TT 29 Transport: Quantum Coherence and Quantum Information Systems - Part 1

Time: Thursday 09:30–12:45 Room: HSZ 304

Invited Talk TT 29.1 Thu 09:30 HSZ 304

Decoherence of fermions subject to a quantum bath — •Florian Marquardt — Sektion Physik, Arnold Sommerfeld Center for Theoretical Physics, und Center for NanoScience, Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 München

The destruction of quantum-mechanical phase coherence by a fluctuating environment is both of fundamental interest and essential for applications of quantum dynamics. While the theory of decoherence is well developed for a two-level system or a single particle, the case of many fermions is less understood, despite its relevance for nanoelectronics.

After giving a general introduction, I will focus on the analysis of decoherence in the most basic interferometer, the Mach-Zehnder setup, whose electronic version has been been realized only recently [1]. Based on our earlier work on the influence of classical noise [2], we have studied the case of a fully quantum-mechanical environment [3]. Using a novel equations-of-motion approach, we have calculated the dephasing rate, including many-body effects like Pauli blocking. I will give a transparent physical interpretation of the results, describe related work on weak localization [4], and discuss the shot noise in the output current.

[1] Y. Ji et al., Nature **422**, 415 (2003); I. Neder et al., cond-mat/0508024.
[2] F. Marquardt and C. Bruder, Phys. Rev. Lett. **92**, 056805 (2004); Phys. Rev. B **70**, 125305 (2004).
[3] F. Marquardt, cond-mat/0410333, to appear in Europhys. Lett. (Dec. 2005).
[4] F. Marquardt, J. v. Delft, R. Smith, and V. Ambegaokar, cond-mat/0510556.

TT 29.2 Thu 10:00 HSZ 304

Landau-Zener transitions in qubits and qubit-oscillator systems — •Martijn Wubs[1], Keiji Saito[2], Sigmund Kohler[1], Yosuke Kayanuma[3], and Peter Hänggi[1] — [1]Institut für Physik, Universität Augsburg, 86135 Augsburg — [2]Department of Physics, Graduate School of Science, University of Tokyo, Bunkyo-Ku, Tokyo 113-0033, Japan — [3]Department of Mathematical Science, Graduate School of Engineering, Osaka Prefecture University, Sakai 599-8531, Japan

In recent years, several solid-state systems have been identified as effective two-level systems, flux qubits and phase qubits for example. An advantage of these 'artificial atoms' is that they can be driven by gate voltages and external radiation fields. These systems are well suited for manipulation via Landau-Zener transitions. In this talk, we first discuss Landau-Zener transitions in a semiclassical model where both the energy difference and the interaction strength between the levels are controlled by external fields [1]. This model is a combination of the classic Landau-Zener and the Rabi problem. The probability of Landau-Zener transitions now depends sensitively on the amplitude, the frequency and the phase of the interaction. Secondly, motivated by recent advances in circuit QED, we studied Landau-Zener transitions in qubits that are strongly coupled to one or several quantum harmonic oscillators. We present exact calculations of some Landau-Zener transition probabilities also for these more complicated quantum systems. Moreover, we discuss the mapping of the quantum model onto the semiclassical model.

[1] M. Wubs, K. Saito, S. Kohler, Y. Kayanuma, P. Hänggi, New J. Phys. **7**, 218 (2005).

TT 29.3 Thu 10:15 HSZ 304

Excitation and Entanglement Transfer and Quantum Critical Points — •Michael J. Hartmann[1,2], Moritz E. Reuter[1,2], and Martin B. Plenio[1,2] — [1]Institute for Mathematical Sciences, Imperial College London, SW7 2PE, UK. — [2]QOLS, The Blackett Laboratory, Imperial College London, SW7 2BW, UK.

We consider analytically and numerically quantum many body systems as quantum channels in the vicinity of their quantum critical point. In our setup two ancillas are weakly coupled to the quantum many body system at different sites and we study the propagation of an excitation and quantum information from one ancilla to the other. We observe two different scenarios: A slow but perfect transfer if the gap between the ground state and the first excited state of the system is large and a fast but un-complete transfer otherwise. We provide a simplified physical model explaining our findings and suggest ways in which they may be employed to detect quantum critical points experimentally.

TT 29.4 Thu 10:30 HSZ 304

Decoherence of spatially separated qubits — •Roland Doll, Sigmund Kohler, Martijn Wubs, and Peter Hänggi — Institut für Physik, Universität Augsburg, 86135 Augsburg

We consider spatially separated qubits coupled to a phonon field which acts as a heat bath and, thus, causes decoherence. For a theoretical description, it is frequently assumed that depending on the spatial separation, either each qubit couples to a separate bath or that all qubits couple via a collective coordinate to one common bath. For weak qubit-bath coupling it is in both cases possible to describe the dissipative dynamics within a Born-Markov approximation, i.e. one neglects memory effects induced by the bath.

In many experimental situations, however, the bath correlation length and the distances between the qubits are comparable such that neither limit is justified. Then it is necessary to take the spatial dependence of the phonon field explicitely into account. We developed a generalized master equation formalism for the dissipative dynamics which becomes intrinsically non-Markovian. The resulting memory effects and the limitations of a Markovian approximation are discussed.

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TT 29.5 Thu 10:45 HSZ 304

Analytic solution for the multiphoton resonances in the mono- and bichromatically driven quantum Duffing oscillator — •Michael Thorwart and Vittorio Peano — Institut für Theoretische Physik IV, Universität Düsseldorf

We investigate the nonlinear response of an anharmonic monostable quantum mechanical resonator to external periodic mono- and bichromatic driving in presence of a harmonic bath. We therefore apply a Floquet-Born-Markovian master equation for the reduced density operator. The quasienergies of the pure system show multiple avoided level crossings corresponding to multiphoton transitions in the resonator. Around the resonances, the master equation can be solved analytically using Van-Vleck perturbation theory. Studying the oscillator position, the lineshape of the resonances will be calculated resulting in simple expressions. For the monochromatic case, we find the general solution for the multiple multiphoton resonances and, most interestingly, a bath-induced transition from a resonant to an antiresonant behavior. In the bichromatic case, the harmonic mixing signals are calculated. Our model finds applications in a suspended nanomechanical beam excited to transverse vibrations as well as for the inductive measurement of a superconducting qubit by a driven Josephson junction.

TT 29.6 Thu 11:00 HSZ 304

Full read and write access to sets of permanently coupled qubits by local control only — •Daniel Burgarth[1] and Vittorio Giovannetti[2] — [1]Department of Physics & Astronomy, University College London, UK — [2]NEST-INFM & Scuola Normale Superiore, Pisa, Italy

We propose a protocol that transfers arbitrary quantum states from a quantum memory to a set of permanently coupled qubits and vice versa by controlling a local subset of qubits only. We give a sufficient condition for the convergence of the protocol and provide some numerical examples. In particular, we demonstrate that perfect state transfer and state preparation is possible on 1d Heisenberg spin chains with random coupling strengths.

— 15 min. break —

TT 29.7 Thu 11:30 HSZ 304

Optimal spin-entangled electron-hole pair pump — •Mikhail Titov[1], Carlo Beenakker[2], and Bjorn Trauzettel[2] — [1]University of Konstanz, Department of Physics, Germany — [2]Instituut Lorentz, Universiteit Leiden, The Netherlands

A nonperturbative theory is presented for the creation by an oscillating potential of spin-entangled electron-hole pairs in the Fermi sea. In the weak potential limit, considered earlier by Samuelsson and Buttiker, the entanglement production is much less than one bit per cycle. We demonstrate that a strong potential oscillation can produce an average of one Bell pair per two cycles, making it an efficient source of entangled flying qubits.

TT 29.8 Thu 11:45 HSZ 304

Spin Decay in a Quantum Dot Coupled to a Quantum Point Contact — •Massoud Borhani, Vitaly Golovach, and Daniel Loss — Department of Physics - University of Basel - Basel - Switzerland

We consider a mechanism of spin decay for an electron spin in a quantum dot due to coupling to a nearby quantum point contact (QPC) with and without an applied bias voltage. The coupling of spin to charge is induced by the spin-orbit interaction in the presence of a magnetic field. We perform a microscopic calculation of the effective Hamiltonian coupling constants to obtain the QPC-induced spin relaxation and decoherence rates in a realistic system. This rate is shown to be proportional to the shot noise of the QPC in the regime of large bias voltage and scales as "aˆ(-6)" where "a" is the distance between the quantum dot and the QPC. We find that, for some specific orientations of the setup with respect to the crystallographic axes, the QPC-induced spin relaxation and decoherence rates vanish, while the charge sensitivity of the QPC is not changed. This result can be used in experiments to minimize QPC-induced spin decay in read-out schemes.

TT 29.9 Thu 12:00 HSZ 304

Nuclear spin state narrowing via gate–controlled Rabi oscillations in a double quantum dot — •Daniel Klauser, W.A. Coish, and Daniel Loss — Departement of Physics and Astronomy, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

We study spin dynamics for two electrons confined to a double quantum dot under the influence of an oscillating exchange interaction. This leads to driven Rabi oscillations between the $|\uparrow\downarrow\rangle$–state and the $|\downarrow\uparrow\rangle$–state of the two–electron system. The width of the Rabi resonance is proportional to the amplitude of the oscillating exchange. A measurement of the Rabi resonance allows one to narrow the distribution of nuclear spin states and thereby to prolong the spin decoherence time. Further, we study decoherence of the two-electron states due to the hyperfine interaction and give requirements on the parameters of the system in order to initialize in the $|\uparrow\downarrow\rangle$–state and to perform a $\sqrt{\mathrm{SWAP}}$ operation with unit fidelity.

TT 29.10 Thu 12:15 HSZ 304

How does a spin decay? A novel time dependent numerical renormalization group approach — •Frithjof B Anders — Theoretische Physik, Universität des Saarlandes, Saarbrücken, Germany

In contrast to equilibrium conditions, the understanding of real-time evolution of many-particle quantum systems is still at its infancy. A novel approach to time dependent non-equilibrium quantum impurity systems based on the numerical renormalization group is presented [1]. As a first application, a spin coupled either a bosonic or a fermionic bath is considered. While the spin-boson model is often used in context of decoherence of qubits as well as for charge transfer reactions in chemistry, the latter describes spin- and charge-relaxation processes in ultra-small quantum dots. I will discuss how the environment governs the time scales of the spin decay in both cases. I will present an outlook to the application of our method to charge transfer dynamics in large functional bio-molecules as well as to DC-currents though ultra-small quantum dots.

[1] F. B. Anders and A. Schiller, Phys. Rev. Lett. 95, 196801 (2005)

TT 29.11 Thu 12:30 HSZ 304

Entanglement scaling in critical two-dimensional fermionic and bosonic systems — •Ming-Chiang Chung — Institut für Theoretische Physik C RWTH Aachen D-52074 Aachen Germany

We study the scaling of entanglement in critical two-dimensional (2D) fermionic and bosonic systems at zero temperature. Our method, which uses coherent states and Green function matrices, is introduced in detail. Examining exactly solvable models, we find that the entanglement entropy for critical 2D systems scales with the linear system size L like $S \sim L \ln L$ for fermions and $S \sim L$ for bosons. For fermions the coefficient of the leading divergence is a function of the chemical potential. We also confirm previous results for noncritical systems.