

TT 13 Transport - Quantum Coherence and Quantum Information Systems

Zeit: Samstag 08:45–12:45

Raum: TU H3027

TT 13.1 Sa 08:45 TU H3027

Relation between high- and low-frequency noise — ●ALEXANDER SHNIRMAN¹, GERD SCHÖN¹, IVAR MARTIN², and YURIY MAKHLIN³ — ¹Institut für Theoretische Festkörperphysik, Universität Karlsruhe — ²Los Alamos National Laboratory, Los Alamos, NM, USA — ³Landau Institute for Theoretical Physics, Moscow, Russia

Low-frequency (1/f) noise dominates the decoherence in most superconducting qubits. Thus it is very important to understand its origin and properties. Recently, coherent two-level systems have been observed in Josephson junctions [1]. These systems influence strongly qubits' dynamics at high (≈ 10 GHz) frequencies. In addition, recent experiments [2] indicate a connection between the high- and low-frequency noise. In this work we note that an ensemble of coherent two-level systems produces simultaneously high- and low-frequency noise. The relation between these two contributions depends on the statistical properties of the ensemble. We analyze several possible distribution functions and relate the results to the known experimental facts. We also note that a similar relation holds for ensembles of many-level fluctuators with discrete spectrum.

[1] R.W. Simmonds et al., Phys. Rev. Lett. 93, 035301 (2004)

[2] O. Astafiev et al., cond-mat/0411216 (2004)

TT 13.2 Sa 09:00 TU H3027

Fermionic Mach-Zehnder interferometer subject to a Quantum Bath — ●FLORIAN MARQUARDT — Department of Physics, Yale University, New Haven, USA

The Mach-Zehnder interferometer represents the simplest possible two-way interference setup, and its recent experimental realization in an electronic system [1] has raised many intriguing questions. The loss of interference contrast with rising voltage or temperature and the shot noise of the output current have been measured. In this talk I will present a theoretical analysis of decoherence in a fermionic Mach-Zehnder interferometer coupled to any quantum mechanical environment [2]. I will discuss the energy-resolved dephasing rate, the connections to the theory of dephasing in weak localization, the importance of Pauli blocking, and the shot noise correction due to the environment. The results will be compared with simpler models of dephasing, including classical noise sources [3].

[1] Y. Ji et al., Nature 422, 415 (2003)

[2] F. Marquardt, cond-mat/0410333 (2004)

[3] F. Marquardt and C. Bruder, Phys. Rev. Lett. 92, 056805 (2004)

TT 13.3 Sa 09:15 TU H3027

Perfect state transfer through dispersive quantum chains — ●DANIEL BURGARTH and SOUGATO BOSE — Department of Physics & Astronomy, University College London, UK

Quantum chains are very promising for the transfer of quantum states along short distances. However, in many cases the transfer is strongly dispersive and its fidelity is in general very small. I will present a simple and experimentally feasible scheme that can achieve perfect state transfer even in the presence of dispersion. It is applicable to a large variety of systems, including Heisenberg spin chains. Furthermore, it has a built-in stability to imperfections, decoherence and dissipation.

TT 13.4 Sa 09:30 TU H3027

Cluster States From Heisenberg Interaction — ●MASSOUD BORHANI — Department of Physics - University of Basel - Switzerland

We show that a special type of entangled states, cluster states, can be created with Heisenberg interactions and local rotations in 2d steps where d is the dimension of the lattice. We find that, by tuning the coupling strengths, anisotropic exchange interactions can also be employed to create cluster states. Finally, we propose electron spins in quantum dots as a possible realization of a one-way quantum computer based on cluster states.

TT 13.5 Sa 09:45 TU H3027

Entanglement measures for multipartite qubit systems and beyond — ●ANDREAS OSTERLOH¹ and JENS SIEWERT² — ¹Institut für Theoretische Physik, Universität Hannover — ²DMFCI, Università di Catania, Catania, Italy

We propose an approach to construct entanglement measures for multipartite systems of qubits, which can be extended to an arbitrary number

of half-integer spins. The essential step is the construction of an operator that we call *comb* in reference to the *hairy ball theorem*. These combs necessarily have to be antilinear operators. A particularly nice feature of this approach is that for qubits (or spin 1/2) the combs are automatically invariant under $SL(2, \mathbb{C})$, which implies that the constructed measures are entanglement monotones by construction. The central idea provides a key to formulate (multipartite) entanglement measures for entanglement of arbitrary subsystems. In order to illustrate our approach, we construct operators for the N -tangle ($N = 3, \dots, 6$) Candidates for maximally entangled states are presented and their tangles are evaluated. An extension towards general half-integer spin is discussed.

TT 13.6 Sa 10:00 TU H3027

Single Electron Spin Dynamics due to Interaction with Nuclear Spins investigated with Time-dependent DMRG — ●ANDREAS FRIEDRICH¹, ALEXANDER V. KHAETSKII², and ULRICH SCHOLLWÖCK¹ — ¹Institut für theoretische Physik C, RWTH Aachen — ²Physics Department, LMU München

We investigate the dynamics of a single electron spin due to its interaction with the underlying spin-1/2 carrying nuclei motivated by decoherence effects in spin-based quantum-bits, like a single electron in a quantum dot which became of central interest in recent years. We study the dependence of characteristic timescales on different initial states and analyze the effects of magnetic fields by means of a special type of time-dependent density-matrix renormalization-group method that allows to prepare different kinds of initial states and let them evolve in time.

TT 13.7 Sa 10:15 TU H3027

Quantum-Error-Correction in spatially correlated quantum-noise — ●ROCHUS KLESSE and SANDRA FRANK — Universität Köln

We study the performance of quantum error-correcting codes in a model that admits error-correlations. The model consists of n spins (qubits) coupled to a common bosonic bath. The amount of error-correlation is determined by the spatial distance d between the spins. We find that the performance of error correcting Calderbank-Shor-Steane codes is very sensitive to error-correlations: while independent errors ($d \rightarrow \infty$) can be effectively corrected, error correlations that are present at vanishing distances d lead to a complete failure of the error correction in the limit of large n . We also discuss the case of intermediate error correlations at finite distances d .

TT 13.8 Sa 10:30 TU H3027

Quantum Frustration in the damped harmonic Oscillator — ●HEINERICH KOHLER¹ and FERNANDO SOLS² — ¹Institut für theoretische Physik, Universität Heidelberg — ²Universidad Complutense Madrid

We study the dissipative properties of a harmonic oscillator subjected to two independent heat baths which couple linearly to its position and to its momentum respectively. We find that the effects of the two heat baths partially cancel each other, due to the noncommutativity of position and momentum (quantum frustration). This leads to unexpected effects as underdamped oscillations in the strong coupling regime. We compare this model with the scenario where only one bath couples linear to the position and the momentum of the central oscillator. In the latter case no quantum frustration effects occur.

Pause

TT 13.9 Sa 11:00 TU H3027

Multiphoton antiresonance and Rabi oscillations of ac driven quantum oscillators — ●M. V. FISTUL¹ and M. I. DYKMAN² — ¹Theoretische Physik III, Ruhr-Universität Bochum — ²Department of Physics and Astronomy, Michigan State University, East Lansing, USA

We report a theoretical analysis of coherent multiphoton quantum transitions of ac driven nonlinear oscillators. We show that these transitions are accompanied by a novel effect, an *antiresonance* of the response. The nonlinear response of a quantum oscillator displays antiresonant dips and resonant peaks with varying frequency of the driving field. The effect is a consequence of special symmetry and is related to resonant multiphoton mixing of several pairs of oscillator states at a time. The shape and magnitude of the dips (peaks) strongly depend on the field. We calculate

the multiphoton Rabi frequency and discuss the possibility to observe the antiresonance and the associated multiphoton Rabi oscillations in various mesoscopic systems, e.g. Josephson junctions, nanomechanical resonators and molecular magnets. The role of a specific source of decoherence, i.e. a low frequency noise is discussed.

TT 13.10 Sa 11:15 TU H3027

Charge Qubits for Quantum Computation: Chances and Limitations — ●MARTINA HENTSCHEL^{1,2}, EDUARDO R. MUCCIOLLO³, and HAROLD U. BARANGER¹ — ¹Duke University, Durham, NC, USA — ²Universität Regensburg — ³University of Central Florida, Orlando, FL, USA

Charge qubits realized in lateral quantum dot systems allow one to combine well-established semiconductor technologies with using the electron's classical charge, rather than its spin, to define the computational basis. The charge qubit we consider is a ring of three identical quantum dots joined by controllable tunneling barriers with one (extra) unpaired electron in the system. A magnetic flux through the ring allows one to define the working point of the qubit such that the two lowest eigenstates are degenerate in energy and have a homogeneous charge distribution which is hoped to reduce the decoherence due to coupling to piezoelectric phonons that is of importance in a double-dot charge qubit. We demonstrate the possibility to carry out one and two qubit operations and find that one qubit operations do not require the varying of magnetic fields locally. Performing a Schrieffer-Wolf transformation we show that the swap two qubit operation can be implemented using a single pulse of appropriate length. Based on a microscopic model and a Markov approximation, we solve the resulting Redfield equation and compare the energy and phase relaxation time with the respective times of a double-dot charge qubit. Interpreting the counterintuitive result, we extend the understanding of charge qubits.

Supported in part by ARO Contract No. DAAD19-02-1-0079.

TT 13.11 Sa 11:30 TU H3027

Inductively coupled charge qubits with asymmetric SQUIDS — ●CARSTEN HUTTER¹, YURIY MAKHLIN², ALEXANDER SHNIRMAN¹, and GERD SCHÖN¹ — ¹Institut für Theoretische Festkörperphysik, Universität Karlsruhe — ²Landau Institute for Theoretical Physics, Moscow, Russia

We investigate various methods of inductive coupling of SQUIDS used as charge qubits. For symmetric SQUIDS, this coupling produces $\sigma_y\sigma_y$ [1] or $\sigma_x\sigma_x$ [2,3] terms in the charge basis. In the latter case the interaction term commutes with the single-qubit Hamiltonian at the degeneracy point, $\propto E_J\sigma_x$. We analyze the stability of the interaction with respect to asymmetries of the parameters of junctions in SQUIDS and find, that the interaction term ceases to commute with the single-qubit Josephson terms, when the symmetry is lifted.

[1] Yu. Makhlin *et al.*, Nature 398, 305 (1999).

[2] J.Q. You *et al.*, Phys. Rev. Lett. 89, 197902 (2002).

[3] J. Lantz *et al.*, Phys. Rev. B 70, 140507(R) (2004).

TT 13.12 Sa 11:45 TU H3027

Coherence stabilization of a driven two-qubit gate by AC fields — ●SIGMUND KOHLER, KAREN M. FONSECA ROMERO, and PETER HÄNGGI — Institut für Physik, Universität Augsburg

In order to perform logical operations, a quantum computer requires tunable nonlinear interactions between two qubits. In particular, a spin-spin interaction of the Heisenberg type has been proposed for the construction of a CNOT gate. The quality of a gate operation is affected by decoherence which results from the coupling of the qubits to external degrees of freedom. In this talk, we propose a coherence stabilization scheme which reduces the influence of bit-flip noise in two-qubit gate operations. As a microscopic model, we consider a pair of driven qubits coupled to a harmonic oscillator bath with an ohmic spectral density. The bath is eliminated within a Floquet-Bloch-Redfield formalism. This allows on the one hand to derive an approximate analytical solution for the dephasing and relaxation times and, on the other hand, provides a physical explanation of the observed coherence stabilization. Our analytical estimates are in good agreement with numerical results.

[1] K. M. Fonseca Romero, S. Kohler, and P. Hänggi, cond-mat/0409774.

TT 13.13 Sa 12:00 TU H3027

Spectroscopy of a driven solid-state qubit and its detector — ●M. THORWART¹, M.C. GOORDEN², and M. GRIFONI³ — ¹Universität Düsseldorf — ²Universiteit Leiden, The Netherlands — ³Universität Regensburg

We study the asymptotic dynamics of a driven quantum two-level system coupled via a quantum detector to the environment [1]. We find multi-photon resonances which are due to the entanglement of the qubit and the detector. Different regimes are studied by employing a perturbative Floquet-Born-Markov approach for the qubit+detector system, as well as non-perturbative real-time path integral schemes for the driven spin-boson system. We find analytical results for the resonances, including the red and the blue sidebands which have been observed in superconducting flux-qubit-SQUID systems [2]. The analytical results agree well with those of exact ab-initio real-time path-integral calculations.

[1] M.C. Goorden, M. Thorwart, and M. Grifoni, Phys. Rev. Lett., in press.

[2] I. Chiorescu, P. Bertet, K. Semba, Y. Nakamura, C.J.P.M. Harmans, and J.E. Mooij, Nature **431**, 159 (2004).

TT 13.14 Sa 12:15 TU H3027

Theoretical Description of Cavity-QED with Superconducting Flux Qubits — ●MARKUS J. STORCZ¹, MATTEO MARIANTONI², RUDOLF GROSS², and FRANK K. WILHELM¹ — ¹Physics Department and CeNS, Ludwig-Maximilians-Universität München — ²Walther-Meißner-Institute Garching

The symbiosis of cavity-quantum-electrodynamics (cQED) and superconducting quantum bit (qubit) circuits has gained great interest lately. This scheme can drastically improve the decoherence properties of superconducting qubits and allows for the manipulation and read-out of qubits more easily than existing architectures. We point out the special design requirements for placing a superconducting qubit circuit inside an e.m. cavity. In particular we explore one possible realization, which is to embed a three Josephson-junction flux qubit into a high quality factor microstrip resonator that can serve as the cavity. Moreover, we investigate the control and read-out of flux qubits in the cavity, and propose a scheme for coupling several qubits by way of cavity modes. We explore the limits of the Jaynes-Cummings model that is commonly used to describe the strongly coupled cavity-qubit system and compare this to a Spin-Boson model. We derive a description of the dissipative cavity-qubit system and its interaction with a photon field (i.e. in the case of flux qubits a microwave field) to analyze the characteristic decay rates of the system.

TT 13.15 Sa 12:30 TU H3027

Spectroscopic Investigation of Dynamic Features of a Ring-Type Charge Qubit — ●THOMAS WAGNER¹, DETLEF BORN², VLADIMIR SHNYRKOV², WOLFRAM KRECH², EVGENI IL'ICHEV¹, and HANS-GEORG MEYER¹ — ¹IPHT Jena — ²Institut für Festkörperphysik, FSU Jena

We investigated dynamic properties of a special Josephson charge qubit consisting of a single-Cooper-pair transistor (with capacitive gate) closed by a superconductive loop. First, focussing the considerations on the term of the effective Josephson inductance, we sketch theoretically some quantum-dynamic features of the qubit depending on gate charge and total phase of the transistor within a two-level model. Second, we report on the experimental implementation of the ring-type charge qubit conception. For readout purposes, the interferometer loop is inductively coupled to a radio frequency tank circuit (e.g. in flip-chip configuration). In this arrangement, the tank serves as inductance detector or spectrometer, respectively. Applying external microwaves to the device, we obtained inductance alterations connected with redistributions of the energy level occupation. This way using methods of nonresonant and resonant spectroscopy, we demonstrated Landau-Zener transitions between ground and excited bands, single-photon and multiphoton absorptions, and measured the energy gap etc.