TT 64: Quantum Information Systems: Mostly Concepts (jointly with HL)

Time: Wednesday 11:00–13:00 Location: EW 202

TT 64.1 Wed 11:00 EW 202

Cold atom - semiconductor hybrid quantum system — •Jan-Philipp Jahn[1], Mathieu Munsch[1], Lucas Beguin[1], Andreas Kuhlmann[1], Aline Faber[1], Tobias Kampschulte[1], Andreas Jöckel[1], Armando Rastelli[2], Fei Ding[3], Oliver G. Schmidt[3], Nicolas Sangouard[1], Philipp Treutlein[1], and Richard J. Warburton[1] — [1]University of Basel, Switzerland — [2]Johannes-Kepler University Linz, Austria — [3]IFW Dresden, Germany

Semiconductor quantum dots are excellent single-photon sources, providing triggered single-photon emission at a high rate and with high spectral purity [1]. Independently, atomic ensembles have emerged as one of the best quantum memories for single photons, providing high efficiency storage and long memory lifetimes [2]. In this project, we combine these two physical systems to exploit the best features from both worlds. On the one hand, we have characterized a new type of self-assembled GaAs/AlGaAs quantum dots that emit narrowband (Δv = 500 MHz) single-photons at a wavelength compatible with Rb atoms. Fine tuning of the photon frequency is achieved via strain. This allows us to perform spectroscopy of the Rb D2-line at the single-photon level, proving that we can address the different hyperfine transitions. On the other hand, we have developed a detailed theory of an EIT-based memory scheme in a dense ultracold ensemble of 87Rb atoms (OD>150) that achieves storage-and-retrieval efficiency exceeding 28% [3].

[1] R. J. Warburton, Nature Mater. 121, 483-493 (2013) [2] F. Bussières et al., J. Mod. Opt. 60, 1519 (2013) [3] M. T. Rakher et al., Phys. Rev. A 88, 053834 (2013)

TT 64.2 Wed 11:15 EW 202

Surface Acoustic Waves as a versatile tool for quantum information processing with solid-state spin qubits — •Martin J. A. Schuetz[1], Eric M. Kessler[2,3], J. Ignacio Cirac[1], Mikhail D. Lukin[2,3], Lieven M. K. Vandersypen[4], and Géza Giedke[1,5] — [1]Max-Planck-Institut für Quantenoptik, H.-Kopfermann-Str 1, D-85748 Garching — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, USA — [3]Physics Department, Harvard University, Cambridge, Massachusetts 02318, USA — [4]Kavli Institute of NanoScience, TU Delft, P.O. Box 5046, 2600 GA Delft, The Netherlands — [5]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastian

Surface acoustic waves (SAW) offer a great variety of applications in the context of solid-state quantum information processing (QIP). The use of SAWs as transport shuttles for single electrons has been demonstrated, high-quality cavities for SAW can be fabricated, and their quantum nature has been explored coupling them to superconducting qubits.

We investigate theoretically the use of SAWs for QIP with spin qubits in GaAs quantum dots. We show that strong coupling between the qubit and SAW cavities is feasible with current cavity designs. We investigate the viability of "quantum acoustics" in this setting, where phononic cavities are used to couple spin qubits and phonons serve as propagating carriers of quantum information. Possibilities to extend these results to other spin qubits such as NV centers in diamond are discussed.

TT 64.3 Wed 11:30 EW 202

Creating and controlling entanglement using coherent time-delayed feedback — •Sven Moritz Hein, Franz Schulze, Alexander Carmele, and Andreas Knorr — Technische Universität Berlin, Institut für theoretische Physik, Nichtlineare Optik und Quantenelektronik, Hardenbergstraße 36, 10623 Berlin, Germany

Entanglement is a quantum-mechanical property interesting from a fundamental point of view as well as for future applications in quantum information science. We propose to use time-delayed quantum-coherent feedback to create and control entanglement between quantum-mechanical objects.

In classical physics, feedback schemes with a distinct feedback delay[1] are successfully applied to control unstable states and periodic orbits. We demonstrate by numerical simulations that this concept can be transferred to the quantum regime. Here, it can be used to enhance the entanglement of photons from a biexciton cascade[2] and also entangle cavities and other quantum nodes in a quantum network. To preserve quantum coherence, the feedback will be modeled in a fully quantum-mechanical way without the use of measurements.

[1] K. Pyragas, Phys. Lett. A 170, 421–428 (1992)
[2] S. M. Hein, et al., Phys. Rev. Lett. 113, 027401 (2014)

TT 64.4 Wed 11:45 EW 202

Temporal shaping of Gaussian single photon pulses — •Emanuel Peinke[1], Gaston Hornecker[2], Julien Claudon[1], Alexia Auffèves[2], and Jean-Michel Gérard[1] — [1]CEA/CNRS joint team "Nanophysics and Semiconductors", INAC, CEA and Université Grenoble Alpes, Grenoble, France — [2]CEA/CNRS joint team "Nanophysics and Semiconductors", Institut Néel, CNRS and Université Grenoble Alpes, Grenoble, France

Single photon pulses with a Gaussian temporal envelope constitute an important resource for optical quantum information processing [1]. We propose here a scheme to shape single photon pulses with high fidelity using a two-level emitter (e.g. a quantum dot (QD)) coupled to a frequency-tunable microcavity. By controlling the cavity resonance frequency on a time-scale shorter than the typical emitter spontaneous emission time, one controls the instantaneous emission rate and thus the temporal envelope of the emitted photon. For realistic experimental parameters, we show that nearly ideal Gaussian pulses can be generated with QD-semiconductor systems and superconducting Josephson circuits.

[1] P. P. Rohde, T. C. Ralph, and M. A. Nielsen. Optimal photons for quantum- information processing. Phys. Rev. A, 72:052332, Nov 2005.

TT 64.5 Wed 12:00 EW 202

Electric dipole spin resonance in the presence of valley degeneracy — •Marko Rancic and Guido Burkard — University of Konstanz

We theoretically investigate the electric dipole spin resonance (EDSR) in a single Si/SiGe quantum dot in the presence of a magnetic field gradient, e.g., produced by a micomagnet. The control of electron spin states can be achieved by applying an oscillatory electric field, which induces periodic back and forth motion of the electron spin inside the quantum dot. This motion inside a magnetic field gradient, produces an effective periodic in-plane magnetic field, and allows for driven spin rotations near resonance. By solving a Lindblad master equation, we discuss possible electron spin relaxation and decoherence mechanisms relevant to EDSR. In Si there is 5% of naturally occurring nuclear spin 1/2 isotope, which causes the electron spin to decohere. Nuclear spins are included in our model through the additional random Overhauser magnetic field. Furthermore, a valley dependent g-factor, combined with intervalley scattering gives rise to another electron spin decoherence mechanism. The goal of our study is to describe the efficiency of a spin echo sequence in the presence of all mentioned relaxation and decoherence mechanisms.

TT 64.6 Wed 12:15 EW 202

Resonant exchange qubit under influence of electrical noise — •Maximilian Russ and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

In this work we investigate the influence of electrical charge noise on a resonant exchange (RX) qubit in a triple quantum dot. This RX qubit is a variation of the exchange-only qubit [1] which responds only to a narrow-band resonant frequency [2,3]. Our noise model includes uncorrelated charge noise in each quantum dot giving rise to two independent (noisy) bias parameters. We calculate the energy splitting of the two qubit states as a function of these two bias detuning parameters to find "sweet spots", where the noise suppression is maximized. Our investigation shows that such sweet spots exist within the low bias regime, in which the bias detuning parameters have the same magnitude as the hopping parameters. The location of the sweet spots depends on the bias detuning and the hopping asymmetry between the quantum dots.

[1] D. P. DiVincenzo et al., Nature **408**, 339 (2000).
[2] J. Medford et al., Phys. Rev. Lett. **111**, 050501 (2013).
[3] J. M. Taylor, V. Srinivasa, and J. Medford, Phys. Rev. Lett. **111**, 050502 (2013).

TT 64.7 Wed 12:30 EW 202

Electrically controlled echo sequences for the exchange-only qubit — •Niklas Rohling and Guido Burkard — Department of Physics, University of Konstanz, Germany

We consider a model of an exchange-only qubit [1] in a triple quantum dot under the influence of the surrounding nuclear spin bath, which we describe by an inhomogeneous Overhauser field. This field can lead to decoherence and leakage out of the logical qubit space. When a strong external magnetic field is applied, the spin in each of the quantum dots precess effectively about the same axis. In this case, only one leakage state has to be taken into account [2]. For this situation, we present a purely exchange-based pulse sequence that corrects decoherence as well as leakage as long as the Overhauser field varies slowly compared to the pulse times. As the pulses rely on the exchange interaction, they can be electrically tuned similarly to the quantum gates of the qubit [1]. For the case of a well-known initial state, we further refine the sequence to allow for first-order correction of errors in the applied pulses in analogy to the Carr-Purcell-Meiboom-Gill sequence known from spin resonance techniques.

[1] D. P. DiVincenzo, D. Bacon, J. Kempe, G. Burkard, and K. B. Whaley, Nature **408**, 339 (2000)

[2] J.-T. Hung, J. Fei, M. Friesen, and X. Hu, Phys. Rev. B **90**, 045308 (2014)

TT 64.8 Wed 12:45 EW 202

Influence of Hyperfine Interaction on the Entanglement of Photons Generated by Biexciton Recombination — •Erik Welander, Julia Hildmann, and Guido Burkard — Department of Physics, University of Konstanz, Germany

The quantum state of the emitted light from the cascade recombination of a biexciton in a quantum dot is theoretically investigated including exciton fine structure splitting (FSS) and electron-nuclear spin hyperfine interactions. In an ideal situation, the emitted photons are entangled in polarization making the biexciton recombination process a candidate source of entangled photons necessary for the growing field of quantum communication and computation. The coherence of the exciton states in real quantum dots is affected by a finite FSS and the hyperfine interactions via the effective magnetic field known as the Overhauser field. We investigate the influence of both sources of decoherence and find that the FSS combined with a stochastic exciton lifetime is responsible for the main loss of entanglement. Furthermore, we examine the possibility of reducing the decoherence from the Overhauser field by partially polarizing the nuclear spins and applying an external magnetic field. We find that an increase in entanglement depends on the degree as well as the direction of nuclear spin polarization.