TT 30: TR: Quantum Coherence and Quantum Information Systems 1 (jointly with MA and HL)

Time: Wednesday 10:30–13:00 Location: HSZ 03

TT 30.1 Wed 10:30 HSZ 03

Lasing without Inversion in Circuit Quantum Electrodynamics — •Michael Marthaler[1], Yasuhiro Utsumi[2], Dmitry Golubev[3], Alexander Shnirman[4], and Gerd Schön[1] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]Department of Physics Engineering, Faculty of Engineering, Mie University 1577, Kurimamachiya-cho, Tsu, Mi-e, 514-8507, Japan — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology,D-76021 Karlsruhe, Germany — [4]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology,D-76021 Karlsruhe, Germany

We study photon generation in a pumped qubit coupled to a transmission line oscillator under the influence of a dissipative electromagnetic environment. It has been demonstrated previously that if population inversion can be produced a lasing state is created in the oscillator. Further effects known from quantum electrodynamics (QED) have also been demonstrated in these circuit QED systems. Here we show that the circuit can also exhibit the effect of "lasing without inversion". This arises since the coupling to the dissipative environment favors photon creation as compared to annihilation, similar to the recoil effect which was predicted for atomic systems. While the recoil effect is very weak and so far elusive the effect predicted here should be readily observable.

TT 30.2 Wed 10:45 HSZ 03

Coherent dynamics of two microscopic defect states coupled via a phase qubit — •Grigorij J. Grabovskij[1], Pavel Bushev[1], Jared H. Cole[2,3], Clemens Müller[4,3], Jürgen Lisenfeld[1], Alexander Lukashenko[1], and Alexey V. Ustinov[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [2]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany — [3]DFG-Center for Functional Nanostructures (CFN), D-76128 Karlsruhe, Germany — [4]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We report on the experimental demonstration of induced coherent interaction between two intrinsic two-level defect states (TLSs) via a phase qubit. During the implementation of the pulse sequence the tunable qubit serves as a quantum shuttle communicating quantum information between the two TLSs. We present a detailed comparison between experiment and theory and find excellent agreement over a wide range of parameters. We then use the theoretical model to study the creation and movement of entanglement between the three components of the system.

TT 30.3 Wed 11:00 HSZ 03

On Superradiant Phase Transitions and Effective Models in Circuit QED — •Oliver Viehmann[1], Jan von Delft[1], and Florian Marquardt[2] — [1]Department of Physics, ASC, and CeNS, LMU München, Germany — [2]Institute for Theoretical Physics, FAU Erlangen-Nürnberg, Germany

Circuit QED systems of artificial atoms interacting with microwaves have been proved to behave in many respects analogously to their counterparts with real atoms in cavity QED. However, it has been predicted recently that the analogy fails if a large number of (artificial) atoms couple strongly to the electromagetic radiation [1]: Whereas for real atoms a no-go theorem rules out the possibility of a superradiant quantum phase transition as the coupling is increased [2], the standard description of circuit QED systems by an effective model based on macroscopic quantities [1,3] does allow it.

We investigate the possibility of a superradiant quantum phase transition in circuit QED systems from a microscopic point of view. Our analysis shows that also circuit QED systems are subject to the no-go theorem. It hence restores the analogy of circuit QED and cavity QED and challenges the applicability of the standard description of circuit QED systems in the regime under concern. In the light of this analysis, the no-go theorem is scrutinized and confirmed in a way more adequate for realistic physical systems.

[1] P. Nataf and C. Ciuti, Nature Commun. **1**, 72 (2010).
[2] K. Rzążewski *et al.*, Phys. Rev. Lett. **35**, 432 (1975).
[3] A. Blais *et al.*, Phys. Rev. A **69**, 062320 (2004).

TT 30.4 Wed 11:15 HSZ 03

Hybrid Quantum System: Coupling Color Centers to Superconducting Cavities — •Robert Amsüss[1], Christian Koller[1], Tobias Nöbauer[1], Stefan Rotter[2], Matthias Schrammböck[1], Jörg Schmiedmayer[1], and Johannes Majer[1] — [1]Atominstitut, TU Wien, Stadionallee 2, 1020 Wien, Österreich — [2]Institut für Theoretische Physik, TU Wien, Wiedner Hauptstraße 8-10, 1040 Wien

Circuit quantum electrodynamics is a system that allows us to carry out new experiments in quantum optics using a superconducting integrated circuit on a chip. In circuit QED, microwave photons are guided and confined by superconducting transmission lines and cavities, and can then be coherently coupled to a transmon qubit. The very small mode volume allows to couple spins of atoms and molecules to the resonator. In that way it becomes possible to couple an ensemble of nitrogen vacancy defects to a superconducting resonator.

TT 30.5 Wed 11:30 HSZ 03

Pulse Sequences for Exchange-Based Quantum Computation — •Daniel Zeuch[1], Robert Cipri[2], Guido Burkard[1], and Nicholas Bonesteel[2] — [1]Department of Physics, University of Konstanz, Konstanz, Germany — [2]Department of Physics and NHMFL, FSU, Tallahassee, Florida, USA

A CNOT-gate is one of the possible fundamental two-qubit gates for universal quantum computation. We consider a system where two qubits are encoded in any three spins of value 1/2 (arranged in a row), where each pair of neighboring spins can interact via the Heisenberg interaction. This could be realized by six quantum dots, each occupied by one excess electron. Electrons can virtually tunnel from one quantum dot to a neighboring dot, which switches on the interaction. Numerically a composition of 19 spin-interactions has been found leading to a quantum gate locally equivalent to a CNOT[1]. This has shown that universal quantum computation in such an *exchange-only* scheme is feasible if the experimental requirements can be met. Here we present a different sequence that consists of a larger number of pulses, but is less restrictive on the preparation of the qubits. One assumption of the former sequence is that the total spin of the system was set to be 1, for which reason one can turn on a magnetic field aligning certain spins during initialization. The new solution works for a total spin of 0 and 1 thus making the magnetic field unnecessary. The new sequence consists of approximately 40 pulses. It was found analytically, which will be the main focus of the talk.

[1] DiVincenzo et al. Nature **408**, 339 (2000)

15 min. break

TT 30.6 Wed 12:00 HSZ 03

Nuclear spin cooling using Overhauser field selective coherent population trapping — •Eric Matthias Kessler[1], Mena Issler[2], Géza Giedke[1], Susanne Yelin[3], Ignacio Cirac[1], Mikhail Lukin[4], and Atac Imamoglu[2] — [1]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Institute of Quantum Electronics, ETH-Zürich, CH-8093 Zürich, Switzerland — [3]Department of Physics, University of Connecticut 2152 Hillside Road, U-3046 Storrs, CT 06269-3046, USA — [4]Department of Physics, Harvard University, Cambridge, MA 02138, USA

We show that a quantum interference effect in optical absorption from two electronic spin states of a solid-state emitter can be used to prepare the surrounding environment of nuclear spins in well-defined states, thereby suppressing electronic spin dephasing. The coupled electron-nuclei system evolves into a coherent population trapping state by optical-excitation-induced nuclear spin diffusion for a broad range of initial optical detunings. The spectroscopic signature of this evolution where the single-electron strongly modifies its environment is a drastic broadening of the dark resonance in optical absorption experiments. The large difference in electronic and nuclear timescales allows to verify the preparation of nuclear spins in the desired state.

TT 30.7 Wed 12:15 HSZ 03

Edge State, Entanglement Entropy Spectra and Critical Anisotropic Honeycomb Lattice Hopping Coupling of —

•Ming-Chiang Chung[1,2], Yi-Hao Jhu[3], Pochung Chen[3], and Sungkit Yip[2] — [1]Physics Division, National Center for Theoretical Science, Hsinchu, 30013, Taiwan — [2]Institute of Physics, Academia Sinica, Taipei 11529, Taiwan — [3]Physics Department, National Tsing Hua University, Hsinchu, 30013, Taiwan

For a bipartite honeycomb lattice, we show that the Berry phase depends not only on the shape of the system but also on the hopping couplings. Using the entanglement entropy spectra obtained by diagonalizing the block Green's function matrices, the maximal entangled state with the eigenvalue $\lambda_m = 1/2$ of the reduced density matrix is shown to have one-to-one correspondence to the zero energy states of the lattice with open boundaries, which depends on the Berry phase. For the systems with finite bearded edges along x-direction we find critical hopping couplings: the maximal entangled states (zero-energy states) appear pair by pair if one increases the hopping coupling h over the critical couplings h_cs.

TT 30.8 Wed 12:30 HSZ 03

Towards ultrastrong coupling of superconducting transmission line resonators — •Frank Deppe[1,2], Thomas Weissl[1,2], Elisabeth Hoffmann[1,2], Max Haeberlein[1,2], Alexander Baust[1,2], Jan Goetz[2], Manuel J. Schwarz[1], Thomas Niemczyk[1], Edwin P. Menzel[1], Achim Marx[1], David Zueco[3], Juan-Jose Garcia Ripoll[4], and Rudolf Gross[1,2] — [1]Walther-Meissner-Institut, Garching, Germany — [2]TU Muenchen, Garching, Germany — [3]CSIC-Universidad de Zaragoza, Zaragoza, Spain — [4]Institutio de Fisica Fundamental, CSIC, Madrid, Spain

Coupled superconducting transmission line resonator systems have potential applications in quantum information processing and fundamental quantum mechanics. Experimentally, high coupling strengths are desirable for a clear demonstration of quantum effects. We achieve coupling strengths of more than 10% of the resonator frequency (ultrastrong coupling) by distributed coupling. We find that, differently from the case of point-like coupling, the normal modes are no longer arranged symmetrically with respect to the single resonator frequency. Nevertheless, a detailed theoretical analysis shows that the system can still be described by a beam splitter Hamiltonian for two effective resonators. We expect that this result will allow for straightforward experimental access to exciting effects such as thermal entanglement in our samples.

This work is supported by the Deutsche Forschungsgemeinschaft via SFB 631, the German Excellence Initiative via NIM, FIS2008-01240, and FIS2009-13364-C02-0 (MICINN).

TT 30.9 Wed 12:45 HSZ 03

Qubit-oscillator system under ultrastrong coupling and extreme driving — •Johannes Hausinger and Milena Grifoni — Universität Regensburg, Germany

We present our recent study on the time-dependent qubit-oscillator Hamiltonian beyond the driven Jaynes-Cummings model [1]. We include counter-rotating terms for both the coupling of the two-level system to the quantized oscillator mode and to the external classical driving. Thus, the dynamics of the qubit can be examined analytically in the ultrastrong coupling regime, where the ratio g/Ω between coupling strength and oscillator frequency approaches unity or goes beyond, and simultaneously for driving strengths much bigger than the qubit energy splitting (extreme driving). Both qubit-oscillator coupling and external driving lead to a dressing of the qubit tunneling matrix element of different nature: the former can be used to suppress specifically certain oscillator modes in the spectrum [2], while the latter can yield coherent destruction of tunneling (CDT). We show that CDT is robust even in the case of ultrastrong coupling. Our findings are within the reach of present experimental superconducting setups for quantum information processing.

[1] J. Hausinger, and M. Grifoni, arxiv:1009.1485
[2] J. Hausinger, and M. Grifoni, arxiv:1007.5437, PRA (in press)