HL 11: Quantum information systems: mostly quantum dots

Time: Monday 12:00–13:45 Location: H16

HL 11.1 Mon 12:00 H16

Phase-locked indistinguishable photons from a solid-state source — •Clemens Matthiesen, Martin Geller, Carsten H. H. Schulte, Claire Le Gall, Jack Hansom, Zhenyong Li, and Mete Atature — Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom

Recent years have seen significant progress in the control of solid-state quantum bits, such as spins in self-assembled InAs quantum dots (QDs). Entangling individual spins through quantum interference of flying qubits has been identified as a promising approach to realising a quantum network of distant spins. Hoever, generating indistinguishable photons (as flying qubits) from separate QDs has proved challenging, due to fast and slow dephasing of the optical QD transitions.

Resonance fluorescence in the Heitler regime [1] provides access to single photons with coherence well beyond the Fourier transform limit of the transition, and holds the promise to circumvent environment-induced dephasing. We first demonstrate that the coherently generated single photons from a single QD display mutual coherence with the excitation laser on a timescale exceeding 3 seconds. Exploiting this degree of mutual coherence we shape single photons pulses. Separate photons generated phase-locked to the excitation laser field are shown to be fundamentally indistinguishable [2], lending themselves to creation of distant entanglement through quantum interference.

[1]Matthiesen et al. Phys. Rev. Lett. 108, 093602 (2012). [2]Matthiesen et al. arXiv:1208.1689 [quant-ph] (2012).

HL 11.2 Mon 12:15 H16

Post-selective Entanglement Generation with solid state single photon sources — •Alexander Pawlis[1,2], Klaus Lischka[1], and Yoshihisa Yamamoto[2] — [1]Universität Paderborn, Paderborn, Deutschland — [2]Stanford University, Palo Alto, California

The ability to isolate single fluorine donors in nano-structures fabricated from fluorine doped ZnMgSe/ZnSe QWs allows for direct access to the atom-like transitions of the donors. Such nano-structures are particularly applicable as solid-state single photon sources (SPS) and electron spin qubits. The quantum interference of single photons emitted from two independent ZnSe:F SPS revealed sufficient indistinguishability [1] for the realisation of all-optical concepts [2] of quantum-computation and -communication in a solid-state material. Furthermore the electron spin of the neutral donor can be used as a long-lived matter qubit [3]. Here we report on the post-selection of polarization entangled photon pairs emitted from two independent ZnSe:F SPS. The density matrix of the state was reconstructed by quantum state tomography and it yields a fidelity of 0.58 [4]. The results constitutes the first realization of two indistinguishable ZnSe:F SPS that can be used to generate substantial entanglement over macroscopic distances.

[1] K. Sanaka et al., Phys. Rev. Lett. 103(5), 053601 (2009). [2] J.L. O'Brien et al., Science 318(5856), 1567{1570 (2007). [3] A. Greilich et al., Phys. Rev. B 85(12), 121303R (2012). [4] K. Sanaka et al., Nano Letters 12, 4611 82012).

HL 11.3 Mon 12:30 H16

Tomography scheme for two spin qubits in a double quantum dot — •Niklas Rohling and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We present a set of measurements which allows the reconstruction of the density matrix for the full two-qubit space of two electron spins in a double quantum dot. Our scheme employs non-local quantum gates induced by the exchange interaction between the spins and selective single-spin rotations by electron spin resonance (ESR). Recently, both kinds of gates have been realized experimentally in the same quantum dot [1]. Projection on specific states can be achieved by an adiabatic spin-to-charge conversion after applying the quantum gate. State tomography for a singlet-triplet qubit, i.e. a subspace of the full two-qubit space, has been demonstrated [2]. It turns out that ESR is harder to realize than exchange interaction. Whereas ESR is unnecessary to gain full information of the state of a single singlet-triplet qubit, it is needed for state tomography of the full four-dimensional space of two single-spin qubits. For each of the measurements we suggest, no more than one $\pi/2$-rotation of one of the spins needs to be done by ESR. We estimate the precision of our tomography scheme in dependence of the fidelity of the quantum gates.

[1] N. Brunner, Y.-S. Shin, T. Obata, M. Pioro-Ladrière, T. Kubo, T. Taniyama, Y. Tokura, and S. Tarucha, Phys. Rev. Lett. **107**, 146801 (2011).

[2] S. Foletti, H. Bluhm, D. Mahalu, V. Umansky, and A. Yacoby, Nature Phys. **5**, 903 (2009).

HL 11.4 Mon 12:45 H16

Characterization of S-$T+$ qubit dynamics via correlation functions — •Christian Dickel[1,2] and Hendrik Bluhm[1,2] — [1]2nd Institute of Physics C, RWTH Aachen University, Aachen, Germany — [2]JARA - Fundamentals of Future Information Technology

Semiconductor spin qubits encoded in the singlet state S and the $m = 0$ triplet state T_0 of two electrons in a double quantum dot (DQD) have been pursued very successfully. GaAs is the most advanced material in this context, but it suffers from dephasing due to the hyperfine interaction. Recently the alternative encoding in S-T_+ has been explored. For the control of such an S-T_+ qubit, the dynamics at the S-T_+ transition are crucial. They are driven by hyperfine coupling and spin-orbit interaction.

Here we show, through experiment and theory, that these dynamics can be probed by measuring temporal correlations of the flip probabilities during Landau-Zener-Stückelberg transitions. Those correlation functions reveal oscillations originating from the relative Lamor precession of the different nuclear species present in GaAs. Incoherent nuclear spin evolution results in a loss of correlations. In the presence of spin-orbit coupling, oscillations with the absolute Lamor frequencies are expected in addition. Observations of the latter could be useful to quantify the spin-orbit coupling in DQDs.

HL 11.5 Mon 13:00 H16

A Landau-Zener-Stückelberg charge qubit — •Florian Forster[1], Gunnar Petersen[1], Dieter Schuh[2], Werner Wegscheider[3], Sigmund Kohler[4], and Stefan Ludwig[1] — [1]CeNS, Universität München — [2]Universität Regensburg — [3]ETH Zürich — [4]Inst. Ciencia Materiales, CSIC, Madrid

Quantum dots in the few electron regime in GaAs/AlGaAs heterostructures are a powerful system for observing fundamental quantum effects. For instance, it is possible to prepare arbitrary charge superposition states of a double quantum dot (DQD) by driving it through avoided crossings. Multiple Landau-Zener transitions can give rise to quantum interference in time, in analogy to the interference in space in Mach-Zehnder interferometers. Here, we perform Landau-Zener-Stückelberg (LZS) interferometry [1] by periodically driving a DQD between two-electron singlet states. We analyze the decoherence of this strongly driven charge qubit as a function of temperature and external noise. Our goal is to use LZS interferometry as a tool to probe the solid state environment interacting with the qubit. To reach this goal we compare our experimental data with numerical calculations based on the Floquet transport theory [2] augmented by dissipative terms. This approach allows an accurate determination of qubit coherence times and its bath properties. Our fundamental studies lay the basis for possible applications in quantum information based on qubits at the interface between adiabatic and non-adiabatic quantum dynamics.

[1] S. N. Shevchenko et. al., Phys. Rep. 492, 1-30 (2010)

[2] S. Kohler et al., Phys. Rep. 406, 397 (2005)

HL 11.6 Mon 13:15 H16

Undoped Si/SiGe heterostructures for field-effect devices — •Simon Pfaehler[1,2], Johannes Kierig[1], Andreas Wild[1,2], Christoph Buhlheller[1,2], Gerhard Abstreiter[2], Kentarou Sawano[3], and Dominique Bougeard[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Walter Schottky Institut, Technische Universität München, Garching, Germany — [3]Advanced Research Laboratories, Tokyo City University, Japan

Two-dimensional electron systems (2DES) in modulation doped heterostructures represent a promising building block for the development of electrostatically defined spin qubits. The hyperfine interaction with the nuclear spin bath being a dominant qubit decoherence mechanism, Si/SiGe heterostructures have been receiving steadily increasing attention for building devices almost free of nuclear spin carrying isotopes. However, such modulation doped heterostructures still suffer from fluctuating charges due to the presence of ionized dopants which can also in the end limit the spin decoherence time.

One possible way to reduce fluctuating charges is to avoid doping in Si/SiGe heterostructures and induce a 2DES capacitively. In this contribution, we report on the realization and experimental characterization of undoped Si/SiGe heterostructures designed for the implementation of electrostatically defined double quantum dots. A global top gate is used to operate this device via field effect to induce a 2DES in the undoped Si quantum well. The electronic behavior is additionally studied in band structure simulations.

HL 11.7 Mon 13:30 H16

Controllable spin environments in carbon based systems — •Moritz Fuchs[1], John Schliemann[2], and Björn Trauzettel[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg — [2]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg

Carbon based quantum dots are promising candidates for the investigation of electron spin dynamics in a nuclear spin environment. While isotopic purification offers a way to control the number of involved nuclear spins, the coupling between these spins and the electron spin changes with the shape of the quantum dot. We analyze the time evolution of a single electron spin bound to a graphene quantum dot for exemplary models using both analytical and numerical methods.