HL 29: Materials and devices for quantum technology I

Time: Wednesday 15:00–18:00 Location: POT 151

HL 29.1 Wed 15:00 POT 151

Mapping of the local valley splitting in a Si/SiGe qubit shuttle device — •Bingjie Chen[1], Mats Volmer[1], Tom Struck[1], Ran Xue[1], Inga Seidler[1], Joachim Knoch[2] und Lars R. Schreiber[1] — [1]JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Germany — [2]Institut für Halbleitertechnik, RWTH Aachen University, Germany

Qubits based on the electron spin in gate-defined ^{28}Si/SiGe quantum dots (QD) are one of the major candidates for the quantum information processing. Due to weak spin-orbit coupling and low hyperfine interaction, their fidelity threshold for quantum error correction is reached. However, valley-state excitations [1-3] have implications for spin dephasing during qubit shuttling [4]. In our experiment, we map the valley splitting energy (E_{VS}) originating from the quantum well confinement at different locations of a qubit shuttle device [5]. We measure their orbital splitting and spin-polarization as a function of various electron fillings and magnetic fields [6]. We fit the local singlet-triplet splitting energy as a lower boundary of the relevant E_{VS}, which is distributed in a range of 11...73 μeV. The correlation length is approximatly the QD size and small dependence on the electric field perpendicular to the quantum well is found. [1]Dodson, J.P. ea., arXiv:2103.14702.[2]McJunkin, T. ea., Phys. Rev. B 104, 085406.[3]Hollman, A. ea., Phys. Rev. Applied 13, 034068.[4]Langrock, V. ea., arXiv: 2202.11793.[5]Seidler, I. ea., npj Quantum Inf. 8, 100.[6]Friessen. M. ea., Phys. Rev. B 75, 115318. This work has been funded by the German Research Foundation (DFG) within the project KN 545/28-1.

HL 29.2 Wed 15:15 POT 151

Accessing broad-band quantum dynamics in the low photon regime — •Markus Sifft[1], A. Kurzmann[2], J. Kerski[2], R. Schott[1], A. Ludwig[1], A. D. Wieck[1], A. Lorke[2], M. Geller[2], and D. Hägele[1] — [1]Ruhr University Bochum, Germany — [2]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany

The analysis of quantum dynamics from measurement records $z(t)$ poses a fundamental challenge in many fields of science and engineering. Measurement records are notoriously difficult to analyze due to inherent or additional background noise, loss of e.g., probe photons, and finite measurement times. We recently introduced quantum polyspectra as a tool to analyze $z(t)$ in terms of higher order spectra whose shapes can be predicted within a quantum master equation approach [1,2]. Here, we solve the problem of analyzing the blinking (charging) dynamics of a semiconductor quantum dot in the regime of low photon rates or high photon loss [3]. The usual telegraph noise of binned photon click events changes to rare single clicks in case of high photon loss. Fitting theoretical quantum polyspectra to their measured counterparts gives full access to the in- and out-tunneling rates γ_{in}, γ_{out} of electrons despite low average photon rates $\gamma_p \ll \gamma_{in}+\gamma_{out}$. We demonstrate the successful evaluation of tunneling rates at up to 99.9 % loss of photons surpassing a previous scheme that handled a 98 % loss using the same data. [1] Hägele et al., PRB 98, 205143 (2018), [2] Sifft et al., PRR 3, 033123 (2021), [3] Sifft et al., arXiv:2109.05862

HL 29.3 Wed 15:30 POT 151

Generation of V_{Si} color centers in 4H-SiC using He and Li focused ion beam — •Christian Gobert[1], Shravan Kumar Parthasarathy[1], Fedor Hrunski[2], Roland Nagy[2], and Patrick Berwian[1] — [1]Fraunhofer Institute for Integrated Systems and Device Technology (IISB), 91058 Erlangen, Germany — [2]Group of Applied Quantum Technologies, University Erlangen-Nuremberg (FAU), 91058 Erlangen, Germany

The silicon vacancy (V_{Si}) color center in 4H-SiC is a promising candidate as a qubit for quantum sensing, communication, and computing, due to its excellent spin and optical properties[1,2], scalability and mature semiconductor technology platform[3]. V_{Si} color centers can be fabricated by means of high energetic irradiation, e.g., using electrons, ions, neutrons, or laser pulses[4]. In this contribution, we report on a direct comparison of 3 different irradiation techniques, i.e. He- Li- and electron irradiation, for the first time on the very same sample material. Characterization is accomplished using confocal photoluminescence (PL) measurements on two perpendicular crystal orientations. We investigate the optical and spin properties of generated V_{Si} color centers and employ PL mappings to judge the scalability of the irradiation technique. To evaluate the quality of the generated V_{Si} color centers, PL excitation spectroscopy (PLE) is applied.

[1] R. Nagy et al., Nat. Commun. 10, 1954 (2019)
[2] R. Nagy et al., Appl. Phys. Lett. 118, 144003 (2021)
[3] C. Babin et al., Nat. Mater. 21, 67-73 (2022)
[4] S. Castelletto, A. Boretti, J. Phys.: Photonics 2 (2020) 022001

HL 29.4 Wed 15:45 POT 151

1.*Quantum Vector Magnetometry of Magnetic Nanoparticles in Living Tissue — •Andre Pointner[1], Philipp Kunze[2], Regine Schneider-Stock[2], Bernhard Friedrich[3], Christoph Alexiou[3], Rainer Tietze[3], and Roland Nagy[1] — [1]Chair of Electron Devices, FAU Erlangen-Nuremberg — [2]Experimental Tumor Pathology, University Hospital Erlangen — [3]Experimental Oncology and Nanomedicine, University Hospital Erlangen

Developing an understanding of the underlying processes of cancer dissemination is to this day a pressing topic in medical research, due to the lack of observation techniques capable of resolving single cell behavior in living tissue. Widefield imaging with ensembles of nitrogen-vacancy centers (NV-Centers) in diamond as a quantum sensor allows the observation of individual cells by mapping selectively attached superparamagnetic iron oxide nanoparticles (SPIONs) on cells of interest. Application of a magnetic bias field results in a magnetic dipole emitted by the SPIONs, which adds onto the known bias field. The magnetic field causes a lift of the degeneracy of the NV-Centers spin states. Evaluating the spin transitions via optically detected magnetic resonance (ODMR) and comparison to the ground state hamiltonian enables the reconstruction of the magnetic field vector. By applying this measurement scheme pixelwise to a sequence of widefield images of the diamond sample, we calculate the corresponding dipole vector for the SPIONs and map the resulting magnetic field over the field of view. This enables single cell tracking in living tissue inside a homemade integrated widefield microscope over the span of multiple days.

HL 29.5 Wed 16:00 POT 151

Fabrication and pre-characterization of 10 μm long single-electron shuttling devices. — •Max Beer[1], Ran Xue[1], Inga Seidler[1], Jhih-Sian Tu[2], Lino Visser[1], Hendrik Bluhm[1], and Lars R. Schreiber[1] — [1]JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Aachen, Germany — [2]Helmholtz Nano Facility (HNF), Forschungszentrum Jülich, Jülich, Germany

The electron-spin in gate-defined quantum dots in a Si/SiGe quantum well is one of the most promising qubits for scalable quantum computing. Scalability can be achieved by coherent coupling such as conveyor-mode single electron-spin shuttling [1]. Aiming at a shuttle distance of 10 μm, we fabricate a shuttling device with three patterned metal-gate layers forming an array of >140 gates. Al_2O_3 deposited by atomic layer deposition (ALD) isolates the gates, but also induces potential disorder in the quantum well. This disorder can be reduced by minimizing the oxid thickness [1]. We investigate two strategies: (I) Reduction of oxide thickness towards the ALD limit and (II) replacement of MOS-gates with Pd-Si Schottky-gates wherever applicable. Shuttling devices are selected by a transport measurement-protocol operating at 4.2 K on single electron transistors, which are operated as charge sensors for electron shuttling at 10 mK [2].

[1] Langrock, V. *et al.*, arXiv: 2202.11793 (2022).
[2] Seidler, I. *et al.*, npj Quantum Inf. 8: 100 (2022).

Work funded by the DFG under project number EXC 2004/1-390534769.

30 min. break

HL 29.6 Wed 16:45 POT 151

Coupling of solid-state quantum emitters to low-loss plasmonic waveguides — •Paul Steinmann, Hans-Joachim Schill, and Stefan Linden — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

Plasmonic waveguides with integrated single photon emitters (SPEs) offer an attractive platform for nanophotonic quantum circuit applications. Here, we report on the coupling of strain-induced SPEs in an MoSe2 monolayer to low-loss plasmonic waveguides. For this purpose, we used electron beam lithography with the negative-tone resist Medusa82 to fabricate dielectric-loaded surface plasmon polariton waveguides (DLSPPWs) on top of a chemically prepared monocrystalline silver platelet. Additional gratings placed at the ends of the waveguides serve as in- and out-coupling structures. An MoSe2 monolayer was deposited on the centre of one of the waveguides by a dry-transfer technique. Operating at 4 Kelvin, surface plasmon polaritons (SPPs) are launched by a green laser at the in-coupling port of the waveguide. The SPPs travel through the waveguide and lead to the excitation of the monolayer. In addition to the exciton and trion signal, we observe sharp emission lines that we attribute to strain-induced trap states. The second-order correlation function of one of the spectrally filtered emission lines was measured with an HBT setup. The measured value g(2)(0)=0.4 indicates the single-photon nature of the emitter. Our findings indicate that TMDC monolayers can be used as integrated SPEs in efficient plasmonic circuits, and thus further pave the way towards plasmonic-based single photon networks.

HL 29.7 Wed 17:00 POT 151

Sensing of electrolytes with nitrogen-vacancy centers in nanodiamonds — •Maximilian Hollendonner[1,2], Sanchar Sharma[2], Durga Dasari[3], Silvia Viola Kusminskiy[2,4], and Roland Nagy[1] — [1]Chair of Electron Devices, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany — [2]Max Planck Institute for the Science of Light, Staudtstraße 2, Erlangen, Germany — [3]3rd Institute of Physics, University of Stuttgart and Institute for Quantum Science and Technology (IQST), Stuttgart, Germany — [4]Institute for Theoretical Solid State Physics, RWTH Aachen University, Aachen, Germany

Today's batteries suffer from performance losses with increasing cell age which is caused by irreversible degradation processes at a molecular level. To understand these processes, it is important to measure them *in-situ* and *in-operando*. Up to now there exists no sensor which can perform this task with sub-micrometer resolution. We propose to use nanodiamonds containing single NV-centers as such sensors inside the liquid electrolyte of a battery. It has been shown that NV-centers are excellent electric field sensors [1,2]. From theoretical considerations we found out that by performing repeated FID pulse sequences it is not only possible to measure the electric field components generated by the ions inside the electrolyte but also the local ionic concentrations at the position of the nanodiamond with nanometer-resolution.

Sources: [1] F. Dolde *et al.*, *Nature Phys* **7**, 459-463 (2011) [2] J. Michl *et al.*, *Nano Lett.* 2019, 19, 8, 4904-4910

HL 29.8 Wed 17:15 POT 151

Interplay of Pauli Blockade with Electron-Photon Coupling in Quantum Dots — •Florian Ginzel and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Both quantum transport measurements in the Pauli blockade regime and microwave cavity transmission measurements are important tools for spin-qubit readout and characterization. In our work [1] we theoretically investigate how a double quantum dot in a transport setup interacts with a coupled microwave resonator while the current through the DQD is rectified by Pauli blockade. We show that the output field of the resonator can be used to infer the leakage current and thus obtain insight into the blockade mechanisms without additional components such as charge or current sensors for each dot. In the case double quantum dot realized in silicon, we show how the valley quasi-degeneracy can impose limitations on this scheme. We also demonstrate that a large number of unknown double quantum dot parameters including (but not limited to) the valley splitting can be estimated from the resonator response simultaneous to a transport experiment, providing more detailed knowledge about the microscopic environment of the dots. Furthermore, we describe and quantify a back-action of the resonator photons on the steady state leakage current.

[1] F. Ginzel and G. Burkard, arxiv:2210.02982 (2022)

HL 29.9 Wed 17:30 POT 151

Structural and electrical characterization of the InAs/CdSe core/shell NWs — •Mane Kalajyan[1], Marvin Marco Jansen[1,2], Nils von den Driesch[3], Erik Zimmermann[1], Nataliya Demarina[4], Anton Faustmann[1], Gerrit Behner[1], Christoph Krause[1], Benjamin Bennemann[1], Jan Karthein[1], Detlev Grützmacher[1,3], Thomas Schäpers[1], and Alexander Pawlis[1,3] — [1]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, Jülich, Germany — [2]Eindhoven University of Technology, Eindhoven, Netherlands — [3]Peter Grünberg Institut (PGI-10), Forschungszentrum Jülich, Jülich, Germany — [4]Peter Grünberg Institut (PGI-2), Forschungszentrum Jülich, Jülich, Germany

InAs nanowires (NWs) are a well-known basis for field-effect transistors (FETs), light-emitting diodes and lasers, quantum devices and biosensors. The larger band gap material CdSe, having a negligible lattice mismatch to InAs, allows for tailoring the conductive channel at the CdSe/InAs core/shell interface, thus making CdSe an excellent candidate for the InAs surface states passivation.

Here, we present the fabrication, structural, and electrical characterization of a unique InAs/CdSe core/shell NW system. The interface between the core and the shell is proven to be flawless by means of HR-TEM micrographs. Moreover, electrical characterization reveals a high-mobility two-dimensional transport channel in the InAs core. Finally, magnetotransport measurements show clear signs of weak antilocalization. These results make the novel InAs/CdSe hybrid NWs a promising basis for the quantum device applications.

HL 29.10 Wed 17:45 POT 151

Electrical excitation of color centers in phosphorus-doped diamond Schottky diodes — •Florian Sledz[1], Igor A. Khramtsov[2], Assegid M. Flatae[1], Stefano Lagomarsino[1], Navid Soltani[1], Shannon S. Nicley[3], Rozita Rouzbahani[3], Paulius Pobedinskas[3], Ken Haenen[3], Jin Qun[4], Xin Jiang[4], Paul Kienitz[5], Peter Haring Bolivar[5], Dmitry Yu. Fedyanin[2], and Mario Agio[1] — [1]Laboratory of Nano-Optics, University of Siegen, Germany — [2]Moscow, Russian Federation — [3]Institute for Materials Research (IMO) & IMOMEC, Hasselt University & IMEC vzw, Belgium — [4]Institute of Materials Engineering, University of Siegen, Germany — [5]Institute of Graphene-based Nanotechnology, University of Siegen, Germany

A robust single-photon source operating upon electrical injection at ambient condition is desirable for quantum technologies. Silicon-vacancy color centers in diamond are promising candidates as their emission is concentrated in a narrow zero-phonon line with a short excited-state lifetime of ~1 ns. Creating the color centers in n-type diamond (phosphorus-doped) allows the implementation of a Schottky-diode configuration. This provides a simpler approach than the traditional complex diamond semiconductor junctions e.g., p-i-n. Selective optical excitation allows addressing of single silicon-vacancy color centers while suppressing background from mainly nitrogen-vacancy defects created during Si ion implantation. This paves a way for the realization of the predicted bright electroluminescence of color centers.