sität Stuttgart — [4]Institut für Theoretische Physik, Georg-August-Universität Göttingen — [5]Institut für Anorganische und Analytische Chemie JWG-Universität Frankfurt; SFB/TRR49

A quantum critical point (QCP) is found in systems where a phase transition at T = 0 is driven by an external control parameter. Although a QCP takes place at T = 0, inaccessible by experiment, it has a significant influence on the physical properties over a wide range of temperature. Here we concentrate on field-induced QCPs in low-dimensional molecule-based spin systems. The molecular approach enables us to generate materials with magnetic exchange coupling constants weak enough for laboratory fields to drive the system into a new ground state. We present data of the magnetocaloric effect across the saturation field of an antiferromagnetic S = 1/2 Heisenberg chain system. These results compare favourably with theoretical predictions. In additon, we report thermodynamic measurements on the field-induced magnetic transition in coupled S = 1/2 dimer systems.

TT 19.16 Tue 18:15 H 3010

Quantum critical scaling behavior of deconfined spinons — •Flavio Nogueira[1], Steinar Kragset[2], and Asle Sudbo[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin — [2]Department of Physics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

We perform a renormalization group analysis of some important effective field theoretic models for deconfined spinons. We show that deconfined spinons are critical for an isotropic SU(N) Heisenberg antiferromagnet, if N is large enough. We argue that nonperturbatively this result should persist down to $N = 2$ and provide further evidence for the so called deconfined quantum criticality scenario. Deconfined spinons are also shown to be critical for the case describing a transition between quantum spin nematic and dimerized phases. On the other hand, the deconfined quantum criticality scenario is shown to fail for a class of easy-plane models. For the cases where deconfined quantum criticality occurs, we calculate the critical exponent η for the decay of the two-spin correlation function to first-order in $\epsilon = 4 - d$.

TT 20: Transport: Nanoelectronics I - Quantum Dots, Wires, Point Contacts 1

Time: Tuesday 14:00–15:30 Location: EB 202

Invited Talk TT 20.1 Tue 14:00 EB 202

Adiabatic pumping in nanostructures — •Michele Governale — Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany

A DC current can be driven through a mesoscopic conductor in the absence of an applied transport voltage by changing periodically in time some of the properties of the conductor. This transport mechanism is known as pumping. If the time-dependent parameters vary slowly as compared to the characteristic internal time scales of the system, pumping is adiabatic, and the average transmitted charge per cycle depends only on the area of the cycle but not on its detailed timing.

In this talk we present the main theoretical concepts in the field and describe some recent developments, such as pumping trough interacting systems [1,2] and in hybrid superconducting-normal structures [3].

[1] J. Splettstoesser, M. Governale, J. König, and R. Fazio, Phys. Rev. Lett. **95**, 246803 (2005).

[2] J. Splettstoesser, M. Governale, J. König, and R. Fazio, Phys. Rev. B **74**, 085305 (2006).

[3] M. Governale, F. Taddei, R. Fazio, and F. W. J. Hekking, Phys. Rev. Lett. **95**, 256801 (2005).

TT 20.2 Tue 14:30 EB 202

Cooper pair pumping in presence of dissipation — •Valentina Brosco[1], Alexander Shnirman[1,2], Rosario Fazio[3,4], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe, Karlsruhe, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Innsbruck, Austria — [3]International School for Advanced Studies (SISSA), Trieste, Italy — [4]NEST-CNR-INFM and Scuola Normale Superiore, Pisa, Italy

In a Cooper pair pump charge transport is obtained via an adiabatic and periodic manipulation of Josephson couplings or gate voltages and it is a coherent process. Several works investigated the connection between Cooper pair pumping and the geometric and topological properties of the pumping cycle in the parameters space [1]. Recently the predicted relation between Berry's phase and pumped charge was demonstrated experimentally [2]. In the present work we analyze the effects of noise on Cooper pair pumping and we show that dissipation may induce a new geometric contribution in the transferred charge. We show that this contribution can be experimentally distinguished both from the usual pumped charge and from the supercurrent contribution and we propose an experiment where the theory can be probed.

[1] M. Aunola and J. J. Toppari, Phys. Rev. B **68**, 020502 (2003); V. Brosco, R. Fazio, F. W. J. Hekking, and A. Joye, cond-mat/0702333. [3] M.Mottonen, J. J. Vartiainen, and J. P. Pekola, cond-mat/0710.5623.

TT 20.3 Tue 14:45 EB 202

Adiabatic pumping in a quantum dot-Aharonov-Bohm interferometer — •Bastian Hiltscher, Michele Governale, and Jürgen König — Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Germany

We study adiabatic pumping in Aharonov-Bohm interferometers, where a quantum dot is embedded in one or in both arms. Charge pumping occurs if two parameters are changed periodically in time. The limit of small frequencies defines the adiabatic regime.
For our calculations we use a real-time diagrammatic technique and combine the properties of AB interferometers [1] with the properties of adiabatic pumping [2] for dots with strong Coulomb interaction. By performing a perturbation expansion in the pumping frequency and in the tunnel-coupling strength we calculate the magnetic-flux dependence of the pumped charge and compare it with the results for rectification of an AC voltage, which may yield an effective DC current as well.
We get information about the character of adiabatic pumping, which could be interpreted as peristaltic, but phase-coherent. Furthermore we find, that adiabatic pumping and rectification show different symmetries and, thereby, are distinguishable.

[1]J. König and Y. Gefen, Phys. Rev. B **65**, 045316 (2002).

[2]J. Splettstoesser, M. Governale, J. König, and R. Fazio, Phys. Rev. B **74**, 085305 (2006).

TT 20.4 Tue 15:00 EB 202

Non-local Andreev reflection in quantum dots — •David Futterer, Michele Governale, and Jürgen König — Institut für Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Germany

We consider a single-level quantum dot attached to one superconducting and two ferromagnetic leads. The transport through this system is influenced by the interplay of proximity effect, spin accumulation, Coulomb interaction and non-equilibrium due to finite bias voltage.

We employ a real-time diagrammatic technique that accounts for coupling both to ferromagnetic[1] and superconducting[2] leads. We perform a systematic expansion in the tunnel-couplings to the leads. In the limit of large superconducting gap, all orders in the tunnel-coupling strength with the superconductor can be resummed. We calculate the transport properties of the system and identify schemes for detection of non-local Andreev reflection.

[1] M. Braun, J. König, and J. Martinek, Phys. Rev. B **70**, 195345 (2004)

[2] M. G. Pala, M. Governale, and J. König, New J. Phys. **9**, 278 (2007)

TT 20.5 Tue 15:15 EB 202

Cross-Correlations in transport through two parallel quantum dots — •Sebastian Haupt[1,2], Jasmin Aghassi[1], Matthias Hettler[2], and Gerd Schön[1,2] — [1]Institut für theoretische Festkörperphysik, Universität Karlsruhe, 76218 Karlsruhe — [2]Forschungszentrum Karlsruhe, INT, Postfach 3640, 76201 Karlsruhe

We study cross-correlations of currents through two parallel quantum dots coupled to four independent electrodes. The quantum dots are coupled by intra-dot Coulomb interactions but tunneling between the dots is forbidden. The transport is calculated within second-order pertubation expansion in the coupling Γ to the electrodes within a diagrammatic technique. We allow for an intermediate coupling regime up to coupling constants of $\Gamma \sim k_B T$ (where k_b is the Boltzmann constant and the temperature is T). The level energy of the two quantum dots can be independently controlled via gate voltages. [1,2] The cross-correlations show different signs depending on the relation of transport process through the dots. For higher temperatures, the regions of equal sign have a spherical shape, whereas at lower temperature, an anglular "L-shape" is observed. This can be explained by the analysis of the relevant transport processes.

[1] D.T. McClure *et al.*, Phys. Rev. Lett. **98**, 056801 (2007)
[2] J. Aghassi *et al.*, Appl. Phys. Lett. **89**, 052101 (2006), Phys. Rev.B **73**, 195323 (2006)

TT 21: Transport: Graphene and Carbon Nanotubes

Time: Tuesday 15:45–19:00 Location: EB 202

TT 21.1 Tue 15:45 EB 202

Electromagnetic response of graphene. — •Sergey Mikhailov and Klaus Ziegler — Institute for Physics, University of Augsburg, 86135 Augsburg, Germany

Recently discovered new carbon based material - graphene - demonstrates a number of interesting and unusual transport and optical properties. Our recent predictions of a new transverse electromagnetic mode in graphene [1] and of its strongly non-linear electromagnetic behavior [2] shows that this material can be used in terahertz electronics for higher-harmonics generation at microwave and terahertz frequencies. In this work we study the influence of the self-consistent field effects, the radiative decay and the scattering on the non-linear electromagnetic response of graphene, and find the optimal experimental conditions, under which the higher harmonics generation effect can be observed in this material.

[1] S. A. Mikhailov, K. Ziegler, Phys. Rev. Lett. 99, 016803 (2007).
[2] S. A. Mikhailov, Europhys. Lett. 79, 27002 (2007).

TT 21.2 Tue 16:00 EB 202

Diffusion and localization in carbon nanotubes and graphene ribbons — •Norbert Nemec[1], Klaus Richter[1], and Gianaurelio Cuniberti[2] — [1]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Institute for Material Science, TU Dresden, 01062 Dresden

We study transport length scales in carbon nanotubes and graphene ribbons under the influence of Anderson disorder. We present generalized analytical expressions for the density of states, the elastic mean free path and the localization length in arbitrarily structured quantum wires. These allow us to analyze the electrical response near the van Hove singularities and in particular around the edge state in graphene nanoribbons. Comparing with the results of numerical simulations, we demonstrate that both the diffusive and the localized regime are well represented by the analytical approximations over a wide range of the energy spectrum. In graphene nanoribbons, we find that the zigzag edge state causes a strong reduction of the localization length in a wide energy range around the Fermi energy.

TT 21.3 Tue 16:15 EB 202

Aharonov-Bohm effect and broken valley-degeneracy in graphene rings — •Patrik Recher[1,2], Björn Trauzettel[3], Adam Rycerz[4], Yaroslav Blanter[2], Carlo Beenakker[1], and Alberto Morpurgo[2] — [1]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, The Netherlands — [2]Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [4]Marian Smoluchowski Institute of Physics, Jagiellonian University, Reymonta 4, 30-059 Kraków, Poland

We analyze theoretically the electronic properties of Aharonov-Bohm rings made of graphene. We show that the combined effect of the ring confinement and applied magnetic flux offers a controllable way to lift the orbital degeneracy originating from the two valleys, even in the absence of intervalley scattering. The phenomenon has observable consequences on the persistent current circulating around the closed graphene ring, as well as on the ring conductance. We explicitly confirm this prediction analytically for a circular ring with a smooth boundary modelled by a space-dependent mass term in the Dirac equation. This model describes rings with zero or weak intervalley scattering. We compare our analytical model to another type of ring with strong intervalley scattering. For the latter case, we study a ring of hexagonal form with lattice-terminated zigzag edges numerically. We find for the hexagonal ring that the orbital degeneracy can still be controlled via the flux, similar to the ring with the mass confinement.

TT 21.4 Tue 16:30 EB 202

Quantum transport in graphene-based nanosystems — •Jürgen Wurm[1,2], Michael Wimmer[1], Inanc Adagideli[1], Harold Baranger[2], and Klaus Richter[1] — [1]Institut für theoretische Physik, Universität Regensburg, 93040 Regensburg — [2]Department of Physics, Duke University, Durham, NC 27708, USA

We numerically investigate the ballistic transport properties of graphene rings and other graphene-based nanostructures using a recursive Green function algorithm to calculate the conductance. Recently, the first transport experiments in ring systems made of graphene have been reported, and Aharonov-Bohm oscillations in the conductance were observed [1]. While our simulations confirm the Aharonov-Bohm oscillations in rings, as well as other quantum interference phenomena such as weak localization and universal conductance fluctuations in chaotic cavities, we also find effects of conductance suppression that are not present in usual two-dimensional electron gases.

[1] S. Russo, J.B. Oostinga, D. Wehenkel, H.B. Heersche, S.S. Sobhani, L.M.K. Vandersypen, A.F. Morpurgo, cond-mat 0711.1508 (2007)

TT 21.5 Tue 16:45 EB 202

Conductance and mobility of charge carriers in graphene on silicon carbide — •Johannes Jobst[1], Sergey Reshanov[1], Daniel Waldmann[1], Heiko B. Weber[1], Konstantin V. Emtsev[2], and Thomas Seyller[2] — [1]Lehrstuhl für Angewandte Physik, Universität Erlangen-Nürnberg, Staudtstr. 7/A3, 91058 Erlangen, Germany — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

We have studied the electronic transport properties of few-layer graphene grown by thermal treatment of 6H silicon carbide. Both graphene grown on the carbon face and on the silicon face were investigated. The transport properties of large area films were characterized in van der Pauw geometry. Mobilities up to $7000\,\mathrm{cm}^2/\mathrm{Vs}$ were observed. In addition, micrometer-sized Hall bar structures were fabricated, which allowed for the determination of Hall mobility and density of charge carriers. The size of these structures was reduced to atomically flat terraces of the silicon carbide surface. However, opposite to our expectations, Hall mobilities determined in these structures did not exceed values of $1000\,\mathrm{cm}^2/\mathrm{Vs}$. The role of surface contamination is discussed.

TT 21.6 Tue 17:00 EB 202

Photocurrent and radiation induced suppression of transport in graphene — Konstantin Efetov[1,2], Mikhail Fistul[1], and •Sergey Syzranov[1] — [1]Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany — [2]L.D. Landau Institute for Theoretical Physics RAS, 119334 Moscow, Russia

We study the ballistic transport in graphene subject to the coordinate dependent potential $U(x)$ and irradiated by monochromatic electromagnetic field (EF). The resonant interaction of quasi-particles with an external radiation opens *dynamical gaps* in their spectrum, resulting in a strong modification of current-voltage characteristics of graphene junctions. The gaps' values are proportional to the amplitude of EF. We obtain that the quasi-particle transmission in diverse junctions, e.g. unipolar (p-p or n-n) junctions, is determined by the tunneling through the gap, and can be fully suppressed for large enough radiation powers. In the case of a p-n junction, as the height of the potential $U(x)$ is larger than the photon energy, the directed current (*photocurrent*) flows through the junction without any dc bias voltage applied. Such a photocurrent arises as a result of inelastic quasiparti-