HL 89: Focus Session: Quantum Information Systems (jointly with MA,TT)

Time: Thursday 16:45–18:15 Location: ER 164

HL 89.1 Thu 16:45 ER 164

Non-local coupling between spin qubits via a transmission line shuttle — •Peiqing Jin[1], Michael Marthaler[1], Alexander Shnirman[2,3], and Gerd Schön[1,3] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [3]DFG Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany

Quantum dots with long lived spin states are promising systems for qubit realizations [1]. Coherent single qubit manipulations have been demonstrated in such systems. However, generating a non-local qubit-qubit interaction, which is crucial for the scalability of quantum computation, is still challenging. Stimulated by recent progresses in circuit quantum electrodynamics setups [2], we propose a mechanism of coupling distant spin qubits formed in double quantum dots via a superconducting transmission line resonator. A strong qubit-resonator interaction arises based on the exchange splitting between the singlet and triplet states. The mechanism allows the system to be operated at the charge degeneracy point where the dephasing is minimized. Remarkably, due to a finite longitudinal qubit-resonator coupling, a strong blue-sideband transition is accessible as a first order process, which favors a fast generation of an entangled qubit pair.

HL 89.2 Thu 17:00 ER 164

Towards quantum information devices based on NV center in low temperature — •Sen Yang[1], Petr Siyushev[1], Seyed Ali Momenzadeh[1], Nan Zhao[1], Naofumi Abe[2], Hideo Kosaka[2], Helmut Fedder[1], and Jörg Wrachtrup[1] — [1]3rd Physics Institute and Research Center SCoPE, Universität Stuttgart, Stuttgart, Germany — [2]Research Institute of Electrical Communication, Tohoku University, Sendai, Japan

The Nitrogen-Vacancy (NV) center in diamond is a promising system for quantum communication/computation. Long coherence time and ultra-clean system make diamond an ideal candidate even in ambient condition. Low temperature gives us ability to address excited states individually [1]. Optically resonant excitation of spin-selective transitions and single shot readout of electron spin become possible [2,3]. This opens up the opportunities of making quantum devices based on the fine structure of excited states and photon NV interaction. One example is quantum repeater. Long coherence time makes spin a good choice as memory. $M_s = \pm 1$ ground states and A1/A2 excited state form Λ system which make writing, reading and flying qubit generation possible. Here, we presents recent results on coherent spin manipulation of NV center in low temperature and results towards quantum devices like quantum repeater.[1] A. Batalov, et al, PRL 102, 195506(2009).[2] L. Robledo, et al, Nature 477, 574(2011).[3] E. Togan, et al, Nature 478, 497(2011).

HL 89.3 Thu 17:15 ER 164

A quantum memory intrinsic to single nitrogen-vacancy centres in diamond — Gregory D. Fuchs[1], •Guido Burkard[2], Paul V. Klimov[1], and David D. Awschalom[1] — [1]Center for Spintronics and Quantum Computation, University of California, Santa Barbara, California 93106, USA — [2]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

A quantum memory, composed of a long-lived qubit coupled to each processing qubit, is important to building a scalable platform for quantum information science. These two qubits should be connected by a fast and high-fidelity operation to store and retrieve coherent quantum states. Here, we demonstrate a room-temperature quantum memory based on the spin of the nitrogen nucleus intrinsic to each nitrogen-vacancy (NV) centre in diamond [1]. We perform coherent storage of a single NV centre electronic spin in a single nitrogen nuclear spin using Landau-Zener transitions across a hyperfine-mediated avoided level crossing. By working outside the asymptotic regime, we demonstrate coherent state transfer in as little as 120 ns with total storage fidelity of 88±6%. This work demonstrates the use of a quantum memory that is compatible with scaling as the nitrogen nucleus is deterministically present in each NV centre defect.

[1] G. D. Fuchs, G. Burkard, P. V. Klimov, and D.D. Awschalom, Nature Physics 7, 789 (2011).

HL 89.4 Thu 17:30 ER 164

Spin decoherence in graphene quantum dots due to hyperfine interaction — •Moritz Fuchs, Valentin Rychkov, and Björn Trauzettel — Institut für Theoretische Physik und Astrophysik, University of Würzburg, 97074 Würzburg, Germany

Carbon based systems are prominent candidates for a solid-state spin-qubit due to weak spin-orbit and hyperfine interactions in combination with a low natural abundance of spin carrying isotopes. We consider the effect of the hyperfine interaction on the coherence of an electron-spin localized at gate-defined graphene quantum dots. It is known, that the hyperfine interaction in these systems is anisotropic promising interesting physics. We calculate the dynamics of an electron spin surrounded by a bath of nuclear spins in a non-Markovian approach, where we find, that the electron spin state is conserved up to small corrections. These corrections, however, show an intriguing interplay of power-law and exponential decaying behavior depending on the orientation of an external magnetic field.

HL 89.5 Thu 17:45 ER 164

Noise spectroscopy using single-shot qubit readout — •Thomas Fink and Hendrik Bluhm — 2nd Institute of Physics C, RWTH Aachen University, 52074 Aachen, Germany

Understanding the noise limiting the dephasing time of qubits and mitigating its effects is crucial for improving qubit performance. For this purpose, dynamical decoupling schemes such as the spin echo and more sophisticated pulse sequences have been developed, which can also be used for noise spectroscopy. We propose an alternative method to investigate the magnitude of the bath fluctuations in the frequency domain using the correlations of single-shot measurements. It consists of correlating the single shot measurement outcomes of subsequent free induction decay pulses. Because our approach is applicable to a broad range of frequencies by simply varying the delay between pulses, it can give insight into spectral ranges where the sensitivity of pulse sequence-based spectroscopy is limited.

We compute the outcome of our procedure applied to GaAs-based electron spin-qubits, for which the coupling of the electron spins to $\sim 10^6$ nuclear spins of the host material has been identified as the dominant source of dephasing. We discuss how this procedure can be used to directly probe the suspected high frequency cutoff in the nuclear spin diffusion spectrum.

Comparing this procedure with spin-echo measurements may also reveal if the bath needs to be treated quantum-mechanically or can be considered as classical.

HL 89.6 Thu 18:00 ER 164

Entangled photons from the polariton vacuum in a switchable optical cavity — •Adrian Auer and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We study theoretically the entanglement of two-photon states in the ground state of the intersubband cavity system, the so-called polariton vacuum. The system is formed by a sequence of doped quantum wells (QWs) located inside a microcavity and the photons can interact with intersubband excitations inside the QWs, which leads to the formation of polariton states. In the ultrastrong coupling regime, the polariton vacuum already contains a finite number of photons. In an explicit solution for the polariton vacuum, we only consider certain two-photon states by post-selection and analyze them for mode entanglement. We find an analytical expression for the entanglement using the concurrence and it depends on the absolute values of the in-plane wave vectors of the photons. For photon energies around the intersubband resonance in the mid infrared regime, the photons are almost maximally entangled, what is fundamentally important for their possible use in quantum information processing. Furthermore, there exists a continuous set of mode pairs, for which the photons are maximally entangled.