TT 39: Transport: Quantum Coherence and Quantum Information Systems - Theory II

Time: Tuesday 10:45–13:00 Location: BEY 81

TT 39.1 Tue 10:45 BEY 81

Self-trapping of photons in circuit QED — •Sebastian Schmidt[1], James Raftery[2], Darius Sadri[2], Hakan Tureci[2], and Andrew Houck[2] — [1]Institute of Theoretical Physics, ETH Zurich, Switzerland — [2]Department of Electrical Engineering, Princeton University, USA

We discuss the theoretical proposal and recent experimental observation of a novel dissipation driven dynamical localization transition of strongly correlated photons in an extended superconducting circuit consisting of two coupled resonators, each containing a superconducting qubit. Interaction with an environment has been argued to provide a mechanism for the emergence of classical behavior from a quantum system. Surprisingly, homodyne measurements reveal the observed localization transition to be from a regime of classical oscillations into a macroscopically self-trapped state manifesting revivals, a fundamentally quantum phenomenon. This experiment also demonstrates a new class of scalable quantum simulators with well controlled coherent and dissipative dynamics suited to the study of quantum many-body phenomena out of equilibrium.

TT 39.2 Tue 11:00 BEY 81

Measurement and dephasing of a flux qubit due to heat currents — •Samuele Spilla[1,2,3], Fabian Hassler[2,4], and Janine Splettstoesser[1,2] — [1]Institut für Theorie der Statistischen Physik, RWTH Aachen University, D-52056 Aachen, Germany — [2]JARA-Fundamentals of Future Information Technology — [3]Dipartimento di Fisica e Chimica, Università di Palermo, I-90123 Palermo, Italy — [4]Institute for Quantum Information, RWTH Aachen University, D-52056 Aachen, Germany

The existence of a phase-dependent thermal current through a temperature-biased Josephson junction has been recently demonstrated experimentally. It is this phase-dependence of the thermal current, which makes it interesting to study its sensitivity and impact on the states of superconducting circuits for quantum computing, e.g., superconducting qubits. I will present an analysis of the thermal current through a superconducting persistent current qubit, made of a superconducting loop interrupted by three Josephson junctions, which is subject to a temperature gradient. It can be shown that the thermal current induced by the temperature gradient depends significantly on the state of the qubit. I will furthermore investigate the impact of the heat current on the coherence properties of the qubit state. We find that even small temperature gradients can lead to dephasing times of the order of microseconds for the Delft-qubit design.

TT 39.3 Tue 11:15 BEY 81

Quantum annealing with qubits with poor decoherence properties — •Michael Marthaler, Philipp Rudo, Johannes Janssen, Matthias Hecker, and Gerd Schön — Institut für Theoretische Festkörperphysik, KIT, Karlsruhe

We analyse adiabatic quantum computing, and assume that each qubit is strongly coupled to an environment. This allows us to model the time evolution of the system simply as a rate equation. The coupling to the environment creates qubit flips, weighted by the energy differences of the eigenstates of the system. The resulting equation can be efficiently simulated by using kinetic monte carlo methods, even for rather large systems. We use our method to explicitly study recent experiments on 108 rf-SQUIDs.

TT 39.4 Tue 11:30 BEY 81

Applying stochastic Bloch-Redfield theory to transport in Josephson junction arrays — •Nicolas Vogt[1,2], Alexander Shnirman[1,2], and Jared H. Cole[3] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, Karlsruhe, Germany — [3]Chemical and Quantum Physics, School of Applied Sciences, RMIT University, Melbourne, Australia

Electrical transport in Josephson junction arrays in the Coulomb-blockade regime has been studied using several different theoretical models. Frequently used models include the sine-Gordon equation for the charge on the capacitances in the array and kinetic Monte-Carlo simulations of the incoherent tunneling of the charge-carrier through the array. These models either include coherent Cooper pair tunneling or microscopic dissipation but not both. Simulations of the full quantum-mechanical system including decoherence are problematic due to the unfavourable scaling of standard master-equations with system size. We use a stochastic unraveling of the Bloch-Redfield equation analogous to the established quantum jump unravelling of the Lindblad equation to obtain the time-evolution of a Josephson junction array coupled to a solid-state environment.

TT 39.5 Tue 11:45 BEY 81

Multi-Stability, Criticality and Steady-State Entanglement in the Nuclear Spin Dynamics of a Double Quantum Dot — •Martin J. A. Schuetz[1], Eric M. Kessler[2,3], Lieven M. K. Vandersypen[4], Juan Ignacio Cirac[1], and Geza Giedke[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany — [2]Physics Department, Harvard University, Cambridge, MA 02318, USA — [3]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA — [4]Kavli Institute of NanoScience, TU Delft, PO Box 5046, 2600 GA, Delft, The Netherlands

We propose a scheme for the deterministic generation of steady-state entanglement between the two nuclear spin ensembles in an electrically defined double quantum dot. Because of quantum interference in the collective coupling to the electronic degrees of freedom, the nuclear system is actively driven into a two-mode squeezed-like target state. The entanglement build-up is accompanied by a self-polarization of the nuclear spins towards large Overhauser field gradients. Moreover, the feedback between the electronic and nuclear dynamics leads to multi-stability and criticality in the steady-state solutions. Prospects for the experimental realization of this scheme and potential extensions towards steady-state entanglement between spatially separated quantum dots are also discussed.

TT 39.6 Tue 12:00 BEY 81

Maximal Rabi frequency of an electrically driven spin in a disordered magnetic field — •Gábor Széchenyi and András Pályi — Eötvös University, Budapest, Hungary

We present a theoretical study of the spin dynamics of a single electron confined in a quantum dot. Spin dynamics is induced by the interplay of electrical driving and the presence of a spatially disordered magnetic field, the latter being transverse to a homogeneous magnetic field. We focus on the case of strong driving, i.e., when the oscillation amplitude of the electron's wave packet is comparable to the quantum dot length. We show that electrically driven spin resonance can be induced in this system by subharmonic driving, i.e., if the excitation frequency is an integer fraction (1/2, 1/3, etc) of the Larmor frequency. At strong driving we find that (i) the Rabi frequencies at the subharmonic resonances are comparable to that at the fundamental resonance, and (ii) at each subharmonic resonance, the Rabi frequency can be maximized by setting the drive strength to an optimal, finite value. Our simple model is applied to describe electrical control of a spin-valley qubit in a weakly disordered carbon nanotube.

[1] arXiv:1310.7350

TT 39.7 Tue 12:15 BEY 81

Non-linear quantum optics and entanglement in arrays of optomechanical oscillators — •Steven Habraken, Zhijiao Deng, and Florian Marquardt — Institut für Theoretische Physik II, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7 91058 Erlangen

We consider arrays of coupled optomechanical cells, each of which consists of a laser-driven localized optical resonance interacting with a mechanical (vibrational) mode. The cells are coupled through photon tunneling. We characterize the phonon-mediated photon-photon interaction in such arrays. As an example, we focus on the case of three coupled optomechanical cells and show that such a setup can be used as a source of entangled photon pairs. We characterize such continuous variable entanglement and study its temperature dependence.

TT 39.8 Tue 12:30 BEY 81

Master equation approach for the description of the dynamics of an holmium atom on Pt(111) — •Christian Karlewski, Michael Marthaler, and Gerd Schön — Institut für Theoretische Festkörperphysik, KIT, 76128 Karlsruhe

We model a holmium atom located on a Pt(111) surface. This system was recently studied experimentally (Nature 503, 242 (2013)). Transitions between the two degenerated ground states are forbidden in first order due to several symmetries (time-reversal, internal symmetries of the total angular momentum, point symmetry of the local environment) yielding long life times. We simulate the dynamics of the whole set of 17 eigenstates (J=8) of the Ho-atom coupled to an environment with a master equation approach. To check the validity of our model it is compared to an experiment in which the system is driven out of equilibrium by a current and relaxes afterwards to one of the two degenerate ground states.

TT 39.9 Tue 12:45 BEY 81

Algebraic versus exponential decoherence in dissipative many-particle systems — Zi Cai[1] and •Thomas Barthel[1,2] — [1]LMU München — [2]Université Paris-Sud and CNRS

Until our recent study, it was assumed that, as long as the environment of a system is memory-less (i.e. Markovian), the temporal coherence decay in the system is always exponential – to a degree that this behavior was synonymously associated with decoherence. However, the situation can change if the system itself is a large many-body system with internal interactions.

I will discuss an open XXZ chain for which the decoherence time diverges in the thermodynamic limit. The coherence decay is then algebraic instead of exponential. In contrast, decoherence in the open transverse-field Ising model is found to be always exponential. In this case, the internal interactions can both facilitate and impede the environment-induced decoherence. The results are based on quasi-exact simulations using the time-dependent density matrix renormalization group (tDMRG) and explained on the basis of perturbative treatments.

[1] Z. Cai and T. Barthel, PRL 111, 150403 (2013)