TT 30: Superconductivity - Poster Session

Time: Monday 15:00–19:00 Location: P2

TT 30.1 Mon 15:00 P2

Sample size dependence of the Josephson behavior of the interfaces in pyrolytic graphite — Ana Ballestar and •Pablo Esquinazi — Division of Superconductivity and Magnetism, University of Leipzig, Leipzig, Germany

Transport properties of TEM lamella graphite samples with embedded interfaces show evidence for granular superconductivity at elevated temperatures [1]. We show that the observed transition temperature decreases linearly with the sample/interface width, and finally vanishes for width size below 200 nm. We discuss the possible origin for this size dependence in terms of weak localization in two dimensions as found in superconducting/normal multilayers [2]. Our results clarify the different temperature dependence of the resistance in bulk pyrolytic graphite samples as well as the difference in the temperature region where a Josephson critical behavior is measured in graphite TEM lamellae.

[1] A. Ballestar et al., New Journal of Phys., 15, 023024 (2013)
[2] J. Guimpel et al., J Low Temp Phys 63, 151 (1986)

TT 30.2 Mon 15:00 P2

Organic crystals: From semi- to superconductors — •Antonia Morherr, Sebastian Witt, Christian Klein, Jan-Peter Bäcker, and Cornelius Krellner — Physikalisches Institut, Goethe-Universität Frankfurt am Main, Deutschland

Intercalated aromatics became attractive in the last years as new class of organic superconductors [1]. Potassium-intercalated picene and phenanthrene showed superconducting transition temperatures of 18 and 5 K. Intercalated Dibenzopentacene reached a T_C of 33.1 K [2], Coronene T_Cs are between 3.5 K and 15 K [3]. So far, all experimental results are obtained on polycrystals, therefore the growth and investigation of single crystals of these materials are of importance for further research in superconductivity. We apply horizontal vapor growth and solution growth intercalation techniques for deeper understanding of the physical properties. Doping with potassium is achieved by co-crystallization and two zone gas transport. In this contribution, we present the physical and structural properties of intercalated single crystals and powder samples. To this end magnetization, resistivity and heat capacity was measured down to 1.8 K.

[1] R. Mitsuhashi et al., Nature 464, 76 (2010)
[2] M. Xue et al., Scientific Reports 2, 389 (2012)
[3] Y. Kubozono et al., Phys. Chem. Chem. Phys. 13, 16476 (2012)

TT 30.3 Mon 15:00 P2

Direct measurement of the magnetic anisotropy of thin sputtered MgB_2 films on MgO substrates in high magnetic fields — •Savio Fabretti[1], Inga-Mareen Imort[1], Timo Kuschel[1], Thomas Dahm[1], Andy Thomas[1,2], Veerendra K. Guduru[3], and Uli Zeitler[3] — [1]Bielefeld University, Bielefeld, Germany — [2]Johannes Gutenberg, Mainz, Germany — [3]Radboud University, Nijmegen, Netherlands

We investigated the magnetic anisotropy ratio of thin sputtered polycrystalline MgB_2 films on MgO substrates. Using high magnetic field measurements, we estimated an anisotropy ratio of 1.35 for T=0 K with an upper critical field of 31.74 T in the parallel case and 23.5 T in the perpendicular case. Direct measurements of a magnetic-field sweep at 4.2 K show a linear behavior, confirmed by a linear fit for magnetic fields perpendicular to the film plane. At an applied magnetic field parallel to the film plane, a deviation from the upper critical field of 3 T was observed by using magnetic sweep measurements; this deviation may be attributable to the different crystal sizes in the polycrystalline films. Furthermore, we observed a change of up to 12% of the anisotropy ratio in dependence of the film thickness.

TT 30.4 Mon 15:00 P2

High trapped fields in MgB_2 bulk samples — •Wolfgang Häßler[1], Günter Fuchs[1], Konstantin Nenkov[1], Juliane Scheiter[1], Axel Handstein[1], Bernhard Holzapfel[1,2], and Ludwig Schultz[1] — [1]Leibniz Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, P.O. Box 270116, 01171 Dresden — [2]Karlsruhe Institute of Technology (KIT), Institute for Technical Physics, P.O. Box 3640, 76021 Karlsruhe

MgB_2 is a promising superconductor for bulk trapped field magnets operating between 15 and 20 K. The absence of weak-link behavior in MgB_2 offers the advantage of a simple and cost-effective technique for fabrication of large bulks with high trapped fields. Bulk superconducting MgB_2 samples, 20 mm in diameter, were prepared by hot-pressing of high energy milled Mg and B powders using nanosized boron powders. High maximum trapped fields of 5.4 T were obtained at 12 K by Hall probe measurements at the centre of the bulk surface in one of the trapped field magnets (height 8 mm). For short MgB_2 samples (height 1.6 mm), trapped fields up to 3.2 T were achieved at 15 K. These high trapped fields are related to extremely high critical current densities up to $10^6 A/cm^2$ at 15 K indicating strong pinning due to nano-crystalline MgB_2 grains. The measured trapped field of 5.4 T at 12 K is the highest reported so far. By increasing height and/or diameter of these bulk MgB_2 samples, even higher trapped fields are expected which demonstrates the large potential of MgB_2 trapped field magnets in the field of engineering applications at temperatures between 15 and 20 K

TT 30.5 Mon 15:00 P2

Thick $BaHfO_3$ doped $YBa_2Cu_3O_{7-\delta}$ films on textured Ni-W tapes — •Max Sieger[1], Jens Hänisch[1], Kazumasa Iida[1], Uwe Gaitzsch[1], Christian Rodig[1], Rainer Nast[2], Ludwig Schultz[1], Bernhard Holzapfel[2], and Ruben Hühne[1] — [1]Institute for Metallic Materials, IFW Dresden, PO Box 27 01 16, D-01171 Dresden, Germany — [2]Institute for Technical Physics, Karlsruhe Institute of Technology (KIT), PO Box 36 40, D-76021 Karlsruhe

High-temperature superconductors grown on metallic tapes (coated conductors) might be used in a wide range of applications such as electric cables, MRI and fusion magnets. To achieve highest transport currents in magnetic fields, flux lines have to be immobilized by introducing nanoscaled pinning centres. In this study, we have prepared $YBa_2Cu_3O_{7-\delta}$ (YBCO) thick films (~ 1 μm) with different amounts of $BaHfO_3$ (BHO) on highly alloyed biaxially textured Ni-W tapes by pulsed laser deposition and discuss the effect of deposition parameters and BHO contents on the superconducting properties. X-Ray diffraction showed a good texture transfer from the nickel alloy tape via the buffer system to the superconducting layer. In general, a superconducting transition temperature T_c of about 88 K with a small transition width was determined. The incorporation of artificial pinning centres led to improved in-field critical current densities $J_c(\mu_0 H)$ and to an increase of the irreversibility field H_{irr}.

TT 30.6 Mon 15:00 P2

Ba_2YNbO_6 and Ba_2YTaO_6 doped $YBa_2Cu_3O_{7-\delta}$ films — •Lars Opherden[1], Jens Hänisch[1], Max Sieger[1], Marco Bianchetti[2], Judith MacManus-Driscoll[2], Ludwig Schultz[1], and Ruben Hühne[1] — [1]Institute for Metallic Materials, IFW Dresden, Dresden, Germany — [2]Department of Material Science and Metallurgy, University of Cambridge, Cambridge , UK

High-temperature superconductors might be applied in advanced electromagnets for the purpose of high field experiments. To realize such new types of superconducting magnets, the critical current density of high-temperature superconductors like $YBa_2Cu_3O_{7-\delta}$ (YBCO) needs to be improved. To achieve this goal, flux lines have to be immobilized in particular at the application temperature. Therefore, we introduce nanoscaled pinning centers applying YBCO targets mixed with different amounts of the secondary phases. The incorporation of Ba_2YNbO_6 and Ba_2YTaO_6 nanoparticles in the YBCO matrix leads to the formation of very fine self-assembled nanorods with significantly improved critical current densities $J_c(B,\theta)$[1,2]. To study this behavior in more detail, thin undoped and doped films were prepared on single crystalline substrates by pulsed laser deposition. X-ray diffraction and texture measurements were carried out to determine the crystal structure, whereas inductive and transport current measurements were performed to evaluate the superconducting properties T_c and $J_c(B)$ in different temperature regions.

[1] G. rcolano *et al.*, Supercond. Sci. Technol. **24** (2011) 095012
[2] S. A. Harrington *et al.*, Supercond. Sci. Technol. **22** (2009) 022001

TT 30.7 Mon 15:00 P2

Superconductivity in epitaxial Ru-doped $BaFe_2As_2$ thin films — •Marco Langer[1,2], Jan Engelmann[1,2], Vadim Grinenko[1], Eike Ahrens[2], Fabian Nitsche[3], Bernhard Holzapfel[1,4], Ludwig Schultz[1,2], and Ruben Hühne[1] — [1]Institute for Metallic Materi-

als, IFW Dresden, PO Box 270116, D-01171 Dresden, Germany — [2]Dresden University of Technology, D-01062 Dresden, Germany — [3]Ludwig-Maximilians-University Munich, Department of Chemistry, D-81377 Munich, Germany — [4]Karlsruhe Institute of Technology, Institute for Technical Physics, D-76344 Eggenstein-Leopoldshafen, Germany

The iron pnictide $BaFe_2As_2$ (Ba122) exhibits superconductivity either by carrier doping, chemical pressure, strain or external pressure. The key parameter for controlling the phase diagram of Ba122 is still under debate.

In order to investigate the driving factor of superconductivity in more detail we prepared thin Ba122 films with different ruthenium doping levels on single-crystal substrates using pulsed laser deposition. Structural investigations were carried out using θ-2θ x-ray diffraction and texture measurements revealing an epitaxial growth of the thin films. Electronic transport and SQUID-susceptibility measurements were performed to determine the electronic phase diagram. The results will be discussed in comparison to published phase diagrams for bulk materials.

TT 30.8 Mon 15:00 P2

Delta-doped $La_{2-x}(Sr,Ba)_xCuO_4$ thin films grown by oxide molecular beam epitaxy — •Christopher Dietl, Federico Baiutti, Meng Wu, Georg Cristiani, Gennady Logvenov, Eva Benckiser, and Bernhard Keimer — Max-Planck-Institute for Solid-State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

We investigate the possibility of delta-doping LCO thin films by replacing selectively LaO-layers by SrO or BaO. In this fashion, a modulated dopant distribution is created, which is predicted to enhance spin fluctuations and thus T_C [1]. The necessary atomic layer-by-layer growth capability is achieved with a state of the art Molecular Beam Epitaxy (MBE) setup allowing to grow films with typical surface roughnesses of $\approx$ 5Å. Oxidization of copper under high vacuum is performed via ozone. The growth is monitored in-situ by Reflection High Energy Diffraction (RHEED) for qualitative stochiometry control. Characterization is performed via XRD, XRR and AFM. The superlattices show superconductivity with the highest critical temperature being $T_c = 35$K.
[1] T. Jarlborg, Appl. Phys. Lett. 94, 212503 (2009)

TT 30.9 Mon 15:00 P2

Photo-induced quasipersistent modification of the normal and superconducting properties of niobium thin films — •Daniel Kohlberger[1], Daniel Bothner[1], Elisabeth Koroknay[2], Michael Jetter[2], Peter Michler[2], Reinhold Kleiner[1], and Dieter Koelle[1] — [1]Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, Universität Tübingen, Germany — [2]Institut für Halbleiteroptik und Funktionelle Grenzflächen and Research Center SCoPE, Universität Stuttgart, Germany

We report on the experimental investigation of resistive and superconducting transport properties of niobium thin films, which have been irradiated with an infrared laser at cryogenic temperatures. After irradiation, we find an increased normal state resistivity and a reduced transition temperature T_c to the superconducting state with respect to the values before irradiation. This photo-induced modification is completely reversible by raising the sample temperature to $T > 60$ K, but remains unchanged over large timescales at lower temperatures. In addition, we demonstrate that by a spatially periodic variation of the laser intensity across the niobium film, the reported effect can be used to generate a periodic pinning potential for Abrikosov vortices at $T < T_c$. This periodic potential is revealed by the occurrence of matching features in the dependence of the critical current I_c on an applied magnetic field B after laser irradiation. Finally, we discuss possible mechanisms of the observed effect.

TT 30.10 Mon 15:00 P2

Magneto-acoustic quantum oscillations in YNi_2B_2C — J. Nössler[1], •S. Yasin[1], S. Erfanifam[1], R. Seerig[1], G. Behr[2], S. Zherlitsyn[1], and J. Wosnitza[1] — [1]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung, D-01069 Dresden, Germany

Magneto-acoustic quantum oscillations in the type-II superconductor YNi_2B_2C (T_c=15.5 K) have been investigated providing information about the effective mass and Dingle temperature for selected electron orbits. Remarkably, the quantum oscillations in the sound velocity have been observed not only in the normal state but even below the upper critical field, $B_{c2} = 8.2$ T, down to 3.6 T. Torque measurements performed with the same sample have revealed a complete suppression of the dHvA oscillations below B_{c2}. The marginal additional damping of the acoustic oscillations observed in the mixed state suggests that the corresponding electron band does not contribute to the superconductivity. This additional damping can be ascribed to the field inhomogeneity in the Shubnikov phase. Angular dependent ultrasound experiments in static (up to 18 T) and pulsed (up to 61 T) magnetic fields applied in the (010) plane have revealed four frequencies observed as well in earlier torque measurements and predicted from band-structure calculations. A new unknown frequency of 6756 T has been resolved from the pulsed-field ultrasound experiments.

TT 30.11 Mon 15:00 P2

Strong coupling behavior of the neutron resonance mode in unconventional superconductors — •Patrik Hlobil, Boris Narozhny, and Jörg Schmalian — Karlsruhe Institute of Technology

We analyze whether and how the neutron resonance mode in unconventional superconductors is affected by higher order corrections in the coupling between spin excitations and fermionic quasiparticles and find that in general such corrections cannot be ignored. In particular, we find that in two spatial dimensions(d=2) the corrections are of same order as the leading, weak coupling contributions demonstrating that the neutron resonance mode in unconventional superconductors is a strong coupling phenomenon. The origin of this behavior lies in the quantum-critical nature of the low energy spin dynamics in the superconducting state and the feedback of the resonance mode onto the fermionic excitations. While quantum critical fluctuations occur in any dimensionality d<3, they can be analyzed in a controlled fashion by means of the epsilon-expansion (epsilon=3-d), such that the leading corrections to the resonance mode position are small. Even if higher order corrections are taken into account, the resonance mode emerges only if the phase of the superconducting gap function varies on the Fermi surface, making it a powerful tool to investigate the microscopic structure of the pair condensate.

TT 30.12 Mon 15:00 P2

Effect of reduced dimensionality on superconductivity in $CeCoIn_5$ probed by thermal expansion and magnetostriction measurements — •Kai Grube[1], Sebastian Zaum[1,2], Felix Eilers[1], Roland Schäfer[1], Eric D. Bauer[3], Joe D. Thompson[3], and Hilbert v. Löhneysen[1,2] — [1]Karlsruhe Institute of Technology, Institut für Festkörperphysik, 76021 Karlsruhe, Germany — [2]Karlsruhe Institute of Technology, Physikalisches Institut, 76131 Karlsruhe, Germany — [3]Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

In $CeCoIn_5$, a route towards reduced dimensionality is provided by an elongation of the unit cell along the c-axis. To determine the related strain dependences of T_c and B_{c2}, we measured thermal expansion and magnetostriction of $CeCoIn_5$ single crystals. The dependence of the strong-coupling parameter was estimated by the ratio between specific heat discontinuity at T_c and Sommerfeld coefficient. Our results show that B_{c2} grows with increasing c-axis lattice parameter due to an increase of the strong coupling nature of the superconductivity. This is in agreement with a recent study on artificial superlattices of alternating superconducting $CeCoIn_5$ and metallic $YbCoIn_5$ layers in which reducing dimensionality increases the ratio B_{c2}/T_c [1].
[1] Y. Mizukami et al., Nature Phys. 7, 849 (2011).

TT 30.13 Mon 15:00 P2

Strong electron-phonon coupling and the superconducting energy gap in $SrPt_3P$ — •Diego A. Zocco[1], Sven Krannich[1], Rolf Heid[1], Klaus-Peter Bohnen[1], Thomas Forrest[2], Alexei Bossak[2], and Frank Weber[1] — [1]Institute for Solid State Physics, Karlsruhe Institute of Technology, D-76021 Karlsruhe, Germany. — [2]European Synchrotron Radiation Facility, F-38043 Grenoble Cedex, France.

We present a study of the lattice dynamical properties of the recently discovered superconductor $SrPt_3P$ ($T_c = 8.4$ K) via high-resolution inelastic x-ray scattering performed on a polycrystalline sample. Previous specific-heat measurements reveal evidence for very strong coupling s-wave superconductivity ($2\Delta/k_BT_c \sim 5$) [1], consistent with our *ab initio* calculations which yield a large electron-phonon coupling constant $\lambda \sim 2$. Our data suggests that a softening of a low-energy phonon mode occurs as temperature is lowered from 300 K to 10 K. Possible

effects upon entering the superconducting state will also be discussed. Our insight into the pairing mechanism in this new superconducting compound will be important for the understanding of Pt-based superconductors in general, in particular the closely related heavy-fermion non-centrosymmetric superconductor $CePt_3P$.

[1] T. Takayama, Phys. Rev. Lett. **108**, 237001 (2012)

TT 30.14 Mon 15:00 P2

Multigap superconductivity in locally non-centrosymmetric SrPtAs as revealed by nuclear quadrupole resonance — •Felix Brückner[1], Rajib Sarkar[1], Marco Günther[1], Hans-Henning Klauss[1], Hannes Kühne[2], Hubertus Luetkens[3], Pabitra Biswas[3], and Titus Neupert[4] — [1]Technische Universität Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Paul Scherrer Institut, Villigen, Switzerland — [4]Princeton University, Princeton, USA

The recently discovered compound SrPtAs has awakened grown scientific interest, because it comprises an exceptional structural feature: it consists of non-centrosymmetric PtAs layers that are weakly coupled to each other. Theoretical calculations predict an unconventional chiral d-wave superconducting state which is unique in material science.

This is in line with evident breaking of time reversal symmetry in μSR experiments.

Our nuclear quadrupole resonance experiments reveal multigap superconductivity and a fully gapped state. In particular, we present spin-lattice relaxation rate ($1/T_1$) measurements and discuss possible pairing symmetries. These results are relevant to understand the pairing mechanism in this and similar compounds.

TT 30.15 Mon 15:00 P2

Fermi surface investigations on the filled skutterudite $LaRu_4As_{12}$ superconductor — •J. Klotz[1,2], K. Götze[1,2], V. Petzold[3], H. Rosner[3], T. Cichorek[4], Z. Henkie[4], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor (HLD), Helmholtz-Zentrum Dresden-Rossendorf — [2]Institut für Festkörperphysik, TU Dresden — [3]Max-Planck-Institut CPfS, Dresden — [4]INTiBS PAN, Wroclaw

Filled skutterudite compounds RT_4Pn_{12} (R: rare-earth element, T = Fe, Ru, Os, Pn = P, As, Sb) exhibit a large variety of phenomena such as exceptionally high thermoelectric power, heavy-fermion superconductivity or metal-insulator transition [1]. Within this class, $LaRu_4As_{12}$ features outstanding superconducting properties (T_c = 10.45 K and $\mu_0 H_{c2} \approx 10.2$ T). The magnetic-field dependence of the electronic specific-heat coefficient γ and the positive curvature of $H_{c2}(T)$ close to T_c indicate the existence of multiple superconducting gaps, making $LaRu_4As_{12}$ a rare example of a cubic superconductor displaying multiband effects [2]. Employing a capacitive torque magnetometer at temperatures down to 20 mK and in fields up to 35 T, we probed the angular dependence of the de Haas-van Alphen effect. We determined effective masses of different bands expecting enhanced masses due to the rather large γ = 59 mJ/mol K^2. In combination with density-functional band-structure calculations, our results provide detailed information about the Fermi surface of $LaRu_4As_{12}$.

[1] M. B. Maple, E. D. Bauer, *et al.*, Physica B, **328**, 29-33 (2003).
[2] L. Bochenek, R. Wawryk, *et al.*, Phys. Rev B. **86**, 060511(R) (2012).

TT 30.16 Mon 15:00 P2

Superconductivity and ferromagnetism in nanostructured Bi_3Ni — •R. Schönemann[1], T. Herrmannsdörfer[1], M. Naumann[1], R. Skrotzki[1,2], M. Kaiser[2], M. Heise[2], M. Ruck[2], K. Kummer[3], D. Graf[4], and J. Wosnitza[1] — [1]Dresden High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Department of Chemistry and Food Chemistry, TU Dresden, Germany — [3]European Synchrotron Radiation Facility (ESRF), Grenoble, France — [4]National High Magnetic Field Laboratory and Department of Physics, Florida State University, Tallahassee, Florida, USA

We have demonstrated the coexistence of superconductivity and ferromagnetism in Bi_3Ni nanostructures which have been prepared by making use of novel chemical-reaction paths [1]. Here, we present recent experiments on novel nanostructures, such as supercrystals consisting of packed Bi_3Ni nanofibers. We have investigated their magnetic and electrical-transport properties by means of XMCD, SQUID magnetometry, pulsed-field susceptometry, and ac-resistance measurements in a wide field and temperature range. Resistivity measurements demonstrate that superconductivity persists well above the Pauli limiting field - with strong anisotropy. These results will be presented in the context of a coexistence of superconductivity and ferromagnetism.

Part of this work was performed at the NHMFL and ESRF beamline ID08.

[1] T. Herrmannsdörfer, R. Skrotzki, J. Wosnitza, D. Köhler, R. Boldt, M. Ruck, Phys. Rev. B 83, 140501 (R) (2011).

TT 30.17 Mon 15:00 P2

^{119}Sn NMR investigations on superconducting $Ca_3Ir_4Sn_{13}$ — •Rajib Sarkar[1], Felix Brueckner[1], Marco Günter[1], Cedomir Petrovic[2], Kefeng Wang[2], Hubertus Luetkens[3], Pabitra Biswas[3], Elvezio Morenzoni[3], Alex Amato[3], and Hans-Henning Klauss[1] — [1]IFP, TU Dresden, D-01069 Dresden, Germany — [2]CMPMS, BNL, Upton, NY-11973, USA — [3]PSI, CH-5232 Villigen PSI, Switzerland

$Ca_3Ir_4Sn_{13}$ was found to exhibit superconducting transition with $T_c \approx 7$ K. It received considerable attention due to the possible coexistence of superconductivity and ferromagnetic spin fluctuation as well as the three-dimensional charge density wave (CDW) from the superlattice transition. [1,2] While thermal, transport, and thermodynamic characterization of $Ca_3Ir_4Sn_{13}$ single crystals suggest that it is a weakly correlated nodeless superconductor, recent μSR investigation reveals that the electron-phonon pairing interaction is in the strong-coupling limit. Here we present ^{119}Sn NMR investigations on $Ca_3Ir_4Sn_{13}$ polycrystalline samples and discuss the symmetry of the superconducting order parameter together with the normal state properties. Our preliminary results of spin-lattice relaxation rate ($1/T_1$) indicate that this is a BCS superconductor with weak-coupling limit.

[1] J. Phys. Soc. Jpn. 19, 113705 (2010).
[2] Phys. Rev. Lett. 109, 237008 (2012).

TT 30.18 Mon 15:00 P2

Doping-induced superconductivity in germanium — •M. Naumann, R. Skrotzki, T. Herrmannsdörfer, R. Schönemann, V. Heera, J. Fiedler, M. Voelskow, A. Mücklich, B. Schmidt, W. Skorupa, M. Helm, and J. Wosnitza — Hochfeld-Magnetlabor Dresden (HLD) und Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), P.O. Box 51 01 19, D-01314 Dresden, Germany

We report observations of superconductivity in highly doped germanium. High dopant concentrations of Al, B, Ga, In, Nb, P, or Sn have been introduced into nanolayers of Ge wafers via ion implantation. The electrical-transport properties of these thin-film samples strongly depend on the element type of dopant atoms, implantation dose, and on subsequent short-term annealing procedures. For Ge:Ga and Ge:In, we observe the emergence of superconductivity for certain sample-preparation conditions. In particular, the occurence of superconductivity requires well balanced flash-lamp or rapid thermal annealing conditions. On the one hand, the local temperature increase during annealing needs to be sufficiently intense to effectively activate dopant atoms as charge carriers. On the other hand, overheating and entire separation of dopant atoms in the germanium matrix needs to be avoided. Most likely, the superconducting state in highly doped germanium is triggered in dopant rich nano clusters and streched over their entire thin-film zone through percolation, tunneling, or proximity-effect networks.

TT 30.19 Mon 15:00 P2

Magnetic-field-dependent reentrant superconductivity in Ga-implanted Si — •R. Skrotzki, T. Herrmannsdörfer, R. Schönemann, V. Heera, J. Fiedler, E. Kampert, F. Wolff-Fabris, T. Förster, M. Voelskow, A. Mücklich, B. Schmidt, W. Skorupa, M. Helm, and J. Wosnitza — Hochfeld-Magnetlabor Dresden (HLD) und Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

We have implanted Ga ions into Si wafers and thereby formed 10 nm thin films of densely-packed amorphous Ga clusters. Via short-term annealing we are able to trigger a structural superconductor-insulator transition. On its superconducting side ($T_c \approx 7$ K), we observe a reentrant transition where zero resistance is intermitted by finite resistance at 0.1 K $< T <$ 1 K. This phenomenon is accompanied by non-linear current-voltage characteristics and suppressed at in- and out-of-plane oriented magnetic fields $H > H_{\mathrm{reentrant}}$. Moreover, we find that $H_{\mathrm{reentrant}}$ accounts for up to 10 T and reveals the same anisotropy as H_{c2} indicating a strong dependence on the vortex density in this non-magnetic material. A detailed phase diagram is drawn from magneto-transport measurements in high magnetic fields of more than 40 T. We assume that fluctuations are responsible for paracon-

ductivity of 2D Aslamazov-Larkin type at $T > T_c$ as well as for the reentrant phenomenon at $T < T_c$. The latter we discuss in terms of thermally activated phase-slip processes in conjunction with transport dynamics of resistively and capacitively shunted superconducting tunnel networks.

TT 30.20 Mon 15:00 P2

Electronic properties of undoped and doped aromatic hydrocarbon systems — •Friedrich Roth[1], Benjamin Mahns[2], Eric Müller[2], Bernd Büchner[2], and Martin Knupfer[2] — [1]Center for Free-Electron Laser Science / DESY, Notkestraße 85, D-22607 Hamburg, Germany — [2]Institute for Solid State and Materials Research Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany

Tuning the electronic structure and carrier density by intercalation is crucial to modern day semiconductor technology. In general, the carrier density plays a pivotal role for the materials properties, because intercalation can induce, e. g., a charge transfer, a shift of the Fermi energy and in general wide-ranging changes in the electronic properties of the system. Furthermore, the prerequisite for the understanding of physical properties of new materials is the knowledge of the electronic structure, both in the undoped as well as in the intercalated phase. After the discovery of superconductivity in potassium doped picene with a rather high transition temperature (of 18 K) polyaromatic hydrocarbons came back into the focus of researcher. In this context, this work presents a summary of the investigations on the electronic structure of several aromatic hydrocarbon systems using electron energy-loss spectroscopy (EELS).

TT 30.21 Mon 15:00 P2

Investigation of the electronic properties of the dual-layered charge transfer salt κ-α'-(BEDT-TTF)$_2$Ag(CF$_3$)$_4$(TCE) — •Michaela Altmeyer, Roser Valenti, and Harald O. Jeschke — Institut für Theoretische Physik, Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

In recent experimental work the synthesis of κ-α'-(BEDT-TTF)$_2$Ag(CF$_3$)$_4$(TCE) was achieved, which was reported to be a superconductor below a critical temperature of $11.1K$. The crystal is the first superconducting dual-layered charge transfer salt containing BEDT-TTF and consists of alternating layers of κ- and α'-type packed BEDT-TTF molecules. While there are superconductors in the family of (BEDT-TTF)$_2$X salts with a κ-type packing motif, the α'-type packed charge transfer salts tend to be Mott-Hubbard-insulators. Therefore we investigate the electronic properties of the dual-layered system within density functional theory. We compare the electronic structure to that of single-layered compounds with α'-type and with κ-type arrangement of BEDT-TTF molecules. This allows us to disentangle the more complex electronic structure of the title compound.

TT 30.22 Mon 15:00 P2

Stability of supercurrents and condensates in type I superconductors — Pavel Lipavsky[4], •Klaus Morawetz[1,2,3], Bretislav Sopik[5], and Michael Maennel[1] — [1]Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — [2]International Institute of Physics (IIP) Av. Odilon Gomes de Lima 1722, 59078-400 Natal, Brazil — [3]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [4]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 12116 Prague 2, Czech Republic — [5]Central European Institute of Technology, Masaryk University, Kamenice 735, 62500 Brno, Czech Republic

Excitations of Cooper pairs into non-condensed bound pairs are similar to excitations of true bosons out of the Bose-Einstein condensate. Using the Landau criterion of superfluidity we evaluate the critical current above which these pair-excitations would lead to a finite resistivity. The predicted value strongly depends on the chosen approximation. The Thouless approach based on the Galitskii T-matrix and the Kadanoff-Martin theory which is in many aspects equivalent to the BCS theory, both lead to zero critical velocity, what is in conflict with the mere existence of supercurrents. In contrast, the T-matrix with multiple scattering corrections provides the critical velocity of pair excitation which is p3-times larger than the critical velocity of pair breaking. This agrees with the experimentally well established fact that supercurrents in type I superconductors are limited by pair breaking, not by pair excitation

TT 30.23 Mon 15:00 P2

DFT Study on 122 pnictide superconductors and related compounds — •Tobias Förster[1], Helge Rosner[2], Andrey Polyakov[1], Marek Bartkowiak[1], Andrea D. Bianchi[3], and Jochen Wosnitza[1] — [1]Hochfeld-Magnetlabor Dresden (HLD), Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Deutschland — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Deutschland — [3]Départment de Physique and RQMP, Université de Montréal, Montréal H3C 3J7, Canada

The Fermi-surface topology of iron-pnictide superconductors stimulated many theories on the pairing mechanism in these materials. Especially the degree of nesting between quasi-two-dimensional hole and electron bands is regarded as a key ingredient. However, also more localized pictures and the duality of both itinerant and localized degrees of freedom of the Fe d electrons are considered. Here, we present a detailed electronic structure study of several AT_2P_2 (A =Ba, La, Ce; T =Fe, Rh, Ir) pnictides with $ThCr_2Si_2$ tetragonal structure type. Applying full potential density functional calculations in different approximations, we attempt to separate the influence of different parameters of the crystal structure on topology and character of the respective Fermi surfaces. For several compounds ($LaFe_2P_2$, $BaIr_2P_2$ und $CeFe_2P_2$), we will compare our calculated results with de Haas-van Alphen measurements and provide implications regarding their superconducting or magnetic properties.

TT 30.24 Mon 15:00 P2

Effect of weak disorder on the phase competition in iron pnictides — •Mareike Hoyer[1], Sergey Syzranov[1,2], and Jörg Schmalian[1,3] — [1]Institut für Theorie der Kondensierten Materie, Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Department of Physics, University of Colorado, Boulder, Colorado, USA — [3]Institut für Festkörperphysik, Karlsruher Institut für Technologie, Karlsruhe, Germany

We investigate the phase competition between magnetism and superconductivity for iron pnictides in the presence of weak disorder. The competition of these two ordered states has been studied in detail by Fernandes and Schmalian [1] who came to the conclusion that in the case of unconventional s^{+-} pairing, the superconducting and antiferromagnetic phase may coexist microscopically but are near to a parameter regime of mutual exclusion. Correspondingly, the multicritical point in the phase diagram is close to the transition from a tetracritical to a bicritical point.

Close to the multicritical point, the free energy of the system can be expanded simultaneously in terms of magnetic and superconducting order parameters and the coefficients can be determined microscopically. We include the effect of impurity scattering in the model and investigate its influence on the phase diagram of iron pnictides.

[1] Rafael M. Fernandes and Jörg Schmalian, Phys. Rev. B **82**, 014521

TT 30.25 Mon 15:00 P2

Manifestation of nematic degrees of freedom in the Raman response of pnictides — •Una Karahasanovic and Joerg Schmalian — Karlsruher Institut für Technologie, Wolfgang-Gaede-Str. 1 D-76131 Karlsruhe

The electronic nematic phase in pnictides, characterized by the broken C_4 symmetry, is believed to be generated by the presence of magnetic fluctuations associated with the striped phase [1], and occurs above the magnetic transition temperature. Detecting the presence of nematic fluctuations in iron-based superconductors is a difficult task, since it involves measuring four spin correlation functions. So far, these fluctuations were detected through the changes that they induce in the shear modulus (since the nematic order parameter couples to the orthorombic distortion). The presence of nematic fluctuations is felt even above the nematic transition, i.e. in the tetragonal phase.

Nematic degrees of freedom also manifest themeselves in the experimentally measurable Raman response function, which is a density-density correlation weighted by an appropriate form factor [2, 3]. We calculate the lineshape of the Raman response function in the tetragonal phase by considering Aslamazov-Larkin type of diagrams. We show that the reponse vanishes for the B_{2g} symmetry of the form factor, but not for the B_{1g} symmetry, as observed in the experiment.

[1] R. Fernandes and J. Schmalian, Supercond. Sci. Technol. 25, 084005 (2012).
[2] Y. Gallais et al, arXiv:1302.6255 (2013).
[3] S. Caprara et al, Phys. Rev. Lett. 95, 117004 (2005).

TT 30.26 Mon 15:00 P2

High-pressure synthesis of 1111-pnictides and related systems — •Agnes Adamski[1], Amir Haghighirad[1,2], Steffi Hartmann[1],

Natalija van Well[1], and Cornelius Krellner[1] — [1]Physikalisches Institut, Goethe University, Frankfurt am Main, — [2]University of Oxford, Department of Physics, Oxford

In 2008 Kamihara et al. found a new class of high-T_c superconductors: iron-based oxypnictides. A transition temperature of 26 K in F-doped LaFeAsO (1111-compound) was reported [1]. Replacing the nonmagnetic La ion by magnetic rare-earth elements in 1111-compounds leads to an increase of the superconducting transition temperatur up to ˜50 K. The crystal growth at high pressure/high temperature (HP/HT) conditions has been proven to be an effective method for the 1111-compounds [2][3].

We report on our progress to synthesize single crystals of these compounds under HP/HT conditions with a multi anvil apparatus, so called Walker-Type module. With this apparatus we can achieve rather hydrostatic pressures up to 8 GPa and temperatures up to 1750 K. We found that using NaCl/KCl as flux material is essential to avoid the formation of FeAs and to support the single crystal growth. The same Walker-Type module was used for the synthesis of related pnictides to search for new superconductors. It seems that high pressure is necessary to stabilized these compounds.

[1] Y. Kamihara et al., J. Am. Chem. Soc. 130, 3297 (2008)
[2] J. Karpinski et al., Physica C 469, 370 (2009)
[3] Z. Ren et al., Adv. Mater 21, 4584 (2009)

TT 30.27 Mon 15:00 P2

Microscopic investigations of the electronic phase diagram of $LaOFe_{1-x}Co_xAs$ — •Philipp Materne[1], Giacomo Prando[2], Hemke Maeter[1], Sabine Wurmehl[2,1], Bernd Buechner[2,1], Hubertus Luetkens[3], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]IFW Dresden, Postfach 270016, 01171 Dresden, Germany — [3]Paul-Scherrer-Institut, 5232 Villigen, Switzerland

The antiferromagnetic parent compound, LaOFeAs, can be tuned into a superconducting ground state by doping in the LaO- and in the FeAs-plane. We microscopically investigated the substitution of Fe by Co using muon-spin relaxation spectroscopy in the pure magnetic doping regime as well as in the coexistence regime. The results were compared with published data of $LaO_{1-x}F_xFeAs$ [1], $CeOFe_{1-x}Co_xAs$ and $CeO_{1-x}F_xFeAs$[2].

[1] H. Luetkens *et al.*, Nat. Mater. **8**, 305 (2009)
[2] G. Prando *et al.*, PRB **87**, 174519 (2013)

TT 30.28 Mon 15:00 P2

Antimony Substitution in Rare Earth 1111-Compounds — •Daniel Schmidt, Sebastian Wolf, and Hans F. Braun — Physikalisches Institut, Universität Bayreuth, 95440 Bayreuth

The rare earth iron arsenide 1111-compounds are well known oxypnictide high T_c superconductors. The phase diagram of the undoped compounds shows generally two parts, a magnetic and a superconducting phase. With sufficient electron doping in the charge carrier layer, that is substitution of oxygen with fluorine, the magnetic phase transition disappears and superconductivity arises. In our work we try to regain the magnetic phase from the superconducting one. Therefore we perform isostructural substitution at the iron arsenide layer by substituting As with Sb atoms in superconducting electron doped polycrystalline samples. We probe the doping level of Sb by observing the lattice parameters thus we can also test for impurity phases. The physical properties are observed by low temperature measurements of the resistivity and susceptibility.

TT 30.29 Mon 15:00 P2

Temperature dependent density of states study in stoichiometric LiFeAs — •Pranab Kumar Nag[1], Danny Baumann[1], Ronny Schlegel[1], Robert Beck[1], Sabine Wurmehl[1,2], Bernd Büchner[1,2,3], and Christian Hess[1,3] — [1]Leibniz-Institute for Solid State and Materials Research, IFW-Dresden, 01171 Dresden, Germany — [2]Institut für Festkörperphysik, TU Dresden, D-01062 Dresden, Germany — [3]Center for Transport and Devices of Emergent Materials, TU Dresden, 01069 Dresden

We present scanning tunneling microscopy / spectroscopy data for the stoichiometric iron arsenide superconductor LiFeAs. Temperature dependent tunneling spectra, obtained at a defined position on the surface, reveal a systematic closing of the superconducting gap with temperature, consistent with a bulk critical temperature of 16 K. We have observed a dip-hump structure in the quasiparticle density of states which is the indication of a strong electron-boson coupling in this material.

TT 30.30 Mon 15:00 P2

Induced magnetism in off-stoichiometric LiFeAs — •Robert Beck[1], Uwe Gräfe[1], Igor Morozov[1,2], Philipp Materne[3], Giacomo Prando[1], Hans-Joachim Grafe[1], Sabine Wurmehl[1,3], and Bernd Büchner[1,3] — [1]Leibniz Institute for Solid State and Material Research, D-01171 Dresden, Germany — [2]Moscow State University, Moscow, 119991 Russia — [3]Institut für Festkörperphysik, TU Dresden, D-01062 Dresden, Germany

We prepared a series of polycrystalline $Li_{1-y}Fe_{1+x}As$ samples in a wide range of nominal compositions ($0 < y < 0.1$ and $0 < x < 0.1$). The structure, composition and main characterization physical properties were studied in detail. Seemingly, the composition strongly affects the electronic ground state of the materials, ranging from superconductivity to bulk ferromagnetism. Concomitantly with the evolution of different ordering parameters as function of composition, we observe systematic trends in both line width and frequency of nuclear quadrupole resonance lines.

TT 30.31 Mon 15:00 P2

High-field NMR spectroscopy of the iron-based superconductor LiFeAs — •Hannes Kühne[1,2], Arneil P. Reyes[2], Philip L. Kuhns[2], Hans-Joachim Grafe[3], Saicharan Aswartham[3], Sabine Wurmehl[3], and Bernd Büchner[3] — [1]Hochfeld-Magnetlabor Dresden (HLD), Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany — [2]National High Magnetic Field Laboratory, Florida State University, Tallahassee, Florida 32310, USA — [3]IFW Dresden, Institute for Solid State Research, D-01171 Dresden, Germany

The iron-based compound LiFeAs exhibits superconductivity below $T_c \simeq 18$ K without introduction of chemical doping. From a number of macroscopic experiments, upper critical fields of 26 T or higher for a magnetic field orientation parallel to the FeAs planes were reported. So far, no local probe techniques were applied for the characterization of the microscopic electronic properties in this high-field parameter regime. We present the results of recently performed high-field NMR experiments on three high quality LiFeAs single crystals, implying upper critical fields much lower than 26 T. We discuss the signatures of the field-induced suppression of the superconducting order parameter, probed by the temperature dependent Knight shift, nuclear spin-lattice and spin-spin relaxation rates for fields and temperatures in the normal and superconducting state.

TT 30.32 Mon 15:00 P2

Local probe studies at copper containing 111 compounds — •Sirko Kamusella[1], Gohil S Thakur[2], Zeba Haque[2], Ashok K Ganguli[2], L C Gupta[2], Hubertus Luetkens[3], and Hans-Henning Klauss[1] — [1]Institut für Festkörperphysik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Department of Chemistry, Indian Institute of Technology,110016 New Delhi, India — [3]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

The recently synthesized LiFeAs-related compounds CuFeAs and CuFeSb [1] are discussed in terms of bulk measurements, ^{57}Fe mössbauer spectroscopy and μSR, comparing it to antiferromagnetic LiFeAs samples. In the compounds presented here the alkali metal sites are replaced by the transition metal copper leading to a stretched Fe-As-bond and therefore deformed As-tetrahedra.

According to these structural differences, CuFeAs and LiFeAs show opposite temperature dependencies of the quadrupolar interaction at the iron site. Furthermore we can confirm the ferromagnetic behavior of CuFeSb [2] up to $T_N = 375$ K, but observe long range antiferromagnetic order below 10 K for CuFeAs, similar to Li-111 samples. Both LiFeAs and CuFeAs show an unusual magnetoelastic coupling, which might play an important role for superconductivity in the 111. We discuss doping options to achieve superconductivity and suggest pressure studies to clarify the effect of pnictide spacing on (anti)ferromagnetism.

[1] G. Thakur *et al.*, unpublished
[2] B. Qian *et al.*, Phys. Rev. B. **85** (2012) 144427

TT 30.33 Mon 15:00 P2

Dilatometric measurements of the detwinning process in $EuFe_2As_2$ — •Ina-Marie Pietsch, Christian Stingl, Hirale S. Jeevan, Jannis Maiwald, Nora Bach, and Philipp Gegenwart — I.Physikalisches Institut, Georg-August Universität, Göttingen, Germany

For the investigation of the anisotropic in-plane behavior of high tem-

perature superconductors we need easy and practicable methods for detwinning single crystals. In our experiments the thermal expansion and magnetostriction has been used to analyze the detwinning process of $EuFe_2As_2$ in a magnetic field. This technique has the advantage that anisotropic behavior can be studied without applying external stress to the system. Using high-resolution capacitive dilatometry we can detect length changes related to the movement of domains due to an applied magnetic field. We examined the detwinning process for a large temperature range above and below the magnetic ordering transition of Eu spins at 19 K. Strikingly, the field-induced detwinning is permanent upon warming up to the structural transition at 187 K, which allows to investigate the anisotropic properties of the system over a wide temperature range.

TT 30.34 Mon 15:00 P2

Optical investigation of the in-plane anisotropy on the underdoped $EuFe_2(As_{1-x}P_x)_2$ single crystals — •Shuai Jiang[1], Hirale S. Jeevan[2], Philipp Gegenwart[2], and Martin Dressel[1] — [1]1.Physikalisches Institut, Universität Stuttgart, Deutschland — [2]I.Physikalisches Institut, Universität Göttingen, Deutschland

Applying uniaxial pressure enables us to detwin the iron-pnictide single crystal and detect the in-plane anisotropy. The effect of this external factor on the nematicity, however, is under debate. We have studied the in-plane anisotropy of as-grown $EuFe_2(As_{1-x}P_x)_2$ single crystals by optics measurements. The single crystal exhibits stripes in the micrometer range because of the birefringence of the twinned domains. Surprisingly, even without using the mechanical detwinning, the mid-infrared optical properties reveal an anisotropy that becomes pronounced below the structural transition temperature. The amplitude is comparable to the anisotropy of the fully detwinned single crystal. This observation is consistent with the SI-STM measurements on the atomic scale. Our in-situ study explores a new way to investigate the intrinsic dynamics of nematicity in iron pnictides.

TT 30.35 Mon 15:00 P2

A light scattering study of detwinned $BaFe_2As_2$ — •Andreas Baum[1], Andreas Walter[1], Bernhard Muschler[1], Florian Kretzschmar[1], Jiun-Haw Chu[2,3], James G. Analytis[2,3], Ian R. Fisher[2,3], and Rudi Hackl[1] — [1]Walther-Meissner-Institut, 85748 Garching, Germany — [2]SIMES, SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA — [3]GLAM and Department of Applied Physics, Stanford, University, Stanford, CA 94305, USA

The magneto-structural phase transition of $BaFe_2As_2$ is studied by Raman spectroscopy with a focus on lattice dynamics. Using uniaxial pressure to detwin the sample allows us to resolve anisotropic features as well as a separation of the structural and magnetic phase transitions.

The As A_{1g} phonon shows a resonance at high energies. With the polarizations aligned along either the antiferromagnetically or the ferromagnetically ordered direction the resonance profile is distinctly different.

The splitting of the E_g phonon at $135\,cm^{-1}$ into two modes having B_{2g} and B_{3g} symmetry can be attributed to the transition into the magnetically ordered state rather than the structural transition.

TT 30.36 Mon 15:00 P2

Resistivity anisotropy measurements on $Ca(Fe_{1-x}Co_x)_2As_2$ — •Stephan Knöner[1], Bernd Wolf[1], Harald Schubert[1], Sheng Ran[2], Paul Canfield[2], and Michael Lang[1] — [1]Physikalisches Institut, J.W. Goethe-Universität, SPP 1458, D-60438 Frankfurt (Main), Germany — [2]Ames Laboratory, Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

Electronic nematicity has been discussed intensively in the research on iron-pnictide superconductors. Evidence for electronic nematicity has been reported from various experiments including magnetic torque measurements [1], scanning tunneling microscopy [2] as well as electronic transport [3]. The nematicity manifests itself in a strong anisotropy in electrical resistance of single crystals detwinned by the application of mild uniaxial strain [3]. Different experimental and theoretical studies support the idea that the transport anisotropy basically results from anisotropic scattering by dopant-induced impurity states [2]. In this contribution, we present measurements of the electrical resistance on detwinned high-quality single crystals of $Ca(Fe_{1-x}Co_x)_2As_2$ with different doping levels x. We discuss the size of the anisotropy, its dependence on the doping level and the effect of hydrostatic pressure tuning [4].

[1] S. Kasahara *et al.*, Nature **486**, 382 (2012)
[2] M. P. Allan *et al.*, Nature Physics **9**, 220 (2013)
[3] J. Chu *et al.*, Science **329**, 824 (2010)
[4] E. Gati *et al.*, PRB **86**, 220511(R) (2012)

TT 30.37 Mon 15:00 P2

Spin Reorientation and Resonance Mode in $Ba_{1-x}Na_xFe_2As_2$ — •Florian Wasser[1], Sabine Wurmehl[2], Saicharan Aswartham[2], Yvan Sidis[3], Astrid Schneidewind[4,5], Ji-Tae Park[5], Bernd Büchner[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany — [2]Institute for Solid State Research, IFW Dresden, D-01171 Dresden, Germany — [3]Laboratoire Léon Brillouin, CEA-CNRS, CEA Saclay, 91191 Gif-sur-Yvette Cedex, France — [4]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation At MLZ, D-85747, Garching, Germany — [5]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM-II), TU München, D-85747 Garching, Germany

Iron-pnictides are a novel class of superconductors displaying a close relation between structure, superconductivity and magnetism. Most parent compounds exhibit a coupled structural and magnetic transition that becomes suppressed upon doping. Here we present our neutron scattering studies on $Ba_{1-x}Na_xFe_2As_2$ which differs from the other systems: At intermediate Na concentrations we find clear evidence for a spin reorientation from in-plane to out-of-plane alignment of the ordered moments. The low-temperature phase with c-aligned moments is unique in this system but it qualitatively agrees with the single-ion anisotropy in pure $BaFe_2As_2$ where it costs less energy to rotate spins from the plane to the c direction than rotating them within the plane. In addition we find a sharp resonance feature in $Ba_{1-x}Na_xFe_2As_2$ at low energy and a broader upturn in intensity at energies comparable to those of the resonance values in Co or Ni doped compounds.

TT 30.38 Mon 15:00 P2

Low-temperature specific heat of $K_{0.71}Na_{0.29}Fe_2As_2$ down to 20 mK — •Andreas Reifenberger, Marius Hempel, Andreas Fleischmann, Ruediger Klingeler, and Christian Enss — Kirchhoff-Institut für Physik, Universität Heidelberg, INF 227, D-69120 Heidelberg

Specific heat measurements on $K_{1-x}Na_xFe_2As_2$ at very low temperatures are helpful for the understanding of the underlying symmetry and magnitude of the superconducting order parameter. To perform the measurements, we used a commercially available calorimeter which we calibrated in the temperature range $0.02\,K \leq T \leq 0.8\,K$. The data on $K_{0.71}Na_{0.29}Fe_2As_2$ imply the presence of a large T^2 contribution to the specific heat which gives evidence of d-wave symmetry of the superconducting order parameter on almost all Fermi-surface sheets. To extend these measurements to even lower temperatures, we have designed a novel calorimeter based on magnetic thermometry. We expect a temperature resolution $\Delta T \approx 0.1\,\mu K$ and an addenda heat capacity of less than $200\,pJ/K$ for $T < 100\,mK$.

TT 30.39 Mon 15:00 P2

The electronic phase diagram of $Ba_{1-x}Rb_xFe_2As_2$ investigated by thermodynamic measurements — •D. Gruner[1], F. Steckel[1], V. Grinenko[1], S. Aswartham[1], C. Hess[1], A. U. B. Wolter[1], S. Wurmehl[1,2], and B. Büchner[1,2] — [1]Institute for Solid State and Materials Research, IFW Dresden, 01069 Dresden, Germany — [2]Institute for Solid State Physics, TU Dresden, 01062 Dresden, Germany

After the discovery of a spin-density-wave (SDW) anomaly at 140 K in $BaFe_2As_2$ by Rotter et al., superconductivity (SC) was achieved in this material by hole-doping with potassium [1]. Since $RbFe_2As_2$ shows bulk SC at 2.6 K [2], via a partial substitution of Ba with Rb in Ba122 the crossover from SC to magnetism can be studied in detail. We have synthesized single crystals of $Ba_{1-x}Rb_xFe_2As_2$ by using the self-flux high temperature solution growth technique. Via AC-susceptibility, specific heat and electrical resistivity measurements the SDW and superconducting behavior was investigated. The corresponding electronic phase diagram of $Ba_{1-x}Rb_xFe_2As_2$ has been constructed. While the substitution of Ba^{2+} with Rb^{+} ions suppresses the SDW anomaly, SC is induced. A superconducting transition as high as ≈ 37.3 K is reached for an Rb content of $x \approx 0.3$. This T_c is comparable to K-doped Ba-122 with $x = 0.4$ and $T_c = 38$ K reported previously [3].

[1] M. Rotter, M. Tegel, and D. Johrendt, Phys. Rev. Lett. **101**, 107006 (2008)
[2] Z. Bukowski *et al.*, Physica C. **470**, Supplement 1, S328 - S329 Superconductivity, (2010)
[3] S. Avci *et al.*, Phys. Rev. B. **85**, 184507 (2012)

TT 30.40 Mon 15:00 P2

Strain experiments on Fe based superconductors using flexible substrates — •Stefan Richter, Sascha Trommler, Fritz Kurth, Kazumasa Iida, Jens Hänisch, Ludwig Schultz, and Ruben Hühne — IFW Leibnitz Institute for Solid State and Materials Research Dresden

Strain is known to have a significant influence on the superconducting properties. Especially uniaxial strain experiments are promising to provide insight in correlations between structure and superconducting properties of anisotropic materials like high temperature superconductors.
However, a systematic investigation of these effects is often difficult since the strain in the sample cannot be easily controlled.
Therefore, we constructed a special bending system that allows changing dynamically the strain in samples based on metallic substrates while simultaneously measuring the electronic properties. Highly textured $Ba(Fe_{(1-x)}Co_x)_2As_2$ thin films grown on flexible IBAD-MgO/Hastelloy substrates by pulsed laser deposition are used for these studies. Depending on the doping level, these films show a superconducting transition temperature of up to 20 K as well as high critical current densities. Based on the bending experiments we will discuss the influence of strain on the superconducting properties.

TT 30.41 Mon 15:00 P2

Preparation and characterization of thin films of the unconventional superconductor FeSe — Eike Venzmer, Alexander Kronenberg, and •Martin Jourdan — Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz

The recently discovered class of iron pnictide compounds features a presumably unconventional mechanism of superconductivity. We investigate the iron chalcogenide FeSe, which is the structurally simplest representative of this class of materials. Epitaxial thin films are prepared by rf-sputtering by co-sputtering from separate Fe and Se targets. This method yield superconducting epitaxial thin films on MgO(100) as well as on $YAlO_3$(010) substrates whereas best results have been achieved on MgO(100). The influence of deposition rates and substrate temperature on phase formation, sample homogeneity, morphology and electronic transport properties are discussed. The main advantage of thin films made by sputterdeposition is an improved morphology which is promising for the future integration in planar tunneling junctions for spectroscopic investigations.

TT 30.42 Mon 15:00 P2

Applied dynamic strain on $FeSe_{0.5}Te_{0.5}$ through piezo-electric substrates. — •Sebastian Molatta, Sascha Trommler, Jens Hänisch, Kazumasa Iida, Michael Schulze, Sabine Wurmehl, Bernd Büchner, Ludwig Schultz, and Ruben Hühne — IFW Dresden, PF 27 01 16, 01171 Dresden

$FeSe_{1-x}Te_x$ is the structural most simple iron-based superconductor and shows a high sensitivity to applied strain. Typically, different substrates are used for the variation of static strain states in thin films to investigate the influence of the lattice parameters on the superconducting properties. However, this approach is restricted to thin layers ensuring a coherent growth. An alternative is to use epitaxial films on piezo-electric substrates, which allows the dynamic change of the lattice parameters to examine the influence of strain on the superconducting properties.

Therefore, we grew $FeSe_{0.5}Te_{0.5}$ films by pulsed laser deposition on different substrates. The epitaxial growth was first optimized on MgO single crystals and transferred afterwards to piezoelectric 0.72 $Pb(Mg_{1/3}Nb_{2/3})O_3$-0.28 $PbTiO_3$ (PMN-PT) substrates. In both cases an epitaxial growth and a superconducting transition T_c of more than 15 K were observed under optimized conditions. Finally, a shift in T_c of about 0.25 K for a change of 0.04% in the in-plane lattice-parameters was found in strain experiments for these $FeSe_0.5Te_0.5$-films grown on PMN-PT.

TT 30.43 Mon 15:00 P2

Preparation of planar SN and SNS‘ junctions on Ba-122 iron pnictide single crystals — •Noor Hasan[1], Stefan Schmidt[1], Sebastian Döring[1], Volker Tympel[1], Frank Schmidl[1], Paul Seidel[1], and Thomas Wolf[2] — [1]Friedrich-Schiller- Universität Jena , Institut für Festkörperphysik — [2]Karlsruhe Institute of Technology, Institut für Festkörperphysik

In order to understand the nature of the superconductivity in iron pnictides it is necessary to examine their electrical properties. Therefore we firstly have fabricated planar hybrid superconductor (S) - normal metal (N) - superconductor (SNS*) junctions with a Pb thin film as basis electrode. We used an artificial (barrier) layer which consists of thin normal conducting gold and titanium films. By oxygenation of the titanium we can add an insulating layer to the barrier system. A double layer film of Pb and In was used as the counter electrode. Then we fabricated the same junction type with a basis electrode using undoped $BaFe_2As_2$ single crystals which were produced with a self-flux method. After that we transferred the technology to superconducting Co-doped $BaFe_2As_2$ single crystals. For comparison between them we will present electrical measurements on these junctions. These include R*T measurements on each electrode and the different junction*s types itself as well as temperature dependent I-V characteristic and differential conductance respectively.

TT 30.44 Mon 15:00 P2

Long-range spin transport and spin-charge separation in nanoscale superconductors — Michael J. Wolf[1], Florian Hübler[1,2], Stefan Kolenda[1], Hilbert von Löhneysen[2,3], and •Detlef Beckmann[1] — [1]Institut für Nanotechnologie, Karlsruher Institut für Technologie — [2]Institut für Festkörperphysik, Karlsruher Institut für Technologie — [3]Physikalisches Institut, Karlsruher Institut für Technologie

We report on nonlocal transport in superconductor hybrid structures, with ferromagnetic as well as normal-metal tunnel junctions attached to the superconductor. In the presence of a strong Zeeman splitting of the density of states, we find signatures of spin transport over distances of several μm [1], exceeding other length scales such as the coherence length, the normal-state spin-diffusion length, and the charge-imbalance length [2]. The relaxation length of the spin signal shows a strong increase with magnetic field, hinting at a freeze-out of relaxation by the Zeeman splitting. Using a combination of ferromagnetic and normal-metal contacts, we demonstrate spin injection from a normal metal, and show a complete separation of charge and spin imbalance [3].
[1] Hübler et al., Phys. Rev. Lett. **109**, 207001 (2012)
[2] Hübler et al., Phys. Rev. B **81**, 184524 (2010)
[3] Wolf et al., Phys. Rev. B **87**, 024517 (2013)

TT 30.45 Mon 15:00 P2

Nonlocal transport and heating in superconductors under dual-bias conditions — •Stefan Kolenda[1], Michael J. Wolf[1], Dimitrij S. Golubev[1,2], Andrei Zaikin[1,3,4], and Detlef Beckmann[1] — [1]Institut für Nanotechnologie, Karlsruher Institut für Technologie — [2]Low Temperature Laboratory (OVLL), Aalto University School of Science — [3]I. E. Tamm Department of Theoretical Physics, P. N. Lebedev Physics Institute, Moscow — [4]Laboratory of Cryogenic Nanoelectronics, Nizhny Novgorod State Technical University

We report on an experimental study of nonlocal transport in superconductor hybrid structures, where two normal-metal leads are attached to a central superconducting wire. Structures of this kind are of interest, since possibly they could serve as Cooper pair splitters, creating spin entangled electrons. With bias voltages below the gap we find s-shaped nonlocal conductance curves as a function of bias applied on both contacts, as predicted theoretically in the presence of dynamical Coulomb blockade (DCB) [1]. With bias voltages above the gap applied on both normal-metal electrodes we find surprisingly large nonlocal conductance signals, almost of the same magnitude as the local conductance. We show that under these conditions heating has a qualitativly similar effect as DCB on nonlocal conductance, mimicking the effect of Cooper pair splitting [2].
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[2] S. Kolenda et al., Phys. Rev. B **88**, 174509 (2013)

TT 30.46 Mon 15:00 P2

Superconductor-Insulator Transition in thin TiN-films — •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, Novosibirsk 630090 Russia

We measured IV-characteristics and magnetoresistance of thin TiN-films in the vicinity of the disorder-tuned superconductor-insulator transition (SIT) for different square sizes (5μm to 240μm).

While the films are superconducting at $B = 0$T, at finite magnetic fields a SIT occurs with a magnetoresistance peak between

$1\text{T} < B(R_{max}) < 2.6\text{T}$ for the different sizes. For temperatures higher than $T \approx 300\text{mK}$ the magnetoresistance curves cross at a single point between $0.7\text{T} < B(R_{cross}) < 1.7\text{T}$ depending on the size and the $R(B)$ behaves linear for small B. For lower temperatures down to $T = 20\text{mK}$ the $R(B)$ rises faster than exponential for $B < B(R_{max})$. The magnetoresistance of the smaller samples (5μm to 30μm) is significantly weaker than that of the bigger samples (60μm to 240μm).

The voltage-biased IV-characteristics reveal a highly non-monotonic behavior both at zero magnetic field and at $B(R_{max})$.

TT 30.47 Mon 15:00 P2

Large oscillations of the magnetoresistance in nanopatterned thin aluminum films — Christopher Espy[1], •Julian Braun[1], Omri Sharon[2], Elke Scheer[1], and Yosef Yeshurun[2] — [1]Universität Konstanz, Konstanz, Germany — [2]Bar-Ilan University, Ramat Gan, Israel

With their experiments on thin superconducting cylinders Little and Parks demonstrated oscillations of the critical temperature with the flux threading the cylinder [1]. The periodicity of $\Phi_0 = h/2e$ supported the picture of a correlated two-electron state, as predicted by BCS theory. However, theoretical studies predict a h/e periodicity in ring-shaped unconventional superconductors that can arise via various mechanisms, when the ring diameter becomes comparable to the BCS coherence length, ξ_0 [2-3].

There is even speculation that this periodicity should be seen in rings made out of aluminum, a conventional s-wave superconductor, with diameters smaller than the coherence length, i.e. in the order of 1 μm [3]. Sochnikov et al. investigated this proposed periodicity in double network patterns of LSCO but didn't find the predicted periodicity [4]. We show first results of our experiments on such double networks of aluminum nano-rings.

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[2] V. Vakaryuk, PRL **101**, 167002 (2008)
[3] Loder et al., PRB **78**, 174526 (2008)
[4] Sochnikov et al., Nat. Nanotech. **5**, 516 (2010)

TT 30.48 Mon 15:00 P2

Analytical solutions for the energy and eigenstates of the flux qubit — •Iris Conradi, Melanie Hauck, Andreas Heimes, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, Karlsruhe

We analyze a gap tunable flux qubit and try to find an analytical solution for the eigenstates and their energy values. Using a semiclassical method we analyze the dependence of the potential energie spectrum on the parameters. Then we use a variation principle to determine analytical expressions for the eigenstates. As a first step we study the quartic potential. Here it is possible to find the e.g. the second excited state in good approximation. This allows us to estimate the anharmonicity of the flux qubit, which determines the speed of single qubit operations. Similarly we also find the second excited state of the double well potential.

TT 30.49 Mon 15:00 P2

The multidimensional eigenstates of the flux qubit — •Melanie Hauck, Iris Conradi, Andreas Heimes, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, Karlsruhe

In order to show the influence of the second dimension of the gap-tunable flux qubit compared to the common one-dimensional description we construct the two-dimensional eigenstates using the eigenstates of the harmonic oscillator and the double-well potential. At first we analytically describe the eigenstates of the one-dimensional problem with different parameter configurations. Variations of the external flux through the main loop cause an asymmetry in the double-well potential. We find the eigenstate of the double well potential for various parameter regimes. We then numerically estimate how the eigenstates in two dimensions can be decomposed into eigenstates of the double well and an harmonic oscillator.

TT 30.50 Mon 15:00 P2

Tunneling and Relaxation of Single Quasiparticles in a Normal-Superconductor-Normal Single Electron Transistor — •Andreas Heimes[1], Ville Maisi[2,3], Dmitry Golubev[2,4], Michael Marthaler[1], Gerd Schön[1,4], and Jukka Pekola[2] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]Low Temperature Laboratory (OVLL), Aalto University School of Science, P.O. Box 13500, 00076 Aalto, Finland — [3]Centre for Metrology and Accreditation (MIKES), P.O. Box 9, 02151 Espoo, Finland — [4]Institute of Nanotechnology, Karlsruhe Institute of Technology, D-76021 Karlsruhe, Germany

We investigate the properties of a hybrid single electron transistor, involving a small superconducting island sandwiched between normal metal leads, which is driven by dc plus ac voltages and works as a single electron turnstile. During the turnstile operation quasiparticles are injected onto the superconducting island, which relax via inelastic electron-phonon scattering and effectively heat up the island. We theoretically model the time evolution of the charge transport and the quasiparticle distribution during the pumping process. Our low-temperature results compare well with recent experimental findings obtained for ac-driven hybrid single-electron turnstiles.

TT 30.51 Mon 15:00 P2

RF-SQUID mediated coupling between microwave resonators — •Fabian Koessel[1,2], Friedrich Wulschner[1], Jan Goetz[1], Borja Peropadre[3], Alexander Baust[1], Elisabeth Hoffmann[1,2], David Zueco[4], Frank Deppe[1,2], Edwin P. Menzel[1], Achim Marx[1], Juan Jose Garcia-Ripoll[3], and Rudolf Gross[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]IFF-CSIC, Madrid, Spain — [4]CSIC-Universidad de Zaragoza and Fundacion ARAID, Spain

Networks of superconducting resonators are promising candidates for the implementation of analog quantum simulators. In this context it is necessary realize a controllable coupling between nearest neighbor resonators. Furthermore, the coupling strength between the resonators has to be larger than the decay rates of the involved resonators. Here, we present experimental data from two microwave resonators which are coupled via an RF-SQUID. The coupling can be turned on and off by applying an external magnetic field, which changes the operation point of the RF-SQUID. Making use of chains of DC-SQUID intersected nonlinear resonators, these devices may pave the way to simulate bosonic many body Hamiltonians in the driven-dissipative regime.

We acknowledge support from the DFG via SFB 631, the German excellence initiative via NIM, and the EU via PROMISCE.

TT 30.52 Mon 15:00 P2

Squeezing physics and path entanglement of continuous-variable propagating microwaves — •E. P. Menzel[1], L. Zhong[1], R. Di Candia[3], P. Eder[1,2], M. Ihmig[4], A. Baust[1], M. Haeberlein[1,2], C. Schneider[1,2], K. Inomata[5], T. Yamamoto[5,6], Y. Nakamura[5,7], E. Solano[3], F. Deppe[1,2], A. Marx[1], and R. Gross[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]University of the Basque Country UPV/EHU and IKERBASQUE Foundation, Bilbao, Spain — [4]TU München, Germany — [5]RIKEN Center for Emergent Matter Science, Japan — [6]NEC Smart Energy Research Laboratories, Japan — [7]The University of Tokyo, Japan

Josephson parametric amplifiers (JPA) have recently become promising devices in circuit quantum electrodynamics. We report on the detailed characterization of a flux-driven JPA at millikelvin temperatures and investigate its squeezing properties by two different detection techniques. By superimposing a squeezed vacuum and a vacuum state on a microwave beam splitter, we demonstrate a frequency-degenerate, continuous-variable path entanglement, which constitutes an essential resource in quantum information and communication protocols.

This work is supported by DFG via SFB 631, German Excellence Initiative via NIM, EU projects SOLID, CCQED, PROMISCE and SCALEQIT, MEXT Kakenhi "Quantum Cybernetics", JSPS FIRST Program, the NICT Commissioned Research, Basque Government IT472-10, Spanish MINECO FIS2012-36673-C03-02, and UPV/EHU UFI 11/55.

TT 30.53 Mon 15:00 P2

Interference effects in superconducting coplanar waveguide structures — •J. Goetz[1], P. Summer[1,2], H.P. Gürtner[1,2], M.J. Schwarz[1], P. Eder[1], F. Wulschner[1], F. Deppe[1,2], A. Marx[1], and R. Gross[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [2]Physik Department, TU München, Garching

The freedom in designing superconducting coplanar waveguide (CPW) structures allows for the on-chip creation of electromagnetic fields with

well defined spatial intensity distributions. Here we show the precise control of interfering fields which can be used for the control of gradiometer type tunable flux qubits. In addition we study the loss channels which our antenna structures add to CPW resonators. Our setup can be used to explore the manifold physics of gap tunable flux qubits coupled to CPW resonators.

This work is supported by the DFG via SFB 631, the Excellence Initiative via NIM, as well as by the EU-projects CCQED and PROMISCE.

TT 30.54 Mon 15:00 P2

Time and Frequency Domain Characterization of the Superconducting Quantum Switch — •A. Baust[1], E. Hoffmann[1,2], P. Eder[1,2], J. Goetz[1], M. Häberlein[1,2], M. Fischer[1,2], M.J. Schwarz[1], F. Wulschner[1], E. Xie[1], L. Zhong[1], H. Huebl[1], K. Fedorov[1], E.P. Menzel[1], F. Deppe[1,2], A. Marx[1], R. Gross[1,2], E. Solano[3], D. Zueco[4], and J.J. Garcia-Ripoll[5] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TUM, Garching, Germany — [3]Universidad del Pais Vasco and IKERBASQUE, Bilbao, Spain — [4]CSIC, Zaragoza, Spain — [5]Universidad Complutense, Madrid, Spain

Superconducting quantum circuits with transition frequencies of a few gigahertz form a powerful toolbox for the investigation of fundamental light-matter interaction, quantum simulation, and quantum information processing. For scalable architectures, it is important to establish controllable coupling between such circuits. To this end, we investigate how a three-Josephson-junction flux qubit mediates tunable and switchable coupling between two superconducting transmission line resonators. We demonstrate the switching behaviour in both time and frequency domain. In addition, we show that ultrastrong coupling between the qubit and a resonant mode is present in our system.

This work is supported by DFG via SFB 631, the German Excellence Initiative via NIM, EU projects CCQED, PROMISCE and SCALE-QIT, the Basque Foundation for Science, Basque Government IT472-10, UPV/EHU UFI 11/55 and Spanish MINECO FIS2012-36673-C03-02, FIS2011-25167, FIS2009-12773.

TT 30.55 Mon 15:00 P2

Controlling the coupling between phosphorus donor spins and a superconducting resonator by light — •Kai Mueller[1,2], Christoph W. Zollitsch[1,2], Felix Hoehne[3], Martin S. Brandt[3], Rudolf Gross[1,2], and Hans Huebl[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [2]Physik-Department, Technische Universität München, Garching — [3]Walter Schottky Institut, Technische Universität München, Garching

In the field of quantum information processing, phosphorus spin ensembles are discussed for information storage due to their exceptionally long spin coherence- and lifetimes of the order of seconds [1, 2]. On the other hand, their long lifetime limits the rate at which this quantum memory can be set. One strategy to overcome this problem is to shine light on the system to excite the phosphorus donor electrons. We investigate a spin ensemble consisting of phosphorus donors in silicon coupled to a superconducting coplanar waveguide resonator operating at GHz frequencies and below 1 K using microwave spectroscopy. When illuminating the silicon with 1050 nm light, we find that the coupling between the spin ensemble and resonator is reduced, which is compatible with the excitation of donor electrons to the conduction band. Additionally, we will discuss the time constants involved in this process. Financial support via SFB 631 and NIM is gratefully acknowledged.

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[2] G. Feher, Phys. Rev. **114**, 1245 (1959)

TT 30.56 Mon 15:00 P2

Collective Quantum Phase-Slip Dynamics in Superconding Nanowire Arrays — •Sebastian T. Skacel[1], Jan N. Voss[1], Tobias Bier[1], Lucas Radke[1], Martin Weides[1], Hannes Rotzinger[1], Hans E. Mooij[2,3], and Alexey V. Ustinov[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, D-76131 Karlsruhe, Germany — [2]Center for Functional Nanostructures, Karlsruher Institut für Technologie, D-76128 Karlsruhe, Germany — [3]Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands

Superconducting nanowire arrays exhibit quantum phase-slip (QPS) phenomenon if the superconductor has a very high normal-state sheet resistance. We experimentally study QPS effects in arrays of nanowires embedded in a resonant circuit at GHz frequencies. We probe this circuit at ultra-low microwave power, applied flux and mK temperatures. The nanowires are fabricated utilizing aluminium grown in a precisely-controlled oxygen atmosphere. In this way, we aim to control the QPS rate for a given wire width. The wires are defined with conventional electron beam lithography down to a width of 20 nm. We will present the fabrication of the nanowire arrays and first microwave measurements at mK temperatures.

TT 30.57 Mon 15:00 P2

Towards tunable transmon chains with individual on-chip bias — •Peter Fehlner, Jochen Braumüller, Lucas Radtke, Saskia Meissner, Hannes Rotzinger, Martin Weides, and Alexey Ustinov — KIT, Karlsruhe, Germany

Superconducting qubits constitute the main building blocks for quantum circuits. In this work we study a multi-qubit architecture [1] consisting of transmon qubits [2].

Such multi-partite quantum systems composed of harmonic and anharmonic resonant circuits manipulate the propagation of electromagnetic waves on a single photon level. These qubits operate at a Josephson to charging energy ratio of a few hundred to preserve sufficient anharmonicity. We employ a coplanar waveguide geometry based on interdigitated finger capacitors containing two Josephson junctions in parallel for each qubit. The sputter-deposited overlap *Al-AlO_x-Al* tunnel junctions are e-beam lithographically patterned for junction ares of about $0.1\mu m^2$. The transmons are capacitively coupled to a half wavelength transmission line resonator. The on-chip bias lines provide individual σ_z control of each qubit in the chain. Resonator readout and global σ_x, σ_y qubit manipulation is mediated by the resonator coupled to the feedline.

We will present sample design, microwave simulations and first results measured at cryogenic temperatures.

TT 30.58 Mon 15:00 P2

Investigation of a tunable transmon qubit in microstrip geometry — •Jochen Braumüller, Lucas Radtke, Oleksandr Lukashenko, Hannes Rotzinger, Martin Weides, and Alexey V. Ustinov — Karlsruhe Institute of Technology (KIT), Physikalisches Institut, 76131 Karlsruhe, Germany

Qubits constitute the main building blocks of a prospective quantum computer. The main challenge is given by their coherence times, determining the feasibility for quantum error correction and scalability. In this work we investigate a transmon qubit having lower sensitivity to charge noise and a reduced dephasing rate compared to a conventional Cooper pair box. The employed microstrip design reduces surface losses due to a decrease in field strength and by focussing of field lines into the substrate. The transmon's large shunt capacitance pads are connected by a split Josephson junction, corresponding to a dc-SQUID. The tunability of the transmon allows frequency selective coupling to other quantum systems. Our design features four frequency detuned microstrip resonators each capacitively coupled to a qubit, enabling frequency multi-plexed simultaneous qubit readout and better statistics of qubit parameters. Chip fabrication is done by sputter deposition of aluminum films and optical lithography. We will present Josephson junction transport characterizations, microwave simulations and qubit measurements.

TT 30.59 Mon 15:00 P2

Ultrasonic saturation of tunneling systems in superconducting circuits — •Saskia Meissner, Lucas Radtke, Jochen Braumüller, Hannes Rotzinger, Martin Weides, Alexey V. Ustinov, and Georg Weiss — Physikalisches Institut, KIT Karlsruhe

Atomic two-level tunneling systems (TLS) are well known to dominate the thermodynamic low temperature properties of amorphous solids. They are formed by an atom or a group of atoms tunneling between two configurations within the disordered solid. These TLS are also present in the disordered thin oxide layer of capacitors in superconducting resonators or tunnel barriers in Josephson junctions in superconducting circuits where they are known as a source of dielectric loss and qubit decoherence.

The resonant part of the dielectric loss, caused by TLS with energies fitting the measurement frequency, can be saturated at sufficiently high microwave power due to the reduction of the TLS's occupation number difference. Here we will exploit the coupling of the TLS to mechanical strain field to saturate them with high frequency ultrasonic waves.

The required ultrasonic waves in the GHz range are generated either by surface acoustic wave transducers directly integrated in the super-

conducting resonator circuit or by bulk acoustic wave transducers on the chip's backside. RF-sputtered zinc oxide is used as piezoelectric film. Chip design, simulation of the resonators and data will be presented.

TT 30.60 Mon 15:00 P2

Probing the Interaction of Individual Two-Level-Systems with Quasiparticles using a Superconducting Qubit — •Alexander Bilmes, Jürgen Lisenfeld, Georg Weiss, and Alexey V. Ustinov — Physikalisches Institut, Karlsruhe Institute of Technology and DFG-Center for Functional Nanostructures (CFN), D-76128 Karlsruhe, Germany

Two-Level-Systems (TLS) are solid state defects which constitute one of the main sources of decoherence in a variety of nanoscale devices while their physical nature remains yet unclear. TLS couple to the environment via their electrical dipole moment and the mechanical strain field. It is possible to use a superconducting phase qubit for coherent manipulation and measurement of TLS which reside inside the tunnel barrier of the qubit's Josephson junction. In order to verify theoretical TLS models, we investigate whether TLS interact with quasiparticles (QP) existing in the qubits circuit. We use an on-chip DC-SQUID to generate QP in-situ. The QP density can be calibrated according to their effect on the phase qubit, where they give rise to a change in energy relaxation time and plasma frequency as has been shown by the group of J.M. Martinis [1]. Here we present first results on the coherence of individual TLS in dependence of TLS asymmetry and QP density. We observe a strong enhancement of the TLS energy relaxation rate by injected QP.
[1] J. Wenner et al., Phys. Rev. Lett. 110, 150502 (2013)

TT 30.61 Mon 15:00 P2

Low-Vibration Design of a 4 K Pulse Tube Cooler operated on Helium Compressors of Small Input Power — Jens Falter[1,2], Bernd Schmidt[1], Andreas Euler[1], Marc Dietrich[1], André Schirmeisen[1,2], and •Günter Thummes[1,2] — [1]TransMIT-Center for Adaptive Cryotechnology and Sensors, Giessen, Germany — [2]Institute of Applied Physics (IAP), Justus-Liebig-University Giessen, Germany

In comparison to conventional Gifford-McMahon coolers, Pulse Tube Coolers (PTC) offer the advantage of having no moving parts at low temperatures. This feature results in high reliability and reduced vibrations of the cold head, which makes the PTC very attractive for highly-sensitive applications. However, due to the periodic compression and expanding cycles in the cold head, also PTCs exhibit two intrinsic effects: (1) a periodic variation in temperature; (2) a periodic elastic deformation ("breathing") of the thin walled pulse- and regenerator-tubes, which leads to residual vibrations. Here we present a two-stage 4 K PTC cold head which was especially designed to work with compressors of low input power in order to minimize these intrinsic effects. Nevertheless, small variations in temperature and residual vibrations remain due to their intrinsic nature. Further reduction of the temperature oscillations can be achieved with metal plates of low thermal diffusivity and the residual vibrations can be further reduced by successfully decoupling the cooler from the experiment.

TT 30.62 Mon 15:00 P2

Ultra-thin TaN films on different substrates for superconducting detectors — •Ilya Charaev, Konstantin Ilin, and Michael Siegel — Institute of Micro- and Nanoelectronic Systems, Karlsruhe Institute of Technology, Hertzstrasse 16, Karlsruhe, Germany

Superconductors widely used for development of detectors with ultimate sensitivity. For example, Tantalum Nitride (TaN) is a promising material for superconducting nanowire single-photon detector (SNSPD) in a wide spectral range. We report on a study of superconducting, normal state and thermal properties of ultra-thin TaN films for SNSPD. The films with a thickness of 5.5 nm were deposited by reactive magnetron sputtering in an Ar+N_2 atmosphere on different substrates like Sapphire, Si, MgO and Si with AlN buffer layer. While the critical temperatures Tc and the critical current density j_c (4.2 K) of TaN films on sapphire and MgO substrates have been found almost identically (about 9.3 K and 4 MA/cm^2 correspondingly) the Tc values of the films on Si substrate were much lower (4.76 K). Using a buffer layer of AlN the T_c of TaN on Si (important for THz applications) has been increased up to 7 K. Thermal coupling (estimated from the hysteresis current density) between TaN films and MgO and Sapphire substrates has been found alike while on Si substrates with AlN buffer layer the coupling was much weaker. A detailed analysis of the influence of substrate material on properties of TaN films will be presented and the potential of TaN films for different applications will be discussed.

TT 30.63 Mon 15:00 P2

Thin NbN film nanowires on GaAs for single-photon detectors — •Ekkehart Schmidt[1], Ulrich Rengstl[2], Elisabeth Koroknay[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

For photonic integrated circuits, on chip emitters as well as detectors are needed to provide efficient data processing. Therefore fast and efficient detectors compatible with large scale integration along with sources, microcavities, waveguides and interferometers based on GaAs technology are required. Due to their single-photon resolution, fast detection, high detection efficiency and low dark count rate, the Superconducting Nanowire Single-Photon Detectors (SNSPDs) seem very promising. We studied transport and superconducting properties of 6 nm thick NbN films on GaAs suitable for SNSPD development. The NbN films were deposited using reactive magnetron sputtering on heated GaAs substrates. A Tc > 10 K of films has been achieved. SNSPDs were patterned using electron-beam lithography (EBL) and reactive-ion etching (RIE). The critical-current density of a 120 nm wide nanowire at 4.2 K exceeds 1.4 MA/cmˆ2. Results on study of optical response of NbN nanowire on GaAs will be presented and potentials of SNSPD integration into GaAs based photonic circuits will be discussed.

TT 30.64 Mon 15:00 P2

High-T_c YBCO nanowires for detector applications — •Steffen Koch[1,2], Juliane Raasch[2], Konstantin Ilin[2], Bernhard Holzapfel[3], Kazumasa Iida[4], Marc Weber[1], and Michael Siegel[2] — [1]Institute for Data Processing and Electronics, Karlsruhe Institute of Technology (KIT) — [2]Institute of Micro- and Nanoelectronic Systems, KIT — [3]Institute for Technical Physics, KIT — [4]Leibniz Institute for Solid State and Materials Research Dresden, IFW Dresden

$YBa_2Cu_3O_{7-d}$ (YBCO) is a promising high-T_c material for the fabrication of superconducting detectors with ultimate sensitivity and ultrafast response in a broad spectral range. Due to its intrinsic interaction times of less than 2 ps [1] the timing jitter of the response of superconducting YBCO nanowire single-photon detectors (SNSPD) should be smaller than in NbN SNSPDs.

The design of a SNSPD made from YBCO requires the patterning of meander lines with widths of the nanowire below 300 nm. The required thickness of the YBCO films ranges from a few nanometers for the absorption of optical photons up to several hundred nanometers in the X-ray range.

We will present results on the development of a technology for YBCO nanowires with thicknesses below 40 nm, widths of a few hundred nanometers and lengths up to tens of micrometres. The superconducting transport properties of different nanowire geometries measured with and without applying a magnetic field will be presented.
[1] M. Lindgren et al., Appl. Phys. Lett. 74 , 853 (1999)

TT 30.65 Mon 15:00 P2

Advances in the development of microstructured Magnetic Penetration Thermometers (MPT) — •J. Geist, S. Kempf, L. Gastaldo, A. Fleischmann, and C. Enss — KIP Heidelberg University

We recently started the development of microfabricated calorimetric detectors with magnetic penetration thermometers (MPT). MPTs make use of the steep temperature dependence of the magnetic penetration depth and the critical magnetic field of a superconducting sensor to monitor its temperature. When the sensor is placed in a weak magnetic bias field, the temperature rise following the absorption of a particle in the detector leads to a change of magnetic flux density $\mathbf{B(r)}$ inside the sensor and in its vicinity, which is detected as a magnetic flux change in the pickup coil of a sensitive magnetometer and serves as a measure of the absorbed energy.

We present numerical design studies as well as first experimental tests of microfabricated MPT sensor layers, patterned to form arrays of micron wide lines and dots which can be read out e.g. using meander-shaped pickup coils. We show that hysteresis effects as previously

observed in MPT devices with large-area superconducting films can be completely suppressed. We also show that elemental superconductors needs to be deposited with high film quality to allow for a high detector sensitivity and therefore energy resolution. Finally, we show that the requirements on the film quality is somehow relaxed when the MPT sensor is made of thick S/N bilayers such as Al/Au or Al/Ag.

TT 30.66 Mon 15:00 P2

Development of dc-SQUIDs for the readout of metallic magnetic calorimeters — •A. Ferring, S. Kempf, M. Wegner, A. Fleischmann, L. Gastaldo, and C. Enss — Kirchhoff-Institute for Physics, Heidelberg University.

The very large bandwidth, the quantum limited noise performance, as well as the compatibility with very low operation temperatures make superconducting quantum interference devices (SQUIDs) the devices of choice for the readout of low temperature microcalorimeters such as metallic magnetic calorimeters (MMCs). For many MMC, low inductance current sensing SQUIDs are used to either directly measure the detector output signal or to act as an ultra low noise amplifier in a multistage SQUID configuration. Due to the desire for devices that are optimized for the readout of state-of-the-art MMCs, we have recently started the development of low-T_c current sensing dc-SQUIDs employing an in-situ sputtered Nb/Al-AlO_x/Nb trilayer.

We discuss our various dc-SQUID designs as well as the properties of produced prototype SQUIDs. In particular, we compare SQUIDs made by three different fabrication processes that are based on selective Niobium etching which is optionally combined with chemical anodization. We investigate the noise performance of our devices with respect to the absolute value and the temperature dependence of the white noise level. Furthermore, we study the presence of an $1/f$-like noise contribution and its temperature dependent behaviour. Finally, we experimentally show that state-of-the-art MMCs can successfully be read out by our SQUIDs.

TT 30.67 Mon 15:00 P2

Microfabrication of Metallic Magnetic Calorimeters — C. Enss, A. Ferring, A. Fleischmann, L. Gamer, L. Gastaldo, J. Geist, •D. Hengstler, S. Kempf, M. Krantz, A. Pabinger, C. Pies, C. Schötz, V. Schultheiss, and T. Wolf — KIP Heidelberg University.

Metallic Magnetic Calorimeters (MMCs) are low temperature particle detectors that nowadays can reliably be produced with multilayer microfabrication techniques. Moreover, the consequent use of these techniques allows for the fabrication of thousands of virtually identical detectors as it is required for large detector arrays. Using various examples of current MMC detectors which are actively used for spectroscopic measurements, we present our state-of-the-art microfabrication processes. This includes the fabrication of micron wide Nb lines with critical current densities close to the bulk value, persistent current switches allowing for a preparation of a persistent current in these Nb lines, temperature sensors made of co-sputtered Au:Er with concentrations between 200 ppm and 900 ppm, as well as overhanging particle absorbers made of electroplated gold with thicknesses between 3 μm and 200 μm. We also discuss a process for thermal anchoring the detectors through a Si wafer by connecting both sides of the wafer with the help of a DRIE-ICP etch and a Au electroplating process. Finally, we discuss the fabrication of thin, large-area ($A > 1\,\mathrm{cm}^2$) freestanding absorbers which are connected to the solid substrate only via some stems with a very small diameter.

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Large-area detector for position and energy resolving detection of molecular fragments — •L. Gamer[1], S. Allgeier[1], D. Hengstler[1], S. Kempf[1], C. Krantz[2], O. Novotny[3], A. Pabinger[1], C. Pies[1], A. Wolf[2], L. Gastaldo[1], A. Fleischmann[1], and C. Enss[1] — [1]KIP Heidelberg University. — [2]MPI-K Heidelberg. — [3]Columbia Astrophysics Laboratory, New York, USA.

To study reactions like the dissociative recombination in laboratory environment, the MPI-K in Heidelberg is building a cryogenic storage ring to prepare molecular ions in their rotational groundstate. The kinematics of these processes can be resolved by a position and energy sensitive detection of the produced molecule fragments. Previously, we described a large-area MMC for position and energy sensitive detection of massive particles. The detector encompasses 16 large-area absorbers, the temperature of each is monitored by a paramagnetic sensor located at a short edge of the absorber. Due to the finite thermal diffusivity in the absorber material, the rise-time of the detector depends on the impact location of the particle. We compare the expected energy resolution and position sensitivity of this detector to experimental results where energy was deposited at different positions. We investigate the impact of backscattering, sputtering and lattice damage effects on the instrumental linewidth by means of Monte Carlo simulations and measurements performed with a similar detector that was irradiated with ions and small molecules. We find that the degradation of energy resolution is less than predicted and show that molecular fragments which differ by only 1 mass unit can clearly be resolved.

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Design of a Large Solid Angle Array of Calorimetric Low Temperature Detectors for Applications in Heavy Ion Research — •Patrick Grabitz[1,2], Artur Echler[1,2,3], Peter Egelhof[1,2], and Saskia Kraft-Bermuth[3] — [1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [2]Johannes Gutenberg Universität, Mainz, Germany — [3]Justus-Liebig-Universität, Gießen, Germany

Calorimetric low temperature detectors (CLTDs) for heavy ion detection have been demonstrated to achieve an excellent relative energy resolution of $\Delta E/E = 1 - 2\mathrm{x}10^{-3}$ in a wide range of energies. Combined with time of flight detectors they were successfully applied in accelerator mass spectroscopy and stopping power measurements. They also have the potential to be applied for determination of fission fragment distributions as well as for mass identification of super heavy elements with $Z \geq 113$. At present a CLTD array consisting of eight individually temperature controlled pixels with an active area of 12x6mm^2 is used in different applications. To exploit the full potential of CLTDs in further experiments the active area has to be increased. The design of the new array with 25 individually temperature controlled pixels and an active area of 15x15mm^2 will be discussed. Results from the first performance tests will be presented.

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Schutzdioden für supraleitende Magnete am KATRIN-Experiment — •Alexander Jansen — KIT - Institut für Kernphysik — Postfach 3640, 76021 Karlsruhe

Die absolute Neutrinomasse ist sowohl für die Astroteilchenphysik, als auch für die Kosmologie von großer Bedeutung. Ziel des KATRIN-Experiments ist die modellunabhängige Messung der Neutrinomasse mit einer Sensitivität von $0.2eV/c^2(90\%C.L.)$ über die Kinematik des Tritium-β-Zerfalls. Hierzu werden die Zerfallselektronen aus der fensterlosen, gasförmigen Tritiumquelle (WGTS) über eine differentielle Pumpstrecke (DPS) und eine kryogene Pumpstrecke (CPS) zum Spektrometerbereich (MAC-E-Filter) geführt, wo ihre Energie mit hoher Präzision gemessen wird.

Die Aufgabe der Transportstrecke (DPS und CPS) ist es, das gesamte Tritiumgas abzupumpen, bevor es das Spektrometer erreichen kann. Gleichzeitig werden die Zerfallselektronen adiabatisch zum Spektrometer geleitet. Der Elektronentransport erfolgt dabei mit Hilfe magnetischer Felder, die durch supraleitende Magnete erzeugt werden. Der sichere Betrieb der Anlage erfordert besondere Maßnahmen zum Schutz der Magnete im Quenchfall. Dabei muss die im Magnetfeld gespeicherte Energie sicher abgeführt werden. Hierzu wurde ein neues Design für die Schutzdioden mit verbesserter Wärmeankopplung konzipiert. Der Vortrag gibt einen Überblick über den Quell- und Transportbereich und stellt das Konzept der Schutzdioden inklusive Testmessungen vor.

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