HL 2: Spin Phenomena in Semiconductors

Time: Monday 9:30–11:00 Location: H31

Invited Talk HL 2.1 Mon 9:30 H31

Observation of quantum Zeno effects for localized spins

— •Alex Greilich[1], Nikita V. Leppenen[2], Vitalie Nedelea[1], Eiko Evers[1], Dmitry S. Smirnov[2], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]St. Petersburg, Russia

One of the main dephasing mechanisms for the localized carrier spins in semiconductors is the coupling to the fluctuating nuclear spin environment. Here we present an experimental observation on the effects of the quantum back action under pulsed optical measurements and demonstrate that the nuclei-induced spin relaxation can be influenced. We show that the fast measurements freeze the spin dynamics and increase the effective spin relaxation time, the so-called quantum Zeno effect. Furthermore, we demonstrate that if the measurement rate is comparable with the spin precession frequency in the effective magnetic field, the spin relaxation rate increases and becomes faster than in the absence of the measurements, an effect known as the quantum anti-Zeno effect.

HL 2.2 Mon 10:00 H31

Interplay of spin-orbit coupling and spin diffusion on spin helices lifetime in GaAs quantum wells

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This work reveals the dependence of the persistent spin helix (PSH) lifetime on spin diffusion coefficient and the electron density, by employing time-resolved magneto-optical Kerr effect microscopy to study the spin polarization evolution in low-dimensional GaAs QWs. It is shown that for the achieving the longest PSH lifetime, the variation of scattering rate with the electron density is of higher importance than the fulfilling of the persistent spin helix condition when the Rashba α and Dresselhaus β parameters are balanced (suppression of D'yakanov-Perel spin dephasing mechanism). More specifically, the PSH relaxation rate is determined mostly by the spin diffusion coefficient that depends on electron density nonmonotonously. The longest experimentally observed PSH lifetime occurs at an electron density, corresponding to the transition from Boltzmann to Fermi-Dirac statistics - several times higher than that when the persistent spin helix is expected. These facts highlight the role the electron density may play when considering applications for spintronic devices.

HL 2.3 Mon 10:15 H31

Selective optical charging and spin preparation of a single quantum dot molecule

— •C. Thalacker[1], F. Bopp[1], A. Ahmadi[1], N. Revenga[1], F. Vögl[1], C. Cullip[1], K. Boos[1], F. Sbresny[1], N. Bart[2], A. Wieck[2], A. Ludwig[2], D. Reuter[3], J. Schall[4], S. Reitzenstein[4], H. Riedl[1], K. Müller[1], and J. J. Finley[1] — [1]Walter Schottky Institut and Physik Department, TU München, Garching, Germany — [2]Ruhr-Universität Bochum, Bochum, Germany — [3]Universität Paderborn, Paderborn, Germany — [4]Technische Universität Berlin, Berlin, Germany

Coherence, ease of control and scalability lie at the heart of hardware for distributed quantum technologies. Spin-photon interfaces based on III-V semiconductor quantum dots (QDs) combine properties such as strong light-matter-interactions, robust spin-photon selection rules and ease of integration into opto-electronic devices. Two vertically stacked QDs, a so-called QD-molecule (QDM) are expected to exhibit enhanced coherence times (T_2^*) due to the formation of singlet-triplet (S-T) qubits. We embed a single QDM into an ultralow capacitance p-i-n diode that allows for ultrafast electrical tuning (>500 MHz). Photon extraction efficiencies are improved to >20% by deterministically placing a circular Bragg grating around the QDM. Using our device we demonstrate all optical control of the charge state, as well as optical spin pumping. Our results form the basis of an optically active S-T spin-qubit with enhanced coherence.

HL 2.4 Mon 10:30 H31

Resonant spin amplification in Faraday geometry

— •Nedelea Vitalie[1], Philipp Schering[2], Dmitry Smirnov[3], Eiko Evers[2], Evgeny Zhukov[1,3], Dmitri Yakovlev[1,3], Manfred Bayer[1,3], Uhrig Götz[2], and Alex Greilich[1] — [1]Experimental Physics 2, TU Dortmund University, Dortmund, Germany — [2]Condensed Matter Theory, TU Dortmund University, Dortmund, Germany — [3]St. Petersburg, Russia

The possibility to use the spin degree of freedom for quantum information continues to drive research on semiconductors nanostructures. The main characteristic in this field is defined by the lifetime of the information or the spin coherence time. One of the most basic parameters of the spin dynamics is the g factor, which is often anisotropic in semiconductor nanostructures. Its transverse component can be measured very precisely when a magnetic field is applied in Voigt geometry by means of the resonant spin amplification effect (RSA).

Model consideration predict [1] that the realization of the RSA effect in Faraday geometry, where a magnetic field is applied parallel to the optically induced spin polarization, can be realized for a central spin interacting with a fluctuating spin environment. To confirm theory, we chose an ensemble of singly-charged (In,Ga)As/GaAs quantum dots, where the resident electron spin interact with the surrounding nuclear spins. The observation of RSA in Faraday geometry requires intense pump pulses with a high repetition rate and can be enhanced by means of the spin-inertia effect. Potentially, it provides the most direct and reliable tool to measure the longitudinal g factor of the charge carrier.

HL 2.5 Mon 10:45 H31

Cavity-enhanced single-shot readout of a quantum dot spin within 3 ns

— •Nadia Olympia Antoniadis[1], Mark Richard Hogg[1], Willy Frederik Stehl[1], Alisa Javadi[1], Natasha Tomm[1], Rüdiger Schott[2], Sascha René Valentin[2], Andreas Dirk Wieck[2], Arne Ludwig[2], and Richard John Warburton[1] — [1]Department of Physics, University of Basel — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum

Rapid, high-fidelity single-shot readout of quantum states is a ubiquitous requirement in quantum information technologies. Readout of spin states in optically active emitters can be achieved by driving a spin-preserving optical transition and detecting the emitted photons. The speed and fidelity of this approach is typically limited by a combination of low photon collection rates and measurement back-action. Here, we demonstrate single-shot optical readout of a semiconductor quantum dot spin state, achieving a readout time of only a few nanoseconds. Our approach embeds a gated InAs quantum dot device into an open microcavity architecture. The Purcell enhancement generated by the microcavity selectively increases the readout transition emission rate, as well as efficiently channelling the emitted photons into a well-defined detection mode. We achieve single-shot readout of an electron spin state in 3 ns with a fidelity of (95.85±0.71)%, and observe quantum jumps using repeated single-shot measurements. Our work reduces the spin readout-time to values well below both the achievable spin T1 and T2* times in InAs quantum dots, opening up new possibilities for their use in quantum technologies.