TT 58: Transport: Poster Session

Time: Wednesday 15:00–18:30 Location: Poster D

TT 58.1 Wed 15:00 Poster D

Second-order coherence of microwave photons emitted by a quantum point contact — •Daniel Otten and Fabian Hassler — JARA-Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

Shot-noise of electrons that are transmitted with probability T through a quantum point contact (biased at a voltage V_0) leads to a fluctuating current that in turn emits radiation in the microwave regime. By calculating the Fano factor F for the case where only a single channel contributes to the transport, it has been shown that the radiation produced at finite frequency ω_0 close to $eV_0/\hbar$ and at low temperatures is nonclassical with sub-Poissonian statistics ($F < 1$). It is the fermionic nature of the electrons producing the radiation, which reduces the probability of simultaneous emission of two or more photons. However, the Fano factor, being a time-averaged quantity, offers only limited information about the system. Here, we calculate the second-order coherence $g^{(2)}(\tau)$ for this source of radiation. We show that due to the interference of two contributions, two photon processes (leading to bunching) are completely absent at zero temperature for $T = 50\,\%$. At low temperatures, we find a competition of the contribution due to Gaussian current-current fluctuations (leading to bunching) with the one due to non-Gaussian fluctuations (leading to antibunching). We show that the competition of the two contributions leads to a non-monotonic behavior of the second-order coherence as a function of time so that there are times for which the second-order coherence remains below 1 at temperatures where the Fano factor is already above 1.

TT 58.2 Wed 15:00 Poster D

Energy transport in nanosystems: master equations approaches — •Kevin Marc Seja[1], Carsten Timm[1], Andreas Wacker[2], and Gediminas Kiršanskas[2] — [1]Institute of Theoretical Physics, TU Dresden, 01062 Dresden, Germany — [2]Division of Mathematical Physics, Lunds universitet, Box 118, 22100 Lund, Sweden

Master equations are a powerful tool to perform quantum-transport calculations in non-equilibrium scenarios. We use a sequential-tunneling Redfield-type approach, which includes off-diagonal elements of the reduced density matrix, to study the thermoelectric properties of nanosystems. We examine how these off-diagonal elements alter physical observables. One point of particular interest is the linear response predicted by such an approach, especially the validity of the Onsager reciprocal relations. An interacting double quantum dot serves as an exemplary system to demonstrate our main results.

TT 58.3 Wed 15:00 Poster D

Transient dynamics in electron transport through an Anderson impurity: A hierarchical quantum master equation approach — •Jakob Bätge, Sebastian Wenderoth, and Rainer Härtle — Institut für theoretische Physik, Georg-August-Universität Göttingen

We investigate the transport properties of an Anderson impurity under the influence of time-dependent electric fields. This includes the transient dynamics starting from product and correlated initial states and the response to voltage pulses, as they are used, for example, in pump-probe experiments. Our study is based on the quantum master equation methodology, where, in particular, we present an extension of the recently developed hierarchical quantum master equation approach [1] to time-dependent problems. The approach is time-local and numerically exact, as was corroborated recently for a time-independent problem by a direct comparison to quantum Monte Carlo simulations [2]. Thus, we have access to a systematic and controlled protocol to simulate long-lived correlated dynamics [3]. Here, we use this method to calculate the magnetization and the electrical current that is flowing through the impurity as a function of time, elucidating the role of resonant, non-resonant and higher-order processes.

[1] R. Härtle *et al.*, PRB **88**, 235426 (2013)
[2] R. Härtle *et al.*, PRB **92**, 085430 (2015)
[3] R. Härtle *et al.*, PRB **90**, 245426 (2014)

TT 58.4 Wed 15:00 Poster D

Zero-bias anomalies in electron transport through quantum dots for temperatures above the Kondo temperature — •Sebastian Wenderoth, Jakob Bätge, and Rainer Härtle — Institut für theoretische Physik, Georg-August-Universität Göttingen

We study the influence of exchange interactions on the steady-state transport properties of simple quantum dot structures that can be described by the single-impurity Anderson model and its spinless counterpart. To this end, we employ the quantum master equation methodolody, including a numerically exact, hierarchical technique [1,2] and, as an additional analytical tool, the Born-Markov approximation. We show that exchange interactions can lead to a zero-bias anomaly in the conductance, even for temperatures that are much higher than the respective Kondo temperature. The comparison of exact and approximate results allows us to reveal the underlying physical mechanisms, in particular the role of first- and second-order processes, decoherence and renormalization effects.

[1] R. Härtle *et al.*, PRB **88**, 235426 (2013)
[2] R. Härtle *et al.*, PRB **92**, 085430 (2015)

TT 58.5 Wed 15:00 Poster D

Andreev current through a quantum dot with spin-orbit coupling — •Daniel Spannenkrebs, Stephan Weiss, and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

We study an interacting quantum dot in the presence of spin-orbit interaction. The dot is coupled to a normal and a superconducting lead. We integrate out the superconductor in the limit of an infinite gap $\Delta \to \infty$. This yields a model which consists of the normal lead and an effective dot with finite pairing amplitude. The coupling of the normal lead to the effective system is taken into account by a real-time diagrammatic method [1]. The calculation of the nonequilibrium Andreev current allows us to investigate the interplay between SO coupling and superconducting correlations on the quantum dot.

[1] M. Governale, M. G. Pala, and J. König, PRB **77**, 134513 (2008).

TT 58.6 Wed 15:00 Poster D

Thermopower signatures and spectroscopy of the canyon of conductance suppression — •Gediminas Kiršanskas, Susanna Hammarberg, Olov Karlström, and Andreas Wacker — Mathematical Physics and NanoLund, Lund University, Box 118, S-22100 Lund, Sweden

Interference effects in quantum dots between different transport channels can lead to a strong suppression of conductance, which cuts like a canyon through the common conductance plot [1]. We consider the thermoelectric transport properties of this canyon of conductance suppression using the second-order von Neumann approach. We observe a characteristic signal for the zeros of the thermopower. This demonstrates that thermoelectric measurements are an interesting complimentary tool to study complex phenomena for transport through confined systems.

[1] H. A. Nilsson et al., PRL **104**, 186804 (2010)

TT 58.7 Wed 15:00 Poster D

Interaction effects in a nanoscale heat engine — •Christian Schiegg[1], Michael Dzierzawa[1], Ulrich Eckern[1], and Karol Izydor Wysokinski[2] — [1]Institut für Physik, Universität Augsburg, Augsburg, Germany — [2]Institute of Physics, Maria Curie-Sklodowska University, 20-031 Lublin, Poland

We consider the three-terminal heat engine based on resonant tunneling through quantum dots that has been proposed by Jordan et al. [1] as an efficient energy harvester. The setup consists of a central heat reservoir coupled to a left and a right lead via resonant tunneling through tunable quantum dots that act as energy filters. Interaction effects on the performance of this heat engine have been taken into account by an effective potential that arises from the screened Coulomb interaction in the non-linear transport regime [2]. Here, we include a short-range repulsion between the leads and the quantum dots within a self-consistent Hartree-Fock approximation for the non-equilibrium steady state. The efficiency and the maximum power of the heat engine are calculated and compared with the non-interacting system and with the results obtained in [2].

[1] A.N. Jordan, B. Sothmann, R. Sanchez, and M. Büttiker, PRB **87**, 07513 (2013).
[2] B. Szukiewicz, U. Eckern, and K. I. Wysokinski, unpublished (2015).

TT 58.8 Wed 15:00 Poster D

Spin-charge coupled dynamics induced by a nonequlibrium magnetization — •Sebastian Tölle[1], Cosimo Gorini[2], and Ulrich Eckern[1] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany

We discuss spin-charge coupled dynamics in a thin metallic film modelled as a two-dimensional electron gas. A proximity-induced dynamical magnetic texture, from a ferromagnet in contact with the normal metal, gives rise to an effective driving force acting on the conduction electrons. Due to the inversion asymmetry of the ferromagnet/normal metal/vacuum structure, we consider an effective Bychkov-Rashba spin-orbit interaction. We show that the latter, together with anisotropic Elliott-Yafet spin relaxation, yields important corrections to the dynamical magnetization-induced effective force. We analyze in particular the spin-pumping configuration of typical experimental setups. A non-trivial competition between the inverse spin Hall and the spin galvanic (inverse Edelstein) effects, both contributing to the build-up of a DC voltage in the sample, is found.

TT 58.9 Wed 15:00 Poster D

Spin-polarized current through the half-metallic Heusler alloy NiMnSb — •Andreas Prinz-Zwick and Rui-Jing Zhang — Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Spintronics is an important field of research because of the various possible applications for such devices, for example, transistors and storage media. Heusler alloys are most interesting in this regard because of their half-metallic properties. In this context, we investigate the spin resolved transmission through the Heusler alloy NiMnSb. The calculation of the band structure of NiMnSb as well as the structural optimization were done using Density Functional Theory as implemented in the SIESTA program. The transport setup contains two semi-infinite leads of gold and a layer of NiMnSb with variable thickness in between. For the calculation of the transport properties we used the SMEAGOL program for electronic transport, which utilizes non-equilibrium Green's functions to calculate the transmission coefficient and the Landauer formula to calculate the current. We find highly spin-polarized currents even with very thin layers of NiMnSb, for example, the spin polarization already exceeds 90% for two unit cells.

TT 58.10 Wed 15:00 Poster D

Simulation of Dipolar Quantum Magnetism with Arrays of Superconducting Qubits — •Phani Raja Muppalla — Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences & Institute for Experimental Physics, University of Innsbruck, A-6020 Innsbruck, Austria

We propose a novel platform for quantum many body simulations of dipolar XY models using state of the art circuit QED technology. Our basic building blocks are 3D Transmon qubits where we use the naturally occurring dipolar interactions to realize interacting spin systems. In order to understand the interaction of two 3D transmons for this proposal we performed numerical simulations using ANSYS HFSS. This opens the way towards the realization of a broad class of tunable spin models in both two- and one-dimensional geometries. We illustrate the possibilities on a simple XY ladder model and show how Dimer phases occurring in this model are robust against disorder and decoherence, and could be observed within state-of-the-art experiments.

[1] M. Dalmonte, S. Mirzaei, P. R. Muppalla, D. Marcos, P. Zoller, G. Kirchmair, PRB **92**, 174507 (2015)

TT 58.11 Wed 15:00 Poster D

Quantum state tomography on long-coherent superconducting transmon qubit — •Andre Schneider, Jochen Braumüller, Steffen Schlör, Martin Weides, and Alexey Ustinov — Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe

The state of a qubit is commonly measured by probing a readout resonator coupled to it with a readout tone and detecting the dispersive shift of the resonator. This measurement only gives access to the z-component of the qubit state. Quantum state tomography provides a measurement for all components of the Bloch vector by rotating the qubit state prior to the readout. We present a method of measuring the Bloch vector components. This method is demonstrated by measuring the time evolution for long-"living" transmon qubits with T_1 and T_2 times in excess of $10\,\mu$s. By recording the decay trace of the qubit state after a slightly detuned $\left(\frac{\pi}{2}\right)^x$ pulse, we detect decay and dephasing as well as Larmor precession of the qubit.

Furthermore, we introduce a benchmark for measuring the qubit manipulation fidelity and optimize the envelopes of the qubit manipulation pulses. Quantum state tomography is a powerful tool to observe changes in the qubit quantum state under interactions with magnonic systems.

TT 58.12 Wed 15:00 Poster D

Characterization of 3D-transmons and rectangular waveguides for transmission experiments — •Lukas Grünhaupt[1], Marcel Langer[1], Jochen Braumüller[1], Andre Schneider[1], Hannes Rotzinger[1], Alexander Averkin[2], Alexey V. Ustinov[1,2], and Martin Weides[1,3] — [1]Institute of Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]National University of Science and Technology MISIS, Moscow 119049, Russia — [3]Material Science in Mainz, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

We report on experiments with 3D-transmon qubits designed and fabricated at KIT. Time domain measurements of our first sample in a 3D aluminum cavity show a lifetime T1 = 1.6 μs and dephasing time T2 = 2.0 μs. By improving the cavity design, we could increase the coherence times by one order of magnitude to T1 = 16 μs and T2 = 13 μs (spin echo dephasing time T2* = 30 μs).

Our goal is to advance the 3D*concept by performing transmission experiments in a rectangular hollow core waveguide, therefore having the superconducting qubit in a truly three-dimensional environment. Consequently, we designed and fabricated a copper waveguide compatible with our cryogenic measurement setup, paying special attention to the impedance matching sections between the coaxial microwave line and the waveguide. We show preliminary transmission measurements at mK temperatures and present the challenges associated with measuring a transmon in a hollow core waveguide.

TT 58.13 Wed 15:00 Poster D

Tuning decoherence in superconducting transmon qubits by mechanical strain — •Jan Brehm, Alexander Bilmes, Georg Weiss, Alexey Ustinov, and Juergen Lisenfeld — Karlsruher Institut fuer Technologie, Karlsruhe, Deutschland

Two-level tunneling systems (TLS) are formed by structural defects in disordered materials. They gained recent attention as an important decoherence source in superconducting qubits, where they appear on surface oxides and at film interfaces. Although the most advanced qubits do not show avoided level crossings arising from a strong coupling to individual TLS, they commonly display a pronounced frequency dependence of relaxation rates, with distinguishable peaks that may point towards weak resonant coupling to single TLS [1]. Previously, we have shown that TLS are tunable via an applied mechanical strain [2]. Here, we employ this method to test whether the characteristic decoherence spectrum of a transmon qubit sample responds to changes in the applied strain, as it can be expected when the decohering bath is formed of atomic TLS. In our experiment, we will employ a highly coherent X-mon qubit sample [1] and tune the strain by bending the qubit chip via a piezo actuator. Our latest results will be presented.

[1] R. Barends et al., PRL **111**, 080502 (2013)
[2] G. J. Grabovskij et al., Science **12**, 232 (2012)

TT 58.14 Wed 15:00 Poster D

Coupling a gate tunable qubit to a 3D cavity — •Steffen Schlör[1], Patrick Zellekens[2], Thomas Schäpers[2], Alexey V. Ustinov[1], and Martin Weides[1,3] — [1]Physikalisches Institut, Karlsruhe Institut of Technology — [2]Peter Grünberg Institut (PGI9), Forschungszentrum Jülich — [3]Institute of Physics, Johannes Gutenberg University Mainz

The goal of the presented work is to implement a voltage tunable superconducting qubit. This kind of circuit could simplify architectures for quantum processors and enable the use of tunable qubits in magnetically sensitive environments. Electrostatic tunability of the Josephson coupling energy can be realized by using a superconductor/semiconductor nanowire as a weak link [1]. The field-dependent charge carrier density in the semiconductor provides a tunable nonlinear inductance.

The presented design includes a 3D microwave cavity promising good isolation of the qubit from the environment. Spectroscopy and time-resolved microwave measurements are performed in a wet ^{3}He/^{4}He cryostat at a temperature of 20 mK. We show simulations of the cou-

pling to the cavity via the electric dipole moment as well as the electromagnetic field distribution. This coupling is important with respect to the electrostatic gate electrode, which has to be implemented without affecting the qubit coherence. Preliminary measurements of the mode spectrum show high internal coherence of the cavity.
[1] Larsen et al., PRL **115**, 127001 (2015)

TT 58.15 Wed 15:00 Poster D

Multiple transmon qubits manipulation and readout through a shared coplanar waveguide resonator — •Ping Yang[1], Jochen Braumülle[1], Andre Schneider[1], Lukas Grünhaupt[1], Lucas Radtke[1], Sebastian Skacel[1], Kirill Shulga[2], Alexey V. Ustinov[1,2], and Martin Weides[1,3] — [1]Physikalisches Institut, KIT, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany — [2]Russian Quantum Center, Moscow region 143025, Russia and National University of Science and Technology MISIS, Moscow 119049, Russia — [3]Materials Science in Mainz, Johannes Gutenberg-Universität Mainz, 55128 Mainz

Superconducting quantum bits (qubits) have attracted significant attention because of their applications for quantum information processing. In order to explore the scalability of superconducting qubits and their collective behavior, we investigate a quantum register formed by up to 8 transmon qubits which could all be manipulated and read out at the same time through a mutual coplanar waveguide resonator. Every qubit is designed to be tunable in frequency and has its own local bias flux. In this way, individual qubits could be either tuned into resonance with the resonator or with each other to allow information exchange, or far detuned to preserve their quantum state. Samples are designed and fabricated in our lab employing electron beam lithography and optical lithography, and then measured in the dilution refrigerator at 20 mK.

TT 58.16 Wed 15:00 Poster D

Quantum Fabry-Perot Interferometer with 3d-transmons — •Maximilian Zanner[1], Lukas Grünhaupt[1], Moritz Kappeler[1], Alexey Ustinov[1,2], and Martin Weides[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]National University of Science and Technology MISIS, Moscow 119049, Russia — [3]Material Science, Johannes Gutenberg University Mainz, 55128 Mainz, Germany

Quantum information processing requires the ability to communicate between different parts within a specific architecture of quantum elements. In order to control the information flux the photons require a propagation channel and non-linear elements. Based on an experiment suggested by Fratini et al. [1] we are trying to build a system of two transmon qubits capacitatively coupled to a rectangular waveguide acting as a Quantum Fabry-Perot Interferometer in the single photon microwave regime. A numerical analysis shows that very unique rectification properties arise caused by the coupling between the two transmon qubits with the waveguide and each other. With the right positioning and detuning of the quantum mirrors it is possible to reach rectification factors of $R > 0.92$. That indicates non-reciprocal effects that were not covered in previous experiments.
[1] F. Fratini et al., PRL **113**, 243601 (2014)

TT 58.17 Wed 15:00 Poster D

Chains of nonlinear and tunable superconducting resonators — •Michael Fischer[1,2,3], Friedrich Wulschner[1,2], Peter Eder[1,2,3], Jan Goetz[1,2], Edwar Xie[1,2,3], Frank Deppe[1,2,3], Kirill Fedorov[1], Hans Hübl[1,2,3], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

We present progress towards the fabrication and characterization of a quantum simulation system of the Bose-Hubbard-Hamiltonian in the driven dissipative regime in the realm of circuit QED. The system consists of series-connected, capacitively coupled, nonlinear and tunable superconducting resonators. The nonlinearity is achieved by galvanically coupled SQUIDs, placed in the current anti-node of each resonator and can be tuned by external coils and on-chip antennas.

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TT 58.18 Wed 15:00 Poster D

Circuit QED with 3D cavities — •Edwar Xie[1,2,3], Peter Eder[1,2,3], Michael Fischer[1,2,3], Jan Goetz[1,2,3], Max Haeberlein[1,2], Karl Friedrich Wulschner[1,2], Frank Deppe[1,2,3], Kirill Fedorov[1], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

In typical circuit QED systems, on-chip superconducting qubits are coupled to integrated coplanar microwave resonators. Due to the planar geometry, the resonators are often a limiting factor regarding the total coherence of the system. Alternatively, similar hybrid systems can be realized using 3D microwave cavities.

Here, we present studies on transmon qubits capacitively coupled to 3D cavities. The internal quality factors of our 3D cavities, machined out of high purity aluminum, are above $1.4 \cdot 10^6$ at the single photon level and a temperature of 50 mK. For characterization of the sample, we perform dispersive shift measurements up to the third energy level of the qubit. We show simulations and data describing the effect of the transmon geometry on it's capacitive properties. In addition, we present progress towards an integrated quantum memory application.

We acknowledge support by the German Research Foundation through SFB 631 and FE 1564/1-1, the EU project PROMISCE, and Elite Network of Bavaria through the program ExQM.

TT 58.19 Wed 15:00 Poster D

Displacement of two-mode squeezed propagating microwave states — •Patrick Yard[1,2], Kirill Federov[1,2], Ling Zhong[1,2,3], Stefan Pogorzalek[1,2], Peter Eder[1,2,3], Michael Fischer[1,2,3], Jan Goetz[1,2], Friedrich Wulschner[1,2], Edwar Xie[1,2,3], Edwin Menzel[1,2], Frank Deppe[1,2,3], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

We study an experimental implementation of the displacement operation on squeezed microwave states. We generate these states using a conventional Josephson parametric amplifier and implement displacement using a specific cryogenic directional coupler. We demonstrate that even for strong displacement amplitudes we do not observe any degradation of the reconstructed quantum states. Furthermore, we investigate the single-mode and two-mode displacement regimes. This allows us to experimentally verify commutation relations between displacement and squeezing operators in a multi-mode case.

We acknowledge support by the German Research Foundation through SFB 631 and FE 1564/1-1, the EU project PROMISCE, and Elite Network of Bavaria through the program ExQM.

TT 58.20 Wed 15:00 Poster D

Implementation of Quantum Stochastic Walks — •Peter Schuhmacher, Luke Govia, Bruno Taketani, and Frank Wilhelm — Universität des Saarlandes

Quantum walks are one of the most prominent frameworks in which to design and think about quantum algorithms. Both the continuous- and discrete-time versions have been shown to provide speed-up over classical information processing tasks , and can be regarded as universal quantum computers. Classical (probabilistic) and quantum unitary random walks yield different distributions due to interference effects. Combining the two, stochastic quantum walks (QSW) can be defined in an axiomatic manner to include unitary and non-unitary effects, and include both classical and quantum walks as limiting cases [1]. While a general purpose quantum computer is still far over the horizon, intermediary technologies have been emerging with the promise to breach classical limitations. Within these, artificial intelligence is one exciting field where the use of quantum physics can lead to important improvements [2]. Here, we focus on the physical realizability of both kinds of quantum stochastic walks (continuous-time and discrete-time).
[1] J. D. Whitfield, C. A. Rodríguez-Rosario and A. Aspuru-Guzik, PRA **81**, 022323 (2010).
[2] H. J. Briegel & G. De las Cuevas, Scientific Reports, 400 (2012).

TT 58.21 Wed 15:00 Poster D

Circuit QED with hybrid metamaterial transmission lines — •Stefan Ruloff, Bruno Taketani, and Frank Wilhelm — Theoretical Physics, Universität des Saarlandes, Saarbrücken, Germany

We're working on the theory of metamaterials providing some interesting results. The negative refraction index causes an opposite orien-

tation of the wave vector **k** and the Poynting vector **S** of the travelling waves. Hence the metamaterial has a falling dispersion relation $\partial\omega(k)/\partial k < 0$ implying that low frequencies correspond to short wavelengths. Metamaterials are simulated by left-handed transmission lines consisting of discrete arrays of series capacitors and parallel inductors to ground [1]. Unusual physics arises when right-and left-handed transmission lines are coupled forming a hybrid metamaterial transmission line [2]. E.g. if a qubit is placed in front of a hybrid metamaterial transmission line terminated in an open circuit, the spontaneous emission rate is weakened or unaffected depending on the transition frequency of the qubit. Some other research interests are the general analysis of metamaterial cavities and the mode structure of hybrid metamaterial cavities for QND readout of multi-qubit operators [3]. Especially the precise answer to the question about the definition of the mode volume of a metamaterial cavity is one of our primary goals.

[1] G. Eleftheriades, A. Iyer & P. Kremer, IEEE Trans. Microw. Theory Tech. **50**, 2702 (2002)
[2] D.J. Egger and F.K. Wilhelm, PRL **111**, 163601 (2013)
[3] L. C. G. Govia et al., Phys. Rev. A **92**, 022335 (2015).

TT 58.22 Wed 15:00 Poster D

Two-qubit Quantum Gates on Qubit Chains — •Raphael Salchner[1], Daniel Egger[2], and Frank Wilhelm-Mauch[3] — [1]Universität des Saarlandes, Saarbrücken, DE — [2]Universität des Saarlandes, Saarbrücken, DE — [3]Universität des Saarlandes, Saarbrücken, DE

Quantum computers are of huge interest for scientific research and applications for their ability to solve exponentially scaling problems. There are several physical implementations of quantum bits, one of them is the superconducting qubit which is built out of Josephson junctions [1]. Usually two qubits are coupled via a resonator, but research has shown that quantum gates can be executed via direct coupling of the qubits [2]. We investigate the effect of weakly coupled idling qubits on two-qubit gate operations. We use numerical optimal control algorithms (GRAPE, Nelder-Mead Simplex) [3] to find control pulses for the Controlled-Z gate, which is important for entangling two qubits. The results indicate that already one spuriously coupled idling qubit can cause the optimization to reach less than 99% gate fidelity, independent of the positioning of the qubits in the circuit. Additionally, several attempts are made to find control pulses that compel the desired gate, all without relevant success.

[1] D. diVincenzo, "Quantum Information Processing: Lecture Notes", 44th IFF Spring School vol. 52, FZ Jülich (2013)
[2] R. Barends et al, arXiv:1402.4848
[3] Navin Khaneja et al., J. Magn. Reson. **172**, 296 (2005)

TT 58.23 Wed 15:00 Poster D

Purcell filtering in circuit QED - Markovian and non-Markovian theory — •Dominik Schramm[1], Frank Wilhelm[1], and Karl-Peter Marzlin[2] — [1]Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Department of Physics, St. Francis Xavier University, Antigonish, Nova Scotia, B2G 2W5, Canada

In circuit QED the measurement fidelity is limited by the Purcell effect, which means a decay of the qubit state through the resonator into the transmission line. This energy leakage can be suppressed by using a bandpass Purcell filter. We study decoherence effects of a system with a Purcell filter by deriving a master equation for the reduced density matrix. We look at the crossover between resonant and dispersive regime. We study in particular the non-Markovian regime to compare the Purcell filter to other suppression methods.

TT 58.24 Wed 15:00 Poster D

Interacting two-level defects as sources of fluctuating high-frequency noise in superconducting circuits — •Clemens Müller[1], Jürgen Lisenfeld[2], Alexander Shnirman[3,4], and Stefano Poletto[5] — [1]ARC Centre of Excellence for Engineered Quantum Systems, The University of Queensland, Brisbane, Austrlalia — [2]Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe, Germany — [3]Institut für Theory der Kondensierten Materie, Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]LD Landau Institute for Theoretical Physics, Moscow, Russia — [5]IBM TJ Watson Research Centre, Yorktown Heights, USA

Since the very first experiments, superconducting circuits have suffered from strong coupling to environmental noise, destroying quantum coherence and degrading performance. In state-of-the-art experiments, it is found that the relaxation time of superconducting qubits fluctuates as a function of time. We present measurements of such fluctuations in a 3D-transmon circuit and develop a qualitative model based on interactions within a bath of background two-level systems (TLS) which emerge from defects in the device material. In our model, the time-dependent noise density acting on the qubit emerges from its near-resonant coupling to high-frequency TLS which experience energy fluctuations due to their interaction with thermally fluctuating TLS at low frequencies. We support the model by providing experimental evidence of such energy fluctuations observed in a single TLS in a phase qubit circuit.

TT 58.25 Wed 15:00 Poster D

Decoherence dynamics in a finite-size quantum Ising model. — •Cyril Saussol, Wolfgang Belzig, and Gianluca Rastelli — University of Konstanz Fachbereich Physik D-78457, Konstanz, Germany.

We study the non-equilibrium dynamics of a quantum Ising chain with N spins coupled to a bath. We consider as initial state an entangled state formed by two many-spin classical states. In the limit in which the transversal magnetic field (TMF) vanishes, the system contains a decoherence-free subspace (DFS). Moreover, this model has also an exact solution. Hence we tackle the problem by using a perturbative approach in the TMF to study the decoherence dynamics. In particular, we are interested to calculate analytically the decoherence time if the system is initialized in an entangled state of the DFS. Finally, we discuss the perspectives of how to prepare optimal, initial entangled states (formed by more than two classical states) in order to increase the decoherence time.

TT 58.26 Wed 15:00 Poster D

Proximity effect in normal-superconductor hybrids for quasiparticle traps — •Amin Hosseinkhani — Peter Grunberg Institute (PGI-2), Forschungszentrum Julich, D-52425 Julich, Germany — JARA-Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

Coherent transport of charges in the form of Cooper pairs is the main feature of Josephson junctions which plays a central role in superconducting qubits. However, the presence of quasiparticles in superconducting devices may lead to incoherent charge transfer and limit the coherence time of superconducting qubits. A way around this so-called "quasiparticle poisoning" might be using a normal-metal island to trap quasiparticles; this has motivated us to revisit the proximity effect in normal-superconductor hybrids. Using the semiclassical Usadel equations, we study the density of states (DoS) both within and away from the trap. We find that in the superconducting layer the DoS quickly approaches the BCS form; this indicates that normal-metal traps should be effective at localizing quasiparticles.

TT 58.27 Wed 15:00 Poster D

shot noise of 1,4-benzenedithiol single-molecule junctions — •Amin Karimi[1], Safa Golrokh[1], Markus Herz[1], Ryoma Hayakawa[1,2], Fabian Pauly[1], and Elke Scheer[1] — [1]Department of Physics, University of Konstanz, Konstanz, Germany — [2]Advanced Electronic Materials Center, National Institute for Materials Science, Namiki, Tsukuba, Japan

Shot noise measurements represent an important tool to characterize quantum transport through nanoscale junctions [1,2]. However, noise measurements are difficult since extrinsic noise sources have to be carefully discarded from the intrinsic signal. We present here a much simpler experimental technique compared to established methods that is operational over several orders of magnitude of conductance and noise. It does not impose additional requirements on the measurement wiring and uses solely commercially available electronics. The performance of the system is tested by investigation of established gold single-atom contacts. We then apply the novel method to single-molecule contacts of benzenedithiol (BDT) between Au electrodes. Our study hence reports that Au-BDT-Au is a molecular junction with a widely tunable conductance. It represents the conceptually simplest quantum system, namely a single channel, quantum coherent junction.

[1] D.Djukic, J. M. van Ruitenbeek, Nano Lett. **6**, 789 (2006)
[2] O. Tal, M. Krieger, B. Leerink, J. M. van Ruitenbeek, PRL **100**, 196804 (2008)

TT 58.28 Wed 15:00 Poster D

Time-dependent transport in molecular junctions using hierarchical quantum master equations — •André Erpenbeck, Christian Schinabeck, Lukas Götzendörfer, and Michael Thoss — Institut für Theoretische Physik und Interdisziplinäres

Zentrum für Molekulare Materialien (ICMM), Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7/B2, D-91058 Erlangen, Germany

Time-dependent currents in molecular junctions can be caused by structural fluctuations or interaction with external fields. In this contribution, we demonstrate how the hierarchical quantum master equation approach can be used to study time-dependent transport in a molecular junction. This reduced density matrix methodology provides an accurate solution to the transport problem including time-dependent energy levels, molecule-lead coupling strengths and transitions between electronic states of the molecular bridge. Employing representative models, the influence of such time-dependencies on the electronic current is analyzed in some detail.

TT 58.29 Wed 15:00 Poster D

Conductance through a ferrocene based molecule — Karthiga Kanthsamy[1], •Ejvind Olsen[1], David Zsolt Manrique[3], Qusiy Al Galiby[3], Christoph Tegenkamp[1,2], Colin Lambert[3], and Herbert Pfnür[1,2] — [1]Institute für Festkörperphysik, Leibniz University Hannover, Hannover, Germany — [2]Laboratory for Nano and Quantum Engineering, Leibniz University Hannover, Hannover, Germany — [3]Department of Physics, Lancaster University, Lancaster LA 14YB, United Kingdom

We investigate the electrical transport through 1,1'-bis [4-thio acetyl phenyl] ferrocene (FBPDT) molecule using mechanically controllable break junction technique (MCBJ). The junctions were broken in vacuum. Two types of measurements were done. First, conductance were measured at constant voltage by repeated opening and closing of the junction. Step-wise change in conductance values are observed below 1G0 after molecular adsorption. The histogram shows dominant peaks at 0.017G0 and 0.002G0. Second, the IV characteristics were measured at stable conductance values below 1G0 which remain linear, but conductance decreases with increasing distance between the electrodes. The theoretical calculations based on density functional theory and non-equilibrium Green's function formalism shows that the rotation of the phenyl ring influences the transmission through the molecule. The molecule is energetically degenerate irrespective of rotation of phenyl ring angle with respect to the cyclo pentyl ring. The phenyl rings act as tunneling barriers resulting in lower conductance compared to ferrocene dithiol.

TT 58.30 Wed 15:00 Poster D

Improved auxiliary-mode approach to time-dependent electron transport — •Bogdan Popescu and Alexander Croy — Max Planck Institut for the Physics of Complex Systems

The theoretical description of time-resolved phenomena in nanoscale devices remains a very challenging task. Several formalisms are available, but efficient approaches for general-purpose computations are still under investigation. In [1] it was proposed to use an auxiliary-mode expansion of the self-energies arising in the time-dependent non-equilibrium Greens function (TDNEGF) formalism. To this end the Fermi function and the level-width function are expanded in terms of simple poles (Lorentzians). This procedure converts the integro-differential equation for the reduced density-matrix into a set of coupled differential equations for auxiliary matrices.

In this contribution we present an improved version of the auxiliary-mode approach, where the auxiliary matrices are replaced by vectors or scalars. This drastically reduces the computational effort and memory requirement of the method. We demonstrate the method using a molecular wire and graphene nanoribbons as examples.

[1] A. Croy and U. Saalmann, PRB **80**, 245311 (2009)

TT 58.31 Wed 15:00 Poster D

Resistance study of the unusual metal-insulator-transition in the organic charge-transfer salt κ-(BEDT-TTF)$_2$Hg(SCN)$_2$Cl — •C. Delleske[1], D. Zielke[1], E. Gati[1], H. Schubert[1], J.A. Schlueter[2], and M. Lang[1] — [1]Physikalisches Institut, SFB TR 49, Goethe Universität, 60438 Frankfurt, Germany — [2]Materials Science Division, Argonne National Laboratory, Argonne, IL 60439, USA

Materials close to a correlation-driven metal-insulator transition are known to show a variety of intriguing phenomena such as anomalous metallic and superconducting states. The organic charge-transfer salts of the BEDT-TTF family provide an ideal playground for studying the interplay between metallic and insulating phases, because of the simultaneous action of on-site and inter-site Coulomb repulsion and their low-dimensionality. Recently, κ-(BEDT-TTF)$_2$Hg(SCN)$_2$Cl has attracted particular interest since it shows a metal-insulator transition at $T_{MI} = 30\,\mathrm{K}$ which has been assigned to charge order [1] , in combination with very strong frustration ($t'/t = 0.84$) [2]. In this contribution, we investigate the in-plane resistivity of crystals which have been grown in our own laboratory. We show that the resistivity jump at the transition is as high as reported in literature [3] indicating comparable high quality of our crystals. A significant hysteresis at the phase transition can be observed in contrast to literature results [3]. Furthermore, we discuss anomalous hysteresis effects in the metallic state.

[1] N. Drichko et al., PRB **89**, 075133 (2014)
[2] H. Jeschke, private communication
[3] S. Yasin et al., Physica B **407**, 1689 (2012).

TT 58.32 Wed 15:00 Poster D

Charge Carrier Dynamics in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl: From Mott Insulator to Quantum Spin Liquid — •Jana-Isabelle Polzin[1], Benedikt Hartmann[1], Takahiko Sasaki[2], and Jens Müller[1] — [1]Institute of Physics, Goethe University Frankfurt, Germany — [2]Institute for Materials Research, Tohoku University, Sendai, Japan

The organic charge transfer salts κ-(ET)$_2$X are model systems for studying strongly-correlated charge carriers and the Mott metal-insulator transition in reduced dimensions. Conducting layers of ET molecules are separated by thin, insulating anion layers X, resulting in a quasi-2D electronic band structure. The ET molecules are arranged in dimers forming a triangular lattice. One free charge carrier exists per dimer, its spin being geometrically frustrated. The Mott insulator κ-(ET)$_2$Cu[N(CN)$_2$]Cl exhibits a gap in the charge-carrying excitations caused by the Coulomb interaction between the electrons and shows antiferromagnetic ordering at $T_N \approx 27\,K$. Recently, it has been shown that disorder induced by X-ray irradiation drives the Mott insulating state with long-ranged antiferromagnetic order into a quantum spin liquid state [1]. We perform comparative measurements of fluctuation (noise) spectroscopy on pristine and irradiated (disordered) samples in order to investigate the changes in electronic transport mechanism and low-frequency charge carrier dynamics [2] when tuning the Mott insulator to the spin liquid ground state.

[1] T. Furukawa et al., PRL **115**, 077001 (2015).
[2] B. Hartmann et al., PRL **114**, 216403 (2015).

TT 58.33 Wed 15:00 Poster D

Transport and thermodynamic studies of the unusual metal-insulator transition in κ-(BEDT-TTF)$_2$Hg(SCN)$_2$Cl under He-gas pressure — •D. Zielke[1], E. Gati[1], S. Köhler[1], S. Winter[1], H. Schubert[1], P. Lunkenheimer[2], J. A. Schlueter[3], and M. Lang[1] — [1]Institute of Physics, SFB/TR49, Goethe-University, Frankfurt, Germany — [2]University of Augsburg, Center for Electronic Correlations & Magnetism, SFB/TR80, Germany — [3]Materials Science Division, Argonne National Laboratory, USA

Organic charge-transfer salts of the BEDT-TTF family show a wide variety of electronic phases resulting from the interplay of strong on-site and inter-site Coulomb repulsion along with low dimensions. The quasi-2D κ-(BEDT-TTF)$_2$Hg(SCN)$_2$Cl is distinct by a high degree of frustration of $t'/t = 0.84$ (at 50 K) [1] and reveals an unusual metal-insulator transition at $T_{\mathrm{MI}} = 30\,\mathrm{K}$ which has been associated with charge-order [2]. We present a study of dc resistance measurements at ambient and at finite hydrostatic He-gas pressure. We find that the MI transition can be rapidly shifted towards lower temperatures with increasing pressure. At $P = 97\,\mathrm{MPa}$ the system remains metallic down to 2.4 K. In addition, our results of thermal expansion measurement show discontinuous changes of the lattice parameters at T_{MI} accompanied by hysteresis which prove the 1$^{\mathrm{st}}$-order character of this transition, in contrast to literature results [3]. Moreover, we observe a glass-like transition at $T_{\mathrm{g}} \approx$ 60-65 K which is consistent with recent calculations [4].

[1] H. Jeschke, priv. comm.
[2] N. Drichko *et al.*, PRB **89**, 075133 (2014).
[3] S. Yasin *et al.*, Physica B **407**, 1689 (2012).
[4] Müller *et al.*, NJP **17**, 083057 (2015).

TT 58.34 Wed 15:00 Poster D

Origin of the Glasslike Dynamics in Molecular Conductors κ-(BEDT-TTF)$_2$X — •Benedikt Hartmann[1], Robert Rommel[1], Jens Brandenburg[1], Steve M. Winter[1], John Schlueter[2], Takahiko Sasaki[3], and Jens Müller[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (M), Germany — [2]Argonne

National Laboratory, Materials Science Division, Argonne (IL), USA — [3]Institute for Materials Research, Tohoku University, Sendai, Japan

The organic molecular conductors κ-(BEDT-TTF)$_2$X exhibit a structural glasslike transition, which can be utilized (i) to modify the correlation strength of the charge carriers close to the Mott metal insulator transition [1], as well as (ii) to study the influence of intrinsic molecular disorder [2]. A deeper microscopic understanding, however, has been lacking. In this contribution we demonstrate that fluctuation (noise) spectroscopy is an effective technique to access the intrinsic properties of the glasslike transition [3]. The temperature dependence of 1/f-type fluctuations can be described by a Vogel-Fulcher-Tamman law, allowing to classify the κ-(BEDT-TTF)$_2$X-salts as highly fragile orientational glasses. Heat pulse experiments and supporting ab initio calculations provide an explanation for the origin of the observed glassy dynamics in κ-(BEDT-TTF)$_2$X in terms of a simple two-level model, making quantitative statements possible and predictions for the occurrence of glassiness in different κ-(BEDT-TTF)$_2$X systems feasible [3].

[1] B. Hartmann et al., PRL **114**, 216403
[2] B. Hartmann et al., PRB **90**, 195150
[3] J. Müller et al., NJP **17**, 083057

TT 58.35 Wed 15:00 Poster D

Inplane anisotropy of the critical field of α-(BEDT-TTF)$_2$MHg(SCN)$_4$ (M = K, Tl) — •Michael Kunz[1,2], Luzia Höhlein[1,2], Sebastian Jakob[1,2], Werner Biberacher[1], Harald Müller[3], Natalya Kushch[4], and Mark Kartsovnik[1] — [1]Walther-Meißner-Institut, Garching, Deutschland — [2]Technische Universität München, Garching, Deutschland — [3]European Synchrotron Radiation Facility, Grenoble, France — [4]Institute of Problems of Chemical Physics, Chernogolovka, Russia

The quasi-two-dimensional organic metals α-(BEDT-TTF)$_2$MHg(SCN)$_4$ (M = K, Tl) undergo a transition into a charge-density-wave (CDW) state with a transition temperature of $T_{\mathrm{CDW}} \approx 8.5\,\mathrm{K}$ for the K-compound and $T_{\mathrm{CDW}} \approx 10\,\mathrm{K}$ for the Tl-compound. At even lower temperatures an inhomogeneous superconducting (SC) state emerges with an onset temperature between 0.3 and 0.5 K. By applying pressure the CDW state can be completely suppressed, giving way to a homogeneous bulk SC state with a sharp transition. We present the azimuthal anisotropy of the upper critical field of α-(BEDT-TTF)$_2$MHg(SCN)$_4$ (M = K, Tl) studied at different pressures above and below the critical pressure where the CDW state is fully suppressed. The experimental results are analyzed in relation to multiple band contributions to SC pairing and possible manifestations of exotic superconductivity.

TT 58.36 Wed 15:00 Poster D

Stamp transfer of carbon nanotubes for nano-electromechanics — Dominik Berndt, Patrick Steger, Julian Heger, Karl Götz, Korbinian Mühlberger, Nicola Paradiso, Christoph Strunk, and •Andreas K. Hüttel — Institute for Experimental and Applied Physics, Universität Regensburg, Regensburg, Germany

Growing "ultraclean" carbon nanotubes via chemical vapour deposition (CVD) over pre-existing contact structures involves high temperatures ($\sim 900°\mathrm{C}$) and aggressive gases (CH_4 and H_2). Consequently this procedure imposes many limitations on the choice of the contact material, in particular regarding superconductors. Many metal thin films are either destroyed during the CVD-process or lose superconducting properties. The alternative explored here is to grow the carbon nanotubes on a separate chip and mechanically transfer them to the Si/SiO_2 chip with contact electrodes. We use a stamping procedure, growing nanotubes on a transparent SiO_2 substrate which is subsequently pressed onto the electrode chip. There the nanotubes are suspended over superconducting Nb contacts with a thickness of 100nm, separated by a 500nm wide trench. In low temperature transport, we examine gate dependence of the conductance, influences of the superconducting contacts, and mechanical features of the transferred nanotubes. The transfer method can be used for all those applications requiring materials that would not withstand the CVD growth conditions.

TT 58.37 Wed 15:00 Poster D

Magnetic field induced electron-vibron coupling in a carbon nanotube quantum dot — •Peter Stiller, Daniel Schmid, Christoph Strunk, and Andreas Hüttel — Institute for Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Quantum dots defined in suspended single wall carbon nanotubes define a nano-electromechanical system where clear quantized harmonic oscillator behaviour becomes visible. We present transport measurements on a clean nanotube device tuned to the few electron regime, i.e., having a highly localized electronic system. Here, we demonstrate the emergence of Franck-Condon sidebands in single electron tunneling, corresponding to the longitudinal vibration, induced by a finite magnetic field along the carbon nanotube axis. The Franck-Condon coupling factor g increases with magnetic field and saturates at $B \approx 5$ T. The behaviour of the sidebands attached to different electronic quantum states is compared, and tentative models are discussed.

TT 58.38 Wed 15:00 Poster D

Current flow paths in bent and deformed carbon nanotubes — •Eric Kleinherbers[1], Thomas Stegmann[1,2], and Nikodem Szpak[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

Due to imminent applications in nanoelectronics it is of high interest to understand the precise conductance properties of bent or deformed carbon nanotubes. Since low-energy electronic excitations in graphene behave like massless Dirac fermions the current flow can be approximated semiclassically and used as a guide in the design of conducting nanotube-elements. Taking into account the curvature effects as well as an emerging inhomogeneous pseudo-magnetic field we calculate the current flow paths theoretically and compare them with numerical simulations of the full electronic transport.

TT 58.39 Wed 15:00 Poster D

Magnetic field-effect transistor in carbon nanotubes — •Magdulin Dwedari[1], Thomas Stegmann[1,2], and Nikodem Szpak[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

It is well known that low-energy electronic excitations in graphene behave like massless Dirac fermions. Since particles (excitations) and antiparticles (holes) react oppositely to the magnetic field a magnetic field-effect transistor emerges when a carbon nanotube is placed in a perpendicular magnetic field and contacted appropriately. We calculate the current flow theoretically within a semiclassical model and simulate it numerically.

TT 58.40 Wed 15:00 Poster D

Gap engineering in strained carbon nanotubes with parallel magnetic field — •Lennart Korsten[1], Thomas Stegmann[1,2], and Nikodem Szpak[1] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]Instituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

Strain and curvature in carbon nanotubes influence the distances and angles between the atomic orbitals. In the tight-binding description of electronic excitations, this leads to anisotropic tunneling amplitudes and to the shift of Dirac points in the energy dispersion relation. Since application of a parallel magnetic field can also move the Dirac points it can be used for opening or closing the energy gap as well as for precise measurements of the strain and curvature effects. We calculate these effects theoretically and simulate the electronic transmission numerically.

TT 58.41 Wed 15:00 Poster D

Current flow paths in deformed graphene: pseudo-magnetic field vs curvature — •Nikodem Szpak[1] and Thomas Stegmann[1,2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Duisburg — [2]nstituto de Ciencias Fisicas, Universidad Nacional Autonoma de Mexico, Cuernavaca

We compare two fundamentally different approaches to the electronic transport in deformed graphene: a) current flow paths obtained with the non-equillibrium Green's function (NEGF) method from the tight-binding model with local strain, b) classical trajectories for relativistic point particles moving in a curved surface with pseudo-magnetic field. The connection between them is established in the long-wave limit via an effective Dirac Hamiltonian in curved space. Geometrical optics approximation applied to focused current beams allows to directly compare the wave and the particle pictures. We obtain very good numerical agreement between the quantum and the semiclassical approaches for a fairly wide set of parameters. We propose a new mechanism of geometric lensing of currents which can find applications

in nanoelectronics.

TT 58.42 Wed 15:00 Poster D

Landau quantized Dirac electrons in a photon cavity — •Lisa Hesse and Klaus Richter — Universität Regensburg, Institut für Theoretische Physik, 93040 Regensburg, Germany

We consider Landau quantized monolayer graphene exposed to an electromagnetic cavity mode. Due to the large degeneracy and Dirac-type characteristics of the Landau-level spectrum graphene is meant to show collective excitation effects under the influence of the additional radiation field in a resonant strong light-matter-coupling regime [1]. The controversially discussed [1, 2, 3] question about the existence of such Dicke-type superradiant quantum phases and connected phenomena due to photon-induced cyclotron transitions opens a challenging subfield of research in graphene. On the basis of a realistic tight-binding simulation we study the interaction of resonant cavity photon modes with Landau quantized states in graphene focusing on the spectral properties of this hybrid system.

[1] D. Hagenmüller and C. Ciuti, PRL **109**, 267403 (2012)
[2] L. Chirolli, M. Polini, V. Giovannetti and A. H. MacDonald, PRL **109**, 267404 (2012)
[3] F. M. D. Pellegrino, L. Chirolli, R. Fazio, V. Giovannetti and M. Polini, PRB **89**, 165406 (2014)

TT 58.43 Wed 15:00 Poster D

Spin-Transport in Graphene with Agregated Hydrogen Clusters — •Fedor Tkatschenko, Jan Bundesmann, Denis Kochan, Jaroslav Fabian, and Klaus Richter — Institut für Theoretische Physik Universität Regensburg

Hydrogen on graphene acts as resonant impurity and in addition can lead to formation of local magnetic moments. Both effects reduce the spin lifetime by orders of magnitude [1]. This can explain the discrepancy between predicted long spin lifetimes compared to the short ones measured in experiments. However, some experiments report a longer spin lifetime after increasing the H concentration [2].

We argue that above some threshold concentration the probability for formation of H-clusters like dimers or trimers strongly increases. The collective impact from H-clusters can differ from isolated H-atoms. This is reflected in the systems electronic structure. Using a single-orbital tight binding approach we calculate the electronic structure for H-clusters on graphene which is shown to be in good agreement with DFT calculations. Furthermore we perform quantum transport calculations and extract the influence on the spin lifetime. We find that the exact configuration of the clusters like the sublattice occupation is essential, as it decides whether magnetic moments are formed or the position of the resonant state.

[1] D. Kochan, M. Gmitra and J. Fabian, PRL **112**, 116602 (2014)
[2] M. Wojtaszeck, I. J. Vera-Marun, T. Massen and B. J. van Wees, PRB **87**, 081402(R) (2013)

TT 58.44 Wed 15:00 Poster D

Spin and Charge Transport in Tailored Carbon Allotropes such as Doped Graphene — •Marie-Luise Braatz[1,2], Nils Richter[1,2], Markus Rein[1], Nils-Eike Weber[3], Khaled Parvez[3], Xinlian Feng[4], Hermann Sachdev[5], Klaus Müllen[5], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), 55128 Mainz, Germany — [3]BASF SE, 67056 Ludwigshafen, Germany — [4]Molecular Functional Materials, Dresden University of Technology, 01069 Dresden, Germany — [5]Max Planck Institute for Polymer Research, 55128 Mainz, Germany

Graphene exhibits extraordinary properties, however, pristine graphene does not have a band gap as needed for many applications. One of the routes to change that is chemical doping [1]. Here we investigate the effect of heteroatom-dopants on the structure and on the electronic and magnetic properties of graphene. The growth conditions are varied to achieve different dopant concentrations and the ensuing materials are systematically characterized. Raman spectroscopy is employed to determine the structural effects of doping and transmission electron microscopy (TEM) can reveal the spatial distribution of dopants. Magnetoresistance effects and magnetization are probed to understand the correlation between the structural and magnetotransport properties [2]. By modifying its growth conditions, the electronic, magnetic and structural properties of graphene can thus be tuned.

[1] H. Wang et al., ACS Catal. **2**, 781 (2012).
[2] M. Rein et al., ACS Nano **9**, 1360 (2015).

TT 58.45 Wed 15:00 Poster D

Magnetotransport in Graphene on the Nano Scale — Philip Willke, •Thomas Kotzott, and Martin Wenderoth — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Magnetotransport in graphene gives rise to a variety of fascinating phenomena like the quantum Hall effect and weak and/or strong localization. Often the origin of these phenomena lies on the atomic scale governed by the crystal structure as well as the scattering mechanisms involved. While macroscopic transport measurements only give an average over all scattering contributions, we combine magnetotransport experiments with atomic scale resolution. We introduce a new magnetic field scanning tunneling potentiometry setup to investigate the local voltage drop in epitaxial graphene below the quantum limit. While monolayer and bilayer graphene sheets show a locally varying quadratic magnetoresistance larger than the macroscopic average, scattering processes at localized defects are almost independent of magnetic field.

TT 58.46 Wed 15:00 Poster D

Pressure tuning of the electrical transport properties of the Weyl semimetal NbP — •Ricardo dos Reis, M. O. Ajeesh, Yan Sun, Chandra Shekhar, Marcus Schmidt, Claudia Felser, Binghai Yan, and Michael Nicklas — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Recently enormous attention has been given to a class of material called Weyl semimetal (WSM) due to the prediction of many exotic phenomena, in particular exceptional transport properties, making these systems not only interesting for fundamental research, but also promising materials for novel applications. WSM can be viewed as the hybrid of 3D graphene and topological insulators. The band crossing point, the so-called Weyl point, acts as a magnetic monopole (a singular point of Berry curvature) in momentum space, which always comes in a pairs. If the time-reversal and inversion symmetries are respected, a pair of Weyl points is degenerate in energy, forming another topological phase called Dirac semimetal. Owing this complex band structure the details of the electronic structure can play a significant role in the electrical transport properties of these materials. In this context, external pressure is an important control parameter to effectively tune lattice structures and the corresponding electronic states in a systematic fashion, avoiding the complexity brought by chemical doping. Here, we present a high pressure study of the magnetotransport properties of the Weyl semimetal NbP, which are particularly important to explore novel phenomena and understand the physics behind.

TT 58.47 Wed 15:00 Poster D

Magnetotransport in 3d topological insulator nanowires — •Raphael Kozlovsky, Sven Essert, Cosimo Gorini, Matthias Stosiek, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

We investigate the transport characteristics of nanowires and nanotubes in external electric and magnetic fields, using mainly numerical tools. In particular, we are interested in systems consisting of three-dimensional topological insulator (3d TI) materials, which we model by bulk and surface Hamiltonians. In such 3d-TI nanowires, a magnetic field along the wire leads to prominent Aharonov-Bohm oscillations that indicate the surface nature of the Dirac states forming due to a non-trivial topological invariant. We investigate their transport properties with specific focus on wires with a non-constant radius along the wire direction giving rise to a spatial variation of the enclosed magnetic flux.

TT 58.48 Wed 15:00 Poster D

Superconductivity in Dirac semimetals — •Tatsuki Hashimoto[1], Shingo Kobayashi[1], and Masatoshi Sato[2] — [1]Nagoya university, Nagoya, Japan — [2]Kyoto university, Kyoto, Japan

In this presentation, we would like to discuss the superconductivity in Dirac semimetals. Dirac semimetal is a material that hosts topologically protected bulk Dirac cones and surface Fermi loop. It has been revealed that the unique spin-orbit interaction in the Dirac semimetals stabilize the unconventional superconductivity. Experimentally, the zero-bias conductance peak that suggests the realization of topological superconductivity has been observed in Cd_3As_2.

We use a $k \cdot p$ Hamiltonian around Γ point with spin and orbital degrees of freedom to describe the Dirac semimetal. For the model, we propose six types of k-independent pair potentials, where two of them are trivial pairings and others are topological ones. By introducing

a single band description of the pair potentials, it is found that the superconducting gap and d-vector have the characteristic structure in each pair potential. To see these, we calculate the electronic specific heat and spin susceptibility and confirm that we can distinguish these superconducting states experimentally. In addition to the bulk physical properties, we also calculate the surface state by using the recursive Green's function method. It is find that either arc or flat shape Andreev bound states appear on the surface depending on the parity of mirror reflection symmetry.

TT 58.49 Wed 15:00 Poster D

Transport and Pairing properties of Helical Edges with Proximity induced Superconductivity and Ferromagnetism — •Felix Keidel[1], François Crépin[2], Pablo Burset[1], and Björn Trauzettel[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, UPMC, Sorbonne Universités, 75252 Paris, France

The scientific interest in Quantum Spin Hall systems is far from declining. While these certainly are fascinating by themselves, there is plenty of new and exciting physics to arise when superconductivity and ferromagnetism are brought into the game. The strong constraint of helicity in the edge states of a two-dimensional topological insulator is responsible for an intimate relation between the allowed scattering processes in a hybrid junction and the parameters of the system, namely the superconducting order parameter and the magnetic field. In our work, we study a helical liquid in proximity to a conventional s-wave superconductor and ferromagnetic insulators by means of a Green's function analysis. The ferromagnet gives rise to sub-gap Andreev/Majorana bound states and non-local crossed Andreev reflection (CAR), both of which decisively affect the pairing and transport properties of the junction. As a result, the simple s-wave symmetry of the superconductor is enrichened and unconventional odd-frequency triplet superconductivity emerges. Strikingly, we have identified a setup that favors CAR over electron co-tunneling and may allow for the indirect measurement of the symmetries of the superconducting order parameter.

TT 58.50 Wed 15:00 Poster D

Optical Measurement of Carrier Mobilities in the Topological Insulator $BiSbTeSe_2$ — •Henning Kuhn, Jingyi Zhu, Matteo Montagnese, Zhiwei Wang, Yoichi Ando, and Paul H.M. van Loosdrecht — 2.Physikalisches Institut, Universität zu Köln

Transient Grating Spectroscopy, an ultrafast pump-probe technique, is employed to investigate the non-equilibrium transport properties of the topological insulator (TI) $BiSbTeSe_2$.

An optically generated periodic modulation pattern of electronic excitations is created at the surface of the TI and its decay is observed, both through the use of 100fs pulses from a mode locked Ti:Sapphire laser system. Experiments are performed in the temperature range from 10K to 300K using a heterodyne detection scheme, which, among other, show clear coherent phonon excitations. From the transient grating decay times, carrier diffusivities and thus carrier mobilities are extracted. The obtained temperature dependence of the mobility will be discussed in terms of the recently proposed puddle model, paying special attention to a potential contribution from surface carriers.

TT 58.51 Wed 15:00 Poster D

Fano Resonances in Majorana Bound State - Quantum Dot Systems — •Alexander Schuray, Luzie Weithofer, and Patrik Recher — TU Braunschweig, Institute for Mathematical Physics, Braunschweig

Majorana bound states (MBS) have recieved a lot of attention in the last years and first experiments with nanowires in proximity to a superconductor [1] possibly present first experimental evidence for their existence.

Systems in which MBS are coupled via a quantum dot to normal leads are also gaining interest, as the parameters of the dot provide an interesting handle for transport signatures [2]. In contrast to previous studies, here we consider two MBS with non-zero overlap coupled to a lead on one side and a quantum dot on the other side. Using the Keldysh formalism we derive the cumulant generating function (CGF) for the tunnel currents in the leads [3]. We show that this setup exhibits a Fano-resonance which we interpret as resulting from interference of two different transport channels. Finally, we validate numerically that our result for this simple model is also applicable to a realistic setup of quantum wire and dot.

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Full Counting Statistics of Chiral Majorana Fermions — Alexander Schuray, •Luzie Weithofer, and Patrik Recher — TU Braunschweig, Institute for Mathematical Physics, Braunschweig

In recent years many detection schemes for chiral Majorana fermions interferometers [1] in which the current or noise is used to identify the Majorana character of the propagating edge states have been proposed. Here, we derive a general formalism to find the general transport properties for chiral Majorana fermions coupled to normal leads. For this we employ Full Counting Statistics [2-3], a Keldysh-technique based method, to find the so-called cumulant generating function (CGF), an expression that gives an insight into the elementary transport processes and from which the full statistics of the current can be obtained by differentiation. Our method reproduces the known results of different interferometers, like Fabry Perot [4] or Hanbury Brown-Twiss [5] in a concise way. Finally, we apply it to a three-terminal setup and discuss its transport properties.

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Influence of Andreev tunneling on the full counting statistics — •Philipp Stegmann and Jürgen König — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

We theoretically discuss the influence of Andreev tunneling on the full counting statistics of charge transfer. The slightest presence of Andreev tunneling yields qualitative different generalized factorial cumulants [1] for the short-time limit in comparison to the nonsuperconducting case. We illustrate this behavior for a superconducting lead weakly tunnel coupled to a normal-state metallic island [2]. By means of this example system, we demonstrate that generalized factorial cumulants can detect the presence of Andreev tunneling for longer times as well if the dependence on the parameter s or the visibly of interactions [1, 3, 4] is studied.

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Effect of the electromagnetic environment on ac driven tunnel junctions — •Moritz Frey and Hermann Grabert — Physikalisches Institut, Universität Freiburg

We analyze the effect of the lead impedance on a tunnel junction driven by a time-dependent voltage source. The external drive excites the modes of the electromagnetic environment and modifies the dynamical Coulomb blockade effect familiar from dc driven junctions. In particular, we consider the electrical current flowing in the leads of the junction when it is driven by a superposition of a constant and a sinusoidal voltage source. The electromagnetic environment gives rise to a suppression of higher harmonics of the average current. We also investigate the current noise and the validity of fluctuation-dissipation relations. Specific predictions are made for a tunnel junction driven through an LC-circuit as studied recently experimentally [1,2].

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