using x-ray diffractometry, atomic force microscopy, scanning electron microscopy and temperature- and magnetic field-dependent conductivity measurements.

TT 19.13 Mon 15:00 Poster D

Measurements of the magnetic vortex lattice in the noncentrosymmetric superconductor Ru_7B_3 — •Yuliia Tymoshenko[1], Alistair Cameron[1], Geetha Balakrishnan[2], Monica Ciomaga Hatnean[2], Don McK. Paul[2], and Dmytro

Inosov[1] — [1]Institut für Festkörperphysik, TU Dresden, D-01069 Dresden, Germany — [2]Department of Physics, University of Warwick, Coventry, CV47AL, United Kingdom

The noncentrosymmetric (NCS) superconductor Ru_7B_3 has a hexagonal structure within the [001] plane. NCS superconductors are of significant interest to the condensed matter community, as their crystal structure breaks inversion symmetry, leading to novel superconducting states with unusual properties. Such states associated with NCS superconductors have been predicted to have a significant effect on the vortex lattice (VL) within these materials. We investigated a large single crystal of Ru_7B_3 by small-angle neutron scattering (SANS). Our goal was to explore the possible influence of the NCS crystal structure on the VL order. During our measurements at the D33 SANS diffractometer at the Laue-Langevin Institute (ILL) in Grenoble, France we clearly observed the formation of VL in Ru_7B_3. The VL maintains its orientation and remains isotropic within the whole studied field and temperature range, implying a similar degree of isotropy in the SC parameters. An unusual VL rotation with decreasing field at base temperature was seen for field parallel to the (100) direction.

TT 19.14 Mon 15:00 Poster D

Interplay of SDW and iCDW order in iron-based superconductors: role of spin-orbit coupling — •Felix Ahn, Felix Lochner, and Ilya Eremin — Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany

We study the interplay of SDW and iCDW order in iron-based superconductors and find that both orders couple to each other due to spin-orbit coupling. Most importantly, we analyze the influence of the CDW formation on the competition between various magnetic phases in iron-based superconductors.

TT 19.15 Mon 15:00 Poster D

Superfluid density and superconducting transition temperature in dirty iron-based superconductors — •Thomas Hartmann, Felix Ahn, and Ilya Eremin — Ruhr-Universität Bochum, Bochum, Deutschland

Measurements on optimally electron doped $LaFeAsO_{1-x}F_x$ samples under pressure up to $\sim$ 23 kbar reveal a clear mutual independence between the critical temperature T_c and the ratio of superfluid density over effective band mass of Cooper pairs n_s/m^*. The ratio increases about $\sim$ 30% at the maximum pressure whereas T_c remains constant, which clearly implies a breakdown of the Uemura relation in $LaFeAsO_{1-x}F_x$ [1]. Here we analyze theoretically this effect by taking into account the effect of nonmagnetic impurities in a multiband superconductor. We show that the ratio between intra-band and inter-band scattering rates can explain the behaviour of the observables under pressure by only acting on structural parameters while the amount of chemical disorder is still constant.
[1] G. Prando *et al.*, PRL **114**, 247004 (2015)

TT 19.16 Mon 15:00 Poster D

Spin response in LiFeAs and NaFeAs iron-pnictides superconductors — •Felix Lochner, Felix Ahn, and Ilya Eremin — Ruhr-Universität Bochum, Bochum, Deutschland

We analyze the spin susceptibility in LiFeAs and NaFeAs by using the ten-orbital tight-binding model that we fitted to the electronic band structure measured by recent ARPES experiments. We identify an effective five-band model for a weak k_z-dependence. Besides we present the bare and RPA-susceptibility and its q_z dependencies to study the magnetic instabilities and estimate the strength of intra-orbital and inter-orbital nesting.

TT 19.17 Mon 15:00 Poster D

Electronic correlations in the superconductors $A\mathbf{Fe_2As_2}$ with A = K, Rb, and Cs — •Sebastian Kuntz[1], Felix Eilers[1], Kai Grube[1], Diego A. Zocco[1], Peter Schweiss[1], Rolf Heid[1], Thomas Wolf[1], Peter Adelmann[1], and Hilbert von Löhneysen[1,2] — [1]Karlsruhe Institute of Technology, Institut für Festkörperphysik, 76021 Karlsruhe, Germany — [2]Karlsruhe Institute of Technology, Physikalisches Institut, 76131 Karlsruhe, Germany

The stoichiometric iron-pnictide superconductors AFe_2As_2 exhibit a diverging effective mass of the normal-conducting quasiparticles with increasing alkali-metal ion radius R_A. This divergence suggests the proximity to a quantum phase transition (QPT) at negative pressures. We have performed thermal expansion, magnetostriction and magnetization measurements to characterize the normal and superconducting properties. We determined the phase diagrams as a function of the magnetic field parallel and perpendicular to the c axis. The measurements reveal the presence of several bands. The quasi-two-dimensional electronic structure of these layered materials leads to a Pauli limitation of the superconductivity for fields perpendicular to the c axis. The influence of the nearby QPT will be discussed and compared with the behavior of other related Fe-based superconductors.

TT 19.18 Mon 15:00 Poster D

Crystal growth and characterization of $\mathbf{SrFe_2(As_{1-x}P_x)_2}$ — •Fryni Baglatzi, Agnes Adamski, and Cornelius Krellner — Physikalisches Institut, Goethe Universität Frankfurt am Main, D-60438, Frankfurt am Main

The discovery of iron-based superconductors brought new excitement to the field of unconventional superconducting (SC). Most studied are the so called (122 compounds), the AFe_2As_2 with A=Ba, Sr or Ca . An important point is, that different substitution series reveal different temperature-concentration phase diagrams, including varying SC order parameters and coexistence regions of magnetism and SC.

The crystal growth of $SrFe_2As_2$ can be achieved by using the self-flux technique. However, exact melting temperatures of various flux to composition ratios are not reported in literature. We determined the melting points for various flux concentrations, using differential thermal analysis (DTA) in order to find out the pseudo binary phase diagram. Furthermore, crystal growth was conducted on the phosphorous doped series. Our samples were analyzed with scanning electron microscope, energy dispersive x-ray analysis and powder diffractometry, in order to determine the phase relations and distribution coefficients.

TT 19.19 Mon 15:00 Poster D

Magnetism and Superconductivity in $\mathbf{LaFeP_{1-x}As_xO}$ — •Sirko Kamusella[1], Rajib Sarkar[1], Hubertus Luetkens[2], Setsuko Tajima[3], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [3]Department of Physics, Osaka University, Osaka 560-0043, Japan

The $LaFeP_{1-x}As_xO$ series bridges the gap between two parent compounds, whose Fermi surfaces differ in dimensionality and position of hole pockets. The resulting phase diagram consists of a superconducting two-dome structure separated by a novel AFM2 magnetic phase [1,2]. Electron doping by (O,F) substitution allows to investigate superconductivity in the full x-range.

^{57}Fe Mössbauer spectroscopy successfully depicts the temperature dependence of the tiny 0.1 μ_B magnetic moment in the AFM2 phase and its rigidity in applied field; with the help of a line width reference absorber. This uncommon approach makes Mössbauer measurements competitive to other local probe methods such as NMR or μSR.

μSR measurements can prove the long range character of this novel AFM2 phase and show the continuous change from a nodal to a nodeless symmetry of the superconducting order parameter upon substitution of P by As. AFM spin fluctuations suggested by NMR before [2] did not become evident in μSR decoupling experiments.
[1] K.T. Lai *et al.*, PR **90**, 064504 (2014)
[2] S. Miyasaka *et al.*, J. Phys. Soc. Jpn. **82**, 124706 (2013)

TT 19.20 Mon 15:00 Poster D

Scanning tunneling microscopy on bulk FeSe — •Jonas Dressner, Jasmin Jandke, Thomas Wolf, and Wulf Wulfhekel — Karlsruhe Institut of Technology, Germany

We used high-resolution scanning tunneling spectroscopy to study bulk FeSe at temperatures down to 30 mK. At this temperature, highly resolved spectra of the quasiparticle density of states could be measured showing multiple superconducting gaps. This is in agreement with the multiband character of this system. Furthermore, features of bosonic excitations are observed in the measured quasiparticle density of states and will be discussed.

TT 19.21 Mon 15:00 Poster D

Epitaxial growth of Fe-based superconductor thin films — Sven Meyer, •Jens Hänisch, and Bernhard Holzapfel — Institut für Technische Physik, Karlsruher Institut für Technologie, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

The Fe-based superconductors (FBS), discovered in 2008, are not only interesting for possible applications due to their large upper critical fields and low anisotropies, but also for basic understanding of un-

conventional superconductivity. With their properties, they constitute a link between the classic low-T_c superconductors (low anisotropies, low thermal fluctuations, s-wave type symmetry) and the oxocuprates (T_c up to 55 K, large H_{c2}, unconventional pairing). Their multi-band nature reminds of MgB_2. We prepare thin films of FBS in the so called 122 family, namely Co- and P-doped $BaFe_2As_2$ to investigate application relevant properties, such as critical current density J_c, by pulsed laser deposition using a frequency-tripled Nd:YAG laser (λ = 355 nm). Microstructure and chemical composition will be investigated by XRD, AFM and SEM, and electrical transport using a 14 T PPMS. The results are compared to literature data on films grown at different wavelengths [1].

[1] H. Hiramatsu et al., APL **104**, 172602 (2014)

TT 19.22 Mon 15:00 Poster D

Physical Properties of Off-Stoichiometric LiFeAs — •Uwe Gräfe[1], Shiv Jee Singh[1], Robert Beck[1], Hans-Joachim Grafe[1], Sabine Wurmehl[1,3], Christian Hess[1,2], and Bernd Büchner[1,3] — [1]IFW Dresden, Institut für Festkörperforschung, Postfach 270116 01171 Dresden — [2]Center for Transport and Devices, TU Dresden, 01169 Dresden — [3]Institut für Festkörperphysik, TU Dresden, 01062 Dresden

It is known that small modifications on the stoichiometry of LiFeAs have high impact on the physical properties in the normal and superconducting state. Here we present a systematic study on the Li-Fe-As system by XRD, NQR and resistivity. We synthesized samples with different nominal compositions of Li, Fe and As by solid state reaction and show that, besides stoichiometric LiFeAs, only enriching the system with Fe forms phase pure samples. The modifications due to this enrichment can be tracked by a shift of the NQR-frequency and the lattice constants. Thus NQR can be taken as a measure for the changes induced by additional Fe in Li-Fe-As. We further show that these changes are not only decreasing T_c but also cause a sudden reduction of normal state resistivity and electron-electron scattering. Altogether we therefore conclude that Fe has a charge doping effect on Li-Fe-As.

TT 19.23 Mon 15:00 Poster D

Dynamic properties of $Ca_{10}(Pt_3As_8)(Fe_{1-x}Pt_xAs)_{10}$ in the superconducting state explored by NMR in high fields — •Felix Brückner[1], Rajib Sarkar[1], Arneil P. Reyes[2], Philip L. Kuhns[2], Maksym Surmach[1], Dmytro Inosov[1], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, TU Dresden, Dresden, Germany — [2]National High Magnetic Field Laboratory, Tallahassee, Florida, USA

The triclinic iron-based superconductor $Ca_{10}(Pt_3As_8)(Fe_{1-x}Pt_xAs)_{10}$ with a T_c of 13 K exhibits a unique pseudogap phase below $T^* = 45$ K, recently probed with inelastic neutron scattering. This phase has been attributed to a possible preformation of Cooper pairs. We present detailed NMR results, including ^{75}As and ^{195}Pt spectra as well as T_1 measurements. These experiments reveal a drop of spin fluctuations just below T^* with a hysteresis in temperature, associated with the emergence of the pseudogap phase. Interestingly, no anomaly at T_c is found. At 3 K, a peak in the T_1 relaxation rate appears, until $1/T_1$ eventually vanishes at lower temperatures. This behavior is persistent in large magnetic fields up to 17 T. To interpret these results, scenarios including magnetic order below T^* are quite unprobable, since Korringa law is well complied at higher temperatures and no magnetic order is found in μSR. However, the origin of the unique behavior remains unclear for now.

TT 19.24 Mon 15:00 Poster D

Crystal growth of YFe_2Ge_2 and the dependence of its superconducting properties on sample preparation — •Jiasheng Chen[1], Konstantin Semeniuk[1], Zhuo Feng[2], Pascal Reiss[1], Philip Brown[1], Giulio Lampronti[3], and Malte Grosche[1] — [1]Cavendish Lab., Cambridge, UK — [2]London Centre of Nanotechnology, UCL, London, UK — [3]Dept. of Earth Sciences, Cambridge, UK

The d-electron system YFe_2Ge_2 exhibits an unusually high Sommerfeld ratio of specific heat capacity of C/T $\sim$ 100 mJ/(molK^2), signaling strong electronic correlations. Evidence of superconductivity has been reported in polycrystals and in flux-grown single crystals [1] with residual resistance ratios (RRR) of the order of 50, but these samples show no thermodynamic signatures of a bulk superconducting transition. We find that by combining (i) a prereaction of YFe_2, (ii) careful control of nominal composition, and (iii) subsequent annealing procedures, the polycrystalline YFe_2Ge_2 samples grown using a radio-frequency (RF) induction furnace can reach RRR values $\sim$ 200 with resistive superconducting transitions temperatures of around 1.85 K. This new generation of sample displays clear heat capacity anomalies as well as nearly 100% diamagnetic screening, confirming the bulk nature of its superconductivity.[2] We present details of the sample preparation and characterization and discuss the correlation between nominal composition and superconductivity.

[1] Y. Zou *et al.*, Physica Status Solidi (RRL) **8**, 928 (2014)
[2] J. Chen *et al.*, arXiv:1507.01436v2.

TT 19.25 Mon 15:00 Poster D

Superconductors in Non–Equilibrium: Higgs Oscillations and Induced Superconductivity — •Nikolaj Bittner[1], Holger Krull[1,2], Andreas Schnyder[1], Takami Tohyama[3], and Dirk Manske[1] — [1]Max–Planck–Institut für Festkörperforschung, D–70569 Stuttgart, Germany — [2]Lehrstuhl für Theoretische Physik, Technische Universität Dortmund, D–44221 Dortmund, Germany — [3]Department of Applied Physics, Tokyo University of Science, Tokyo 125–8585, Japan

Nonequilibrium pump–probe time–domain spectroscopy opens new perspectives in studying the dynamical properties of the strongly correlated electron systems. In particular, new effects, such as transient superconductivity [1] or Higgs oscillations of the superconducting condensate [2], can be obtained. Using various methods we present a theoretical study of the nonequilibrium dynamics in superconductors. Firstly, within the framework of the density matrix formalism we study Higgs oscillations in superconductors, which allow to detect the properties of the superconducting condensate as a function of time. For two–band superconductors the interplay between the phase (Leggett) and amplitude (Higgs) modes is analyzed in detail and new predictions are made. Secondly, employing the time–dependent Lanczos algorithm to the one–dimensional extended Hubbard model we observe appearance of a transient Meissner effect, which is a fingerprint of the induced superconductivity.

[1] S. Kaiser et al., PRB **89** , 184516 (2014)
[2] R. Matsunaga et al., PRL **111**, 057002 (2013)

TT 19.26 Mon 15:00 Poster D

Topological surface currents in chiral d-wave superconductors — •Wenbin Rui and Andreas P. Schnyder — Max-Planck-Institut für Festkörperforschung

Motivated by the locally non-centrosymmetric superconductor SrPtAs, the surface states of a multi-band chiral d-wave superconductor are investigated by using a tight-binding model which exhibits two point nodes. These gap closing points realize Weyl nodes that are protected by a nonzero Chern number. The nontrivial topology of this chiral d-wave superconductor manifests itself at the surface in terms of zero-energy arc states that connect the projected Weyl points in the surface Brillouin zone. By self-consistently solving Bogoliubov-de Gennes equations, we determine the spin and orbital character of the surface states. Moreover, we compute the spontaneous spin and charge currents at the surface of the superconductor, which arise due to the nontrivial topology and the strong spin-orbit interaction. We find that the currents are coupled to the chirality of the superconductor and show that they give rise to a small spin polarization at the surface, which could be measured by scanning SQUID microscopy.

TT 19.27 Mon 15:00 Poster D

Casimir forces between two impurities in a lattice — Dmitry Efremov[1], •Andrei Pavlov[1], and Jeroen van den Brink[1,2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, Germany — [2]Department of Physics, Technical University Dresden, Dresden, Germany

We considered an interaction of impurities due to phonon exchange, leading to a long-range interaction, which behaves like Casimir forces. The contribution of virtual phonons is calculated by exact diagonalization of phonon operators on finite-sized lattices and by consideration of diagrams, describing exchange of phonons up to the second order of the perturbation theory, in an inverse space independently. The obtained results are consistent with good precision. The phonon interaction leads to attraction of impurities, but it is not strong enough for causing phase separation of the impurities inside a lattice both at zero and non-zero (but still small) temperatures.

TT 19.28 Mon 15:00 Poster D

Magneto-optical Kerr-effect at low temperatures: Investigation of superconductor/ferromagnet heterostructures —

•Patrick Zahn[1,2], Claudia Stahl[1], Stephen Ruoss[1], Joachim Gräfe[1], Jonas Bayer[1,2], Gisela Schütz[1], and Joachim Albrecht[2] — [1]Max Planck Institute for Intelligent Systems, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]Institute for Innovative Surfaces FINO, Aalen University, Beethovenstraße 1, 73430 Aalen, Germany

With XMCD microscopy it is possible to visualize the critical current density of the superconductor YBCO with high spatial resolution [1,2]. Therefore, soft magnetic CoFeB is introduced as sensor layer. The magnetic stray fields of the supercurrents lead to a local reorientation of the magnetic moments in the ferromagnet, which are then imaged via X-ray microscopy. These experiments have to be carried out at the scanning x-ray microscope MAXYMUS at the synchrotron Bessy II in Berlin. For that purpose pre-characterization of the sensor is highly desirable: Magnetic interactions between the superconductor and the ferromagnetic sensor layer have been investigated at low temperatures using Kerr-effect measurements. Therefore hysteresis loops are obtained by a sophisticated magnet and field ramping setup within the NanoMOKE3 system [3]. The results are used to optimize the ferromagnetic sensor layer for XMCD microscopy of superconductors.

[1] C. Stahl et al., PRB **90**, 104515 (2014)
[2] S. Ruoß et al., APL **106**, 022601 (2015)
[3] J. Gräfe et al., Rev. Sci. Instrum. **85**, 023901 (2014)

TT 19.29 Mon 15:00 Poster D

Boosting the superconducting spin valve effect in a metallic superconductor/ferromagnet heterostructure — •Pavel Leksin[1,2], Andrey Kamashev[2], Joachim Schumann[1], Vladislav Kataev[1], Jürgen Thomas[1], Bernd Büchner[1,3], and Ilgiz Garifullin[2] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, D-01171 Dresden, Germany — [2]Zavoisky Physical-Technical Institute, Russian Academy of Sciences, 420029 Kazan, Russia — [3]Technical University Dresden, D-01062 Dresden, Germany

We demonstrate a crucial role of the morphology of the superconducting layer for the operation of the multilayer S/F1/F2 spin valve. For that, we studied two types of superconducting spin valve heterostructures, with a rough and with a smooth superconducting layer, respectively, with transmission electron microscopy in combination with transport and magnetic characterization. We have found that the quality of the S/F interface is not critical for the S/F proximity effect as regards the suppression of the critical temperature of the S layer. However, it appears to be of a paramount importance for the performance of the S/F1/F2 spin valve. The magnitude of the conventional superconducting spin valve effect significantly increases, when the morphology of the S layer is changed from the type of overlapping islands to a smooth one. We attribute this drastic effect to a homogenization of the Green function of the superconducting condensate over the S/F interface in the S/F1/F2 valve with a smooth S layer surface.

TT 19.30 Mon 15:00 Poster D

Microwave spectroscopy and electronic transport properties of ferromagnetic Josephson junctions and superconducting spin-valves — Marcel Thalmann, Marcel Rudolf, and •Torsten Pietsch — Zukunftskolleg & Department of Physics, University of Konstanz, Universitätsstraße 10, 78464 Konstanz, Germany

Hybrid superconducting nanostructures recently attracted tremendous interest, due to their great potential in dissipation-less spin-electronics with unprecedented switching rates. The practical realisation of such devices, however, requires a complete understanding of the transfer and dynamics of spin- and charge currents between superconducting (S) and ferromagnetic (F) circuit elements, as well as the coupling between spin- and charge degrees of freedom in these systems. We investigate novel transport phenomena in superconductor-ferromagnet hybrid nanostructures under non-equilibrium conditions. Microwave spectroscopy is used to elucidate fundamental questions related to the complex interplay of competing order parameters and the question of relaxation mechanisms of non-equilibrium distributions with respect to spin, charge and energy. Recent experiments on two complimentary device structures are discussed: I) in diffusive S/F/S Josephson junctions with non-sinusoidal current-phase relationship and II) local and non-local transport measurements and microwave spectroscopy in F/S/F lateral spin-valves.

TT 19.31 Mon 15:00 Poster D

Superconducting Spin-Triplet-MRAM with Infinite Magnetoresistance Ratio — •Daniel Lenk[1], Roman Morari[1,2,3], Vladimir I. Zdravkov[1,2,4], Aladin Ullrich[1], Günter Obermeier[1], Claus Müller[1], Anatoli S. Sidorenko[2], Hans-Albrecht Krug von Nidda[1], Siegfried Horn[1], Lenar R. Tagirov[1,3], and Reinhard Tidecks[1] — [1]Institut für Physik, Universität Augsburg, D-86159 Augsburg, Germany — [2]D. Ghitsu Institute of Electronic Engineering and Nanotechnologies ASM, Academiei Str. 3/3, MD2028 Kishinev, Moldova — [3]Solid State Physics Department, Kazan Federal University, 420008 Kazan, Russia — [4]Present Address: Institute of Applied Physics and Interdisciplinary Nanoscience Center, Universität Hamburg, Jungiusstraße 9A, D-20355 Hamburg, Germany

We fabricated a nanolayered hybrid superconductor-ferromagnet spin-valve structure, i.e. the superconducting transition temperature of this structure depends on its magnetic history. The observed spin-valve effect is based on the generation of the long range odd in frequency triplet component, arising from a non-collinear relative orientation of the constituent ferromagnetic layers. We investigated the effect both as a function of the sweep amplitude of the magnetic field, determining the magnetic history, and the applied transport current. Moreover, we demonstrate the possibility of switching the system from the normal o the superconducting state by applying field pulses, yielding an infinite magnetoresistance ratio.

TT 19.32 Mon 15:00 Poster D

Measurement of the Magnetic Penetration Depth in p-Doped Superconducting Diamond Films — •Lorenz Fuchs[1], Markus C.P. Brunner[1], Ina Schneider[1], Klaus Kronfeldner[1], Jessica Bousquet[2], Etienne Bustarret[2], and Christoph Strunk[2] — [1]University of Regensburg — [2]Institut Néel, Grenoble

Boron-doped diamond becomes superconducting once a critical doping concentration of $4.5 \times 10^{20} cm^{-3}$ is reached [1]. Mutual inductance measurements with a two-coil setup have been performed to determine the magnetic penetration depth $\lambda(T)$, which is a measure for the superfluid stiffnes $\theta \sim 1/\lambda^2(T)$. Two superconducting p-doped diamond films with thicknesses of 145nm and 345nm were investigated. At low temperatures these values agree reasonably with the values expected within BCS-theory using T_c, carrier density and mean free path determined from electric transport measurements. Magnetic penetration depths of $3.7\mu m$ for the thinner and $2.6\mu m$ for the thicker film have been found. λ decreases and accordingly θ increases with increasing film thickness. On the other hand, the superfluid stiffness drops by a factor of 2 or even more at $T_c/2$, i.e., much faster than expected from BCS-theory, but remains finite between $T_c/2 < T < T_c$. At present it is unclear, whether this behavior results from the proliferation of phase fluctuations already far below T_c or from a spatial inhomogeneity of the films.

TT 19.33 Mon 15:00 Poster D

Spin-dependent thermoelectric effects in superconductor-ferromagnet tunnel junctions — Stefan Kolenda[1], Christoph Sürgers[2], and •Detlef Beckmann[1] — [1]Institut für Nanotechnologie, Karlsruher Institut für Technologie — [2]Physikalisches Institut, Karlsruher Institut für Technologie

Recently, large thermoelectric effects were predicted to occur in superconductor-ferromagnet tunnel junctions with a spin-splitting of the density of states [1]. We have reported on the observation of these effects in samples where the spin splitting was induced by an applied magnetic field [2]. Here, we show results on samples where the spin splitting is enhanced by exchange coupling to the ferromagnetic insulator europium sulfide.

[1] Machon et al., PRL **110**, 047002 (2013);
Ozaeta et al., PRL **112**, 057001 (2014).
[2] Kolenda et al., arXiv:1509.05568.

TT 19.34 Mon 15:00 Poster D

Scanning tunneling spectroscopy to probe odd-triplet contributions to the long-ranged proximity effect in Al-EuS — •Simon Diesch[1], Christoph Sürgers[2], Detlef Beckmann[2], Peter Machon[1], Wolfgang Belzig[1], and Elke Scheer[1] — [1]Universität Konstanz, Konstanz, Germany — [2]Karlsruhe Institute of Technology, Karlsruhe, Germany

Experiments on superconductor-ferromagnet-systems have shown Cooper pairs tunneling through ferromagnetic layers, indicating Cooper pairs of equal spin, thus corresponding to a long-range triplet proximity effect [1]. Most experimental evidence for triplet superconductivity comes from observations of the thickness dependence of the Josephson current through a ferromagnetic barrier, but there is an

increasing interest in obtaining direct spectroscopic evidence [2].

This project aims to analyze the DOS of thin films of the ferromagnetic insulator europium sulfide on superconducting aluminum or vice versa, using a scanning tunneling microscope in spectroscopy mode at 280 mK and in varying magnetic fields. We observe significant broadening of the superconducting energy gap and a variety of sub-gap structures induced by the presence of the ferromagnet and interpret our findings based on the diffusive theory [3,4]

[1] F. S. Bergeret, PRL **86**, 4096 (2001)
[2] F. Hübler, PRL **109**, 87004 (2012)
[3] P. Machon, PRL **110**, 047002 (2013)
[4] J. Linder, PRB **81**, 214504 (2010)

TT 19.35 Mon 15:00 Poster D

Superconducting Atom Chips — Christoph Hufnagel[2], Deshui Yu[2], Chin Chean Lim[2], Alessandro Landra[2], Chee Howe Ew[2], and •Rainer Dumke[1,2] — [1]Division of Physics & Applied Physics, School of Physical & Mathematical Sciences, Nanyang Technological University, Singapore — [2]Centre for Quantum Technologies, National University of Singapore, Singapore

Recently superconducting atom chips have generated a lot of interest due to their attractive properties, such as the Meissner effect for type-I superconductors and vortices for type-II superconductors. Thermaland technical noise in proximity to superconducting surfaces have been shown both theoretically and experimentally to be significantly reduced compared to conventional atom chips. Superconducting atom chips have the potential to coherently interface atomic and molecular quantum systems with quantum solid state devices. I will present recent developments in our superconducting atom chip experiment.

TT 19.36 Mon 15:00 Poster D

Interplay between Superconductivity and Coulomb Blockade — •Thomas Lorenz, Susanne Sprenger, and Elke Scheer — Universität Konstanz, Germany

Studying the interplay between superconductivity and Coulomb blockade (CB) can be achieved by investigating an all superconducting single electron transistor (SSET) consisting of an island coupled to the leads by two tunneling contacts. The majority of experiments performed so far were using superconducting tunnel contacts made from oxide layers, in which multiple Andreev reflections (MAR) can be excluded.

Using a mechanically controlled break junction (MCBJ) made of aluminum enables tuning the contributions of MAR in one junction continuously and thereby addressing different transport regimes within the same sample. Our results offer the possibility to attribute particular features in the transport characteristics to the transmission probabilities of individual modes in the MCBJ contact. We discuss our findings in terms of dynamical CB, SSET behaviour and MAR when continuously opening the MCBJ from the fully closed state to a tunneling contact.

TT 19.37 Mon 15:00 Poster D

Proximity effect and Andreev reflection in single-C_{60} junctions — •Jonathan Brand, Nicolas Néel, and Jörg Kröger — Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany

Single C_{60} molecules deposited on an ultrathin oxide film on Nb(110) were investigated using a low-temperature scanning tunnelling microscope. Spectroscopy of the differential conductance (dI/dV) in the tunnelling range indicates proximity-induced superconductivity in junctions comprising the oxide layer as well as single C_{60} molecules. Andreev reflection is enhanced upon controlled fabrication of tip-surface contacts. With decreasing electrode separation the Bardeen-Cooper-Schrieffer energy gap gradually evolves into a zero-bias peak in dI/dV spectra reflecting the spectroscopic signature of Andreev reflection. The current-voltage characteristics of the tunnelling and contact junctions are well described by the Blonder-Tinkham-Klapwijk theory. Our spectroscopic data evidence the influence of the electrodes' atomic-scale structure on electron transport across normal metal-superconductor interfaces.

Funding by the Deutsche Forschungsgemeinschaft through KR 2912/10-1 is acknowledged.

TT 19.38 Mon 15:00 Poster D

Perturbation theory for a single-level quantum dot connected to superconducting leads — •Vladislav Pokorný[1], Martin Žonda[2], Václav Janiš[1], and Tomáš Novotný[2] — [1]Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 18221 Praha, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University in Prague, Ke Karlovu 5, 12116 Praha, Czech Republic

The zero-pi quantum phase transition in a single-level quantum dot attached to two superconducting leads is studied via the perturbation expansion in the interaction strength. We use the Nambu formalism and the standard many-body diagrammatic representation of the impurity Green functions to formulate the self-consistent perturbation expansion. We show that at zero temperature second order of the expansion in its spin-symmetric version yields a good agreement with the numerical renormalization group calculations for the position of the phase boundary as well as for the parameters in the zero phase. We present results for phase diagrams, level occupation, induced local superconducting gap, Josephson current and energy of the Andreev bound states. We also show the agreement of the second order perturbation method with the existing experimental data.

TT 19.39 Mon 15:00 Poster D

Towards quantum signatures in a swept-bias Josephson junction — •Harald Losert, Karl Vogel, and Wolfgang P. Schleich — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm, Germany

Josephson junctions are one of the best examples for the observation of macroscopic quantum tunneling. The phase difference in a current-biased Josephson junction behaves like the position of a particle in a tilted washboard potential. The escape of this phase-particle corresponds to the voltage switching of the associated junction.

Quantum mechanically, the escape from the washboard potential can be explained as tunneling from the ground state, or an excited state. However, it has been shown [1][2], that in the case of periodic driving the experimental data for quantum mechanical key features, e.g. Rabi oscillations or energy level quantization, can be reproduced by a completely classical description.

Motivated by this discussion, we investigate a swept-bias Josephson junction in the case of a large critical current. In particular, we contrast the switching current distributions resulting from a quantum mechanical and classical description of the time evolution.

[1] M. Marchese *et al.*, Eur. Phys. J. Special Topics **147**, 333 (2007)
[2] J. A. Blackburn *et al.*, PRB **85**, 104501 (2012)

TT 19.40 Mon 15:00 Poster D

Low frequency dielectric properties of amorphous AlO_x — •Arnold Seiler, Saskia Meissner, Hannes Rotzinger, and Georg Weiss — Physikalisches Institut, Karlsruher Institut für Technologie

Tunneling systems (TS) are well known to dominate the low temperature properties of amorphous and disordered solids. In superconducting circuits they interact with resonators and qubits and limit their quality factors and coherence times.

We go further and want to know, whether the TS in the dielectric material used in these circuits were distributed according to the standard tunneling model. Therefore we investigate different plate capacitor geometries containing the same dielectric AlO_x as used in qubits. With resonators and large capacitors we cover a broad frequency range to probe the dielectric response of the TS.

Here we present the low frequency measurements on capacitors of 0.25 mm^2 and 1 mm^2 down to 15 mK. Surprisingly the application of a magnetic field leads to a dramatic change of the dielectric response. In respect to glasses a similar effect is known the elastic response of from superconducting metallic glasses but was not expected in the dielectric behavior of an insulating material.

TT 19.41 Mon 15:00 Poster D

Dielectric susceptibility measurements of amorphous AlO_x using superconducting resonators — •Saskia Meissner, Arnold Seiler, Hannes Rotzinger, and Georg Weiss — Physikalisches Institut, KIT Karlsruhe

The performance of superconducting circuits like Quantum Bits, SQUIDs and resonators is well known to be limited due to dielectric loss caused by tunneling systems (TS). They are a source of noise, energy loss and decoherence due to their coupling to electric fields.

Measurements of individual TS coherently coupled to a Josephson Junction (JJ) already indicate their broad energy distribution in the range of qubit frequencies.

Here we present measurements of the low temperature dielectric re-

sponse of thin film AlO_x in a wide frequency range in order to extract the spectral distribution of TS for a comparison with the standard tunneling model. AlO_x films are fabricated in the same way as those of JJ implemented as plate capacitors. Direct capacitance measurements and selected resonances of lumped element superconducting resonators offer excitation frequencies from the kHz range up to the GHz range where superconducting quantum circuits are commonly operated.

TT 19.42 Mon 15:00 Poster D

NbN-AlN-NbN Josephson junctions on different substrates — •Michael Merker, Christian Bohn, Marvin Völlinger, Konstantin Ilin, and Michael Siegel — KIT, Karlsruhe, Deutschland

Josephson junction technology is important for the realization of high quality cryogenic devices such as SQUIDs, RSFQ or SIS-mixers. The material system based on NbN/AlN/NbN tri-layer has gained a lot of interest, because it offers higher gap voltages and critical current densities compared to the well-established Nb/Al-AlOx/Nb technology. However, the realization of high quality Josephson junctions is more challenging. We developed a technology of Josephson junctions on a variety of substrates such as Silicon, Sapphire and Magnesium oxide and compared the quality parameters of these junctions at 4.2 K.The gap voltages achieved a range from 4 mV (for the junctions on Si) to 5.8 mV (in case of MgO substrates) which is considerably higher than those obtained from Nb based Josephson junctions. Another key parameter is the ratio of the subgap resistance to the normal state resistance. This so-called subgap ratio corresponds to the losses in a Josephson junction which have to be minimized. So far, subgap ratios of 26 have been achieved. Further careful optimization of the deposition conditions is required to maximize this ratio, The details of the optimization of technology and of characterization of NbN/AlN/NbN junctions will be presented and discussed.

TT 19.43 Mon 15:00 Poster D

Investigation of a Josephson junction based parametric amplifier — •Patrick Winkel[1], Martin Weides[1,2], and Alexey V. Ustinov[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe — [2]Materials Science in Mainz, Johannes Gutenberg-Universität Mainz, 55128 Mainz

We design, fabricate and experimentally investigate a parametric amplifier based on the nonlinear inductance of Josephson junctions. Our design is rather conventional and based on a strongly coupled coplanar waveguide quarter-wave resonator terminated by a SQUID. The SQUID inductance depends periodically on the enclosed magnetic flux inside the loop. This tunable nonlinear inductance is used to adjust the resonance frequency of the whole device. We replace the single SQUID with a series array of SQUIDs to decrease the effective nonlinearity and to increase the dynamic range without affecting the bandwidth. The required pump tone is introduced through a separate flux line by applying an rf-drive. For a critical pump power and detuning between pump and resonance frequency, the system reaches a bifurcation regime. Close to this critical point, the response of the system is highly sensitive to small perturbations, which are intentionally introduced by the signal fed into the amplifier.

TT 19.44 Mon 15:00 Poster D

Dual-circuit Hamiltonian construction for superconducting elements in high-impedance environments — •Jascha Ulrich and Fabian Hassler — JARA-Institute for Quantum Information, RWTH Aachen University

Devoret has popularized a simple and easy-to-use recipe for the Hamiltonian description of arbitrary superconducting circuits involving nonlinear Josephson inductances in terms of node fluxes. In the last years, phase slip elements, nonlinear capacitors electromagnetically dual to the Josephson inductances, have attracted a lot of interest. Unfortunately, Devoret's construction cannot be applied directly to circuits involving nonlinear capacitors. Here, we give a simple dual formulation of Devoret's recipe in terms of loop charges which is well suited for the description of phase slip elements and is particularly timely in view of recent experimental advances in their realization using superconducting nanowire. However, we argue that our construction is not restricted to phase slip elements, but more generally useful for the effective description of Josephson junctions embedded in high-impedance environments. As an example, we illustrate how our formalism can give new physical insights and facilitate the phenomenological modeling of the fluxonium qubit and the 0-π qubit.

TT 19.45 Mon 15:00 Poster D

Josephson junctions array resonators — •Oscar Gargiulo, Phani Muppalla, Iman Mirzaei, and Gerhard Kirchmair — Institute for Quantum Optics and Quantum Information, Innsbruck, Austria

We present an experimental analysis of the self- and cross-Kerr effect of extended plasma resonances in Josephson junction chains. The chain consists of 1600 individual junctions and we can measure quality factors in excess of 10000. The Kerr effect manifests itself as a frequency shift that depends linearly on the number of photons in a resonant mode. By changing the input power we are able to measure this frequency shift on a single mode (self-kerr). By changing the input power on another mode while measuring the same one, we are able to evaluate the cross-kerr effect. We can measure the cross-Kerr effect by probing the resonance frequency of one mode while exciting another mode of the array with a microwave drive.

TT 19.46 Mon 15:00 Poster D

Single crystal $Bi_2Sr_2CaCu_2O_8$ structures as THz-emitters — •Raphael Wieland[1], Fabian Rudau[1], Julian Langer[1], Nickolay Kinev[2], Jie Yuan[3], Ya Huang[3,4], Min Ji[3,4], Xianjing Zhou[3,4], Akira Ishii[3], Peiheng Wu[4], Takeshi Hatano[3], Huabing Wang[3,4], Valery Koshelets[2], Dieter Koelle[1], and Reinhold Kleiner[1] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, Universität Tübingen, Tübingen, Germany — [2]Kotel'nikov Institute of Radio Engineering and Electronics, Moscow, Russia — [3]National Institute for Materials Science, Tsukuba, Japan — [4]Research Institute of Superconductor Electronics, Nanjing University, Nanjing, China

By means of Josephson Junctions (JJs) one can easily convert a dc voltage into high-frequency electromagnetic radiation. The high-Tc superconductor $Bi_2Sr_2CaCu_2O_8$ (BSCCO) has a layered crystal structure in such a way that JJs form intrinsically. This allows to fabricate hundreds of stacked junctions with reasonable effort. Terahertz emission can be observed at relatively low bias currents but also at higher input power. Emission frequencies from 0.4 to 2.4 THz have been measured. A hot spot forms at high bias currents with effect on both intensity and linewidth of the THz emission.BSCCO mesas probably act as a cavity for electromagnetic standing waves that synchronize all junctions in the stack. We investigated hotspot formation and THz emission using a combination of transport measurements, low temperature scanning laser microscopy and electromagnetic wave detection via a superconducting receiver.

TT 19.47 Mon 15:00 Poster D

Development of RF-SETs for error detection in single electron pumps — •David Reifert, Niels Ubbelohde, Ralf Dolata, Thomas Weimann, and Alexander Zorin — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig. Germany

Semiconductor single electron pumps allow the controlled transport of electrons with a frequency f (about 1 GHz) which results in a current ($I = e \times f$) in the range of about 0.1 nA. However, since the pumping mechanism is prone to errors due to the stochastic nature of the transport mechanism, the accuracy of these devices is limited (0.2 ppm at the moment). We developed a method to detect and account the errors of these pumps. To realize this error detection we integrate several electron pumps in a serial circuit with intermediate charge nodes between them, so the pumping errors can be detected by monitoring the charge of the nodes. As ultra-sensitive charge detectors we used superconducting Al single electron transistors (SETs) capacitively coupled to the intermediate nodes. To increase the readout bandwidth of the SET and, therefore detect errors at relatively high rate, we put the SETs in resonant tank circuits and measured the reflectance from these resonators. With such an integrated device we can achieve a significant improvement in accuracy. The measurement setup and the progress of counting measurements with such a RF-SET will be reported.

TT 19.48 Mon 15:00 Poster D

Microfabricated Thick Proximity Bi-layers as Sensors for Magnetic Penetration Thermometers (MPTs) — •Jeschua Geist, Daniel Hengstler, Andreas Fleischmann, Loredana Gastaldo, Sebastian Kempf, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University, Germany

Microcalorimeters with inductively coupled temperature sensors like metallic magnetic calorimeters (MMC) are widely used for many applications.Whereas MMCs use dilute paramagnetic alloys as temperature

sensors operated at temperatures below 30 mK, magnetic penetration depth thermometers (MPT) make use of the steep temperature dependence of the magnetic penetration depth of a superconducting sensor, potentially offering improved temperature sensitivity at higher and hence easier accessible temperature. Operated below T_c of the sensor material, the temperature change upon the absorption of an X-ray in the detector leads to a change of the magnetic flux density $B(\mathbf{r})$ inside the superconducting sensor and in its vicinity which is detected using a SQUID and serves as a measure of the absorbed energy.

So far we studied the elemental superconductors, Hf, Ir, Ti, Al, Nb, and recently thick proximity bilayers of Al and Au, promising a large range of operational temperatures. We also demonstrated that the penetration of flux lines and the hysteresis of the magnetisation can be engineered by patterning the superconducting sensor layer in form of discs or stripes. We present data on thick bilayers, allowing to tune not only T_c, but also the transition width and therefore the dynamic range, with various geometries and corresponding numerical simulations.

TT 19.49 Mon 15:00 Poster D

Fabrication of the 4k-Pixel Molecule Camera MOCCA and its Integration into the Cryogenic Storage Ring CSR — •L. Gamer[1], C. Enss[1], A. Fleischmann[1], L. Gastaldo[1], S. Kempf[1], C. Krantz[2], O. Novotný[2], D. Schulz[1], and A. Wolf[2] — [1]Heidelberg University — [2]MPIK Heidelberg

The Cryogenic Storage Ring at the Max Planck Institute for Nuclear Physics in Heidelberg is able to store heavy molecular ions in their rotational and vibrational ground states. In a near future electron-ion-interactions, such as the dissociative recombination, will be investigated in laboratory environment at conditions that are close to those in cold interstellar plasmas. To reconstruct the full kinematics of these processes, a position and energy sensitive coincident detection of multiple reaction products is necessary. We recently designed and fabricated MOCCA, a 4k-pixel molecule camera based on magnetic calorimeters with a detection area of 45 mm × 45 mm segmented into 64×64 absorbers. We present the detector design and microfabrication as well as the plans for integrating MOCCA and its ^{3}He/^{4}He dilution refrigerator into CSR.

TT 19.50 Mon 15:00 Poster D

Microwave SQUID multiplexing of large MMC detector arrays — •M. Keller, M. Wegner, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University

Metallic magnetic calorimeters (MMCs) are the devices of choice for many spectroscopic applications since they provide a very good energy resolution, a very fast intrinsic signal rise time as well as an excellent linearity. While single MMCs or small detector arrays are typically read out by dc-SQUIDs, the readout of very large arrays requires a cryogenic multiplexing technique to limit the parasitic heat load to the cold stage of the cryostat, the system complexity as well as cost.

A very promising approach for the readout of very large MMC arrays is microwave SQUID multiplexing. Here, the initial detector signal is transduced into a resonance frequency shift of a related superconducting $\lambda/4$ microwave resonator by means of a non-hysteretic, unshunted rf-SQUID. By coupling many resonators - each with unique resonance frequency - to a common transmission line, this frequency domain multiplexing technique allows for the readout of hundreds or thousand pixels with only one HEMT amplifier and two coaxial cables.

In this contribution we discuss the performance of a recently developed 64 pixel MMC detector array that is read out by means of an on-chip multiplexer. For the very first time we demonstrate the simultaneous readout of two MMCs by means of a microwave SQUID multiplexer.

TT 19.51 Mon 15:00 Poster D

Dc-SQUIDs for the readout of magnetic microcalorimeters — •Anna Ferring, Andreas Fleischmann, Mathias Wegner, Sebastian Kempf, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Heidelberg, Germany.

Two-stage current-sensing dc-SQUIDs are presently the devices of choice to read out single-channel magnetic microcalorimeters (MMCs) since they provide quantum-limited noise performance, large system bandwidth and are compatible with operation temperatures well below 100 mK. However, it is very well known that parasitic inductances in the SQUID input circuitry lead to a reduction of the signal size of the detector and that SQUID noise often sets a limit to the energy resolution. In order to minimize these effects, we develop two-stage current-sensing dc-SQUIDs optimized for MMC readout as well as dc-SQUIDs suited for direct temperature sensor readout.

In this contribution we discuss our SQUID designs including single second-order gradiometric SQUIDs, N-SQUID series arrays as well as SQUIDs with meander-shaped SQUID inductance that are eligible for direct temperature sensor readout. We show that our SQUIDs exhibit exceptional small low-frequency excess flux noise and are hence very well suited for MMC readout. We further present an integrated setup in which detector and SQUID are located on the same chip to maximize the coupling efficiency of the superconducting flux transformer. Finally, we discuss experimental data of a detector setup with direct temperature sensor readout and prove that this strategy should allow for reaching a sub-eV energy resolution.

TT 19.52 Mon 15:00 Poster D

Metallic Magnetic Calorimeters for high resolution X-ray spectroscopy — •M. Krantz, D. Hengstler, C. Schötz, M. Keller, J. Geist, P. Schneider, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — KIP Heidelberg University.

We develop microfabricated, energy dispersive particle detector arrays based on metallic magnetic calorimeters (MMCs) for high resolution x-ray spectroscopy to challenge bound-state QED predictions. Our MMCs are usually operated below 30 mK and use a paramagnetic temperature sensor placed in a weak magnetic field, read-out by a SQUID, to measure the energy deposited by single x-ray photons. We discuss the physics of MMCs, their microfabrication and the detector performances of three detector arrays together with the cryogenic setups used for their operation. Two of these arrays, maXs-20 and maXs-200, are linear 1x8 arrays optimized for x-rays with energies up to 20 and 200 keV respectively. maXs-20 achieved an energy resolution of 1.6 eV for 6 keV x-rays and maXs-200 achieved an energy resolution of 45 eV for 60 keV x-rays. Both detectors already allowed to investigate excellent physics in several labs around the world. The third detector, the maXs-30, is our first 2d 8x8 pixel array prototype with an active detection area of 16 mm^2 and is optimized for x-rays up to 30 keV with an expected energy resolution below 6 eV when operated at 10 mK in a cryogen free ^{3}He/^{4}He-dilution refrigerator at the tip of a 40 cm long cold finger.

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Optimization of metallic magnetic calorimeters with embedded ^{163}Ho — •Ch. Fischer[1], H. Dorrer[2], Ch. E. Düllmann[2], K. Eberhardt[2], Ch. Enss[1], A. Fleischmann[1], L. Gastaldo[1], C. Hassel[1], D. Hengstler[1], S. Hähnle[1], K. Johnston[3], S. Kempf[1], T. Kieck[2], M. Krantz[1], U. Köster[4], F. Schneider[2], A. Türler[5], M. Wegner[1], and K. Wendt[2] — [1]Kirchhoff-Institut für Physik, Heidelberg — [2]Johannes Gutenberg-Universität, Mainz — [3]Physics Department CERN, Geneva — [4]Institut Laue-Langevin, Grenoble — [5]Laboratory of Radiochemistry and Environmental Chemistry, Paul Scherrer Institut, Villigen

The Electron Capture in ^{163}Ho (ECHo) collaboration plans to reach sub-eV sensitivity on the electron neutrino mass by the analysis of high statistics of ^{163}Ho electron capture spectra. Large arrays of metallic magnetic calorimeters (MMCs) with enclosed ^{163}Ho read out using microwave SQUID multiplexing will be used for the measurement of the spectrum. With first prototypes of MMCs having the ^{163}Ho source ion-implanted in the absorbers, operated at 25 mK, an energy resolution $\Delta E_{FWHM} = 7.6$ eV and a signal rise time $\tau = 130$ ns have been achieved, paving the way to the first stage of the experiment (ECHo 1k). We present the optimization of MMCs and of the methods to embed the high purity ^{163}Ho source in detector absorbers. In particular we discuss how to define the optimal activity per pixel considering the limits coming from the allowed unresolved pileup fraction and from the additional contribution of detector heat capacity related to the magnetic moments of ^{163}Ho.

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Development of phonon and photon detectors for rare events searches using scintillating crystals — •Felix Ahrens[1], Christian Enss[1], Andreas Fleischmann[1], Loredana Gastaldo[1], Clemens Hassel[1], Sebastian Hendricks[1], Sebastian Kempf[1], Yong-Hamb Kim[2], Martin Loidl[3], Xavier-François Navick[3], and Matias Rodrigues[3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Deutschland — [2]Korea Research Institute of Standards and Science, Daejeon, Rep. of Korea — [3]Commissariat à l'énergie atomique, Saclay, France

The use of scintillating crystals in cryogenic experiments searching for neutrinoless double beta decay and for direct interaction of dark matter particles allows for an efficient background reduction due to particle discrimination. We develop phonon and photon detectors based on metallic magnetic calorimeters (MMCs) to perform simultaneous measurements of heat and light generated by the interaction of a particle in a scintillating crystal. As designed we expect for the phonon sensor an energy resolution of $\Delta E_{\mathrm{FWHM}} < 100\,\mathrm{eV}$ and a signal rise time $\tau < 200\,\mu\mathrm{s}$ whereas for the photon detector we expect $\Delta E_{\mathrm{FWHM}} < 5\,\mathrm{eV}$ and $\tau < 50\,\mu\mathrm{s}$. We discuss the design and the fabrication of these detectors and present recent results.

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Study of single-spiral superconducting nanowire single-photon detectors in magnetic fields — •Ilya Charaev[1], Robert Lusche[2], Alexei Semenov[2], Konstantin Ilin[1], and Michael Siegel[1] — [1]Institut für Mikro- und Nanoelektronische Systeme, KIT, Hertzstraße 16, 76187 Karlsruhe — [2]Institut für Optische Sensorsysteme, DLR, Rutherfordstraße 2, 12489 Berlin

We present single-spiral superconducting nanowire single-photon detectors (SNSPD) with critical currents I_c and detection efficiencies which were improved by applying a magnetic field B. The structures were made from 100 nm wide and 5 nm thick superconducting NbN nanowires. We investigated circular spirals and rectangular spirals, both with a pitch of 150 nm and superconducting transition temperature about 12 K. We achieved a more than 10 percent increase of the critical current in magnetic fields for rectangular spirals. Contrary, circular spirals showed fully symmetrical I_c(B) dependencies, with the maximum of I_c at zero field.

The detection efficiency of spirals has been studied in a wide spectral range and in magnetic fields up to 500 mT. In circular spirals, the rates of light and dark counts were symmetric in magnetic fields at all achievable experimental conditions. In rectangular spirals, photon count rates were asymmetric with the minima at opposite direction of the field than the maximum of I_c. Dark count rates in these structures also demonstrated asymmetric behavior with respect to the magnetic field for the whole range of applied bias currents.

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Influence of back reflections on the detection efficiency of superconducting nanowire single-photon detectors on GaAs — •Ekkehart Schmidt[1], Mario Schwartz[2], Thomas Herzog[2], Konstantin Ilin[1], Michael Jetter[2], Peter Michler[2], and Michael Siegel[1] — [1]Institut für Mikro- und Nanoelektronische Systeme (IMS), Karlsruher Institut für Technologie, Hertzstrasse 16, 76187 Karlsruhe, Germany — [2]Institut für Halbleiteroptik und funktionelle Grenzflächen (IHFG), Universität Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

In an on chip quantum photonic device, which consists of quantum dots, a waveguide based logic and a SNSPD, the quantum dots are conveniently excited by a laser beam. Backside reflection of these excitation photons can lead to their detection by the SNSPD and therefore to malfunction of the whole photonic circuit. We studied the effect of back reflections at the substrate/sample-holder interface on the detection properties of NbN SNSPDs on a GaAs substrate with a 12 nm AlN buffer layer. The SNSPDs have a width of 120 nm, a thickness of 6 nm, a critical temperature of 9.9 K and a critical current density of 2.8 MA/cm^2 at 4.2K. Two identical SNSPDs were fabricated from the same NbN film at a distance of 50 μm from each other. One of these SNSPDs was covered with a bi-layer of 20 nm thick AlN and 110 nm thick Al to prevent top illumination, making it only sensitive to backscattered photons. Results of the study of the influence of backscattered photons on the optical response of the SNSPDs and possibilities to avoid them will be discussed in detail.