HL 37: Materials and devices for quantum technology II

Time: Thursday 9:30–12:15 Location: POT 251

HL 37.1 Thu 9:30 POT 251

Long-range shuttling of single electron by Si/SiGe conveyor — •Ran Xue[1], Max Beer[1], Jhih-Sian Tu[2], Simon Humpohl[1], Inga Seidler[1], Tom Struck[1], Tobias Hangleiter[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

Electrostatically confined electrons are promising candidates for spin-qubits due to their long coherence in ^{28}Si/SiGe. To scale up qubit numbers and integrate control electronics, we propose to use a 10 μm long quantum bus (QuBus), which requires four control lines independent of the shuttle distance. Providing a propagating sinusoidal potential in a gate-defined 1D channel, adiabatic movement of a quantum dot filled by a single electron representing the qubit has achieved a shuttling fidelity of $99.4 \pm 0.02\%$ in a 420 nm long QuBus [1]. Here, we propose and demonstrate the tomography of a single electron shuttling process on a scaled-up 10 μm long QuBus. The electron is shuttled forth and back over micrometer-scale by a time-reversible pulse composed by only four sine-waves. Our tomography measures the shuttling fidelity and detects shuttling failures such as electron tunneling across pockets of the sinusoidal shuttling potential due to local potential disorder [2].

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

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

HL 37.2 Thu 9:45 POT 251

Telecom C-band photon emission from (In,Ga)As quantum dots generated by filling nanoholes in In0.52Al0.48As layers — •Dennis Deutsch, Christopher Henrik Buchholz, Klaus Jöns, and Dirk Reuter — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

Quantum communication technology requires sources for the on-demand generation of entangled photon pairs, preferably in the optical C-band for long-haul fiber-based communication. Quantum dots grown on InP substrates seem to be an ideal candidate: Here photon pairs can be generated from the biexciton-exciton cascade with emission wavelengths around 1.55 μm. However, the conventional approach of Stranski-Krastanov grown InAs quantum dots leads to several challenges related to the strain driven growth. In this study we report on an alternative approach allowing for unstrained quantum dots by filling of local droplet etched (LDE) nanoholes. The quantum dots are embedded in an $In_{0.52}Al_{0.48}As$ matrix lattice-matched to the InP substrate and grown by molecular beam epitaxy. We show detailed investigations of the hole morphology measured by atomic force microscopy. Statistical analysis of nanoholes shows promising symmetry for a good number of them when etched at optimized temperatures. Furthermore, we see that filling of the holes with $In_{0.53}Ga_{0.48}As$ works under the right growth conditions. By capping the filled holes and performing photoluminescence measurements we observe emission in the O-band up into the C-band depending on the filling height of the nanoholes.

HL 37.3 Thu 10:00 POT 251

Scalable Quantum Memory Nodes using nuclear spins in Silicon Carbide — •Shravan Kumar Parthasarathy[1,2], Birgit Kallinger[1], Florian Kaiser[3,4], Patrick Berwian[1], Durga Dasari[3,4], Jochen Friedrich[1], and Roland Nagy[2] — [1]Fraunhofer Institute for Integrated Systems and Device Technology (IISB), Erlangen, Germany — [2]Chair of Electron Devices, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany — [3]3rd Institute of Physics and Stuttgart Research Center of Photonic Engineering (SCoPE), University of Stuttgart,70569 Stuttgart, Germany — [4]Center for Integrated Quantum Science and Technology (IQST), Germany

The ultimate motivation of my project is to address the possibility of building a quantum analogue of Internet of Things in order to improve the standards of quantum information processing. A distributed quantum computing network which is capable of achieving this goal, would require large sets of memory nodes. The challenge in this field has been in realizing such memory nodes with features for scalable quantum computing. Solid state spins in 4H-Silicon Carbide (4H-SiC) provides a suitable platform in achieving this goal wherein a controlled generation of highly coherent qubit registers using nuclear spins (^{13}C or ^{29}Si) and silicon vacancy color centers (V_Si^- center) are possible. A numerical model is hence established in order to investigate the influence of material or experimental parameters on number of such controllable nuclear spins. This study would be helpful in finding the optimal parameters to maximize qubits in Quantum Memory Nodes.

HL 37.4 Thu 10:15 POT 251

Coherent Conveyor Mode Shuttling of Electrons and their Spin — •Tobias Offermann, Tom Struck, Lino Visser, Mats Volmer, Ran Xue, Hendrik Bluhm, and Lars R. Schreiber — JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Aachen, Germany

A missing key technology for scaling up electron spin qubits in ^{28}Si/SiGe is a coherent medium-range coupling between two qubits. It would enable a sparse-qubit architecture and makes space for signal-line fan-out and cryogenic electronics tiles integrated on the qubit chip. We present an approach named *conveyor-mode shuttling*, which relies on physically transporting the electron by a propagating wave-potential with simple input signals across an electrostatically defined quantum-channel [1,2]. We will introduce high fidelity single electron shuttling at a velocity high enough to reduce the shuttling time well below the typical spin-dephasing time of natural silicon. We show initialisation of the shuttle device on one end by two electrons in a spin-singlet. Shuttling only one of these electrons, we generate a separated Einstein-Podolsky-Rosen spin-pair. Combining the electrons by shuttling again, we detect their spin-singlet fraction by Pauli-spin blockade and explore the spin-coherence of the shuttling process.

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

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

HL 37.5 Thu 10:30 POT 251

Prospects for electrically controlled, directly fiber-coupled circular Bragg gratings as high performance quantum light sources — •Lucas Rickert[1], Fridtjof Betz[2], Matthias Plock[2], Sven Burger[2,3], and Tobias Heindel[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Zuse Institute Berlin, Takustraße 7, 14195 Berlin, Germany — [3]JCMwave GmbH, Bolivarallee 22, 14050 Berlin, Germany

Semiconductor quantum dots in (hybrid) circular Bragg gratings (hCBGs) have shown seminal performances as bright sources of indistinguishable entangled photons at wavelengths below 900 nm and have also shown significant boosts in performances for telecom wavelength single photons sources. To fully harness their potential for photonic quantum technologies, a direct coupling to single mode fibers (SMFs) for robust quantum light sources as well as designs with gate-contacts allowing for electrical control of the embedded emitters charge environment and spectral Stark-tuning is desirable. In this contribution, we present hCBG-based designs enabling electrical control, which are numerically optimized to show >85% direct fiber coupling efficiencies to SMFs, and Purcell enhancements >20 at operation wavelengths for 930 nm, 1310 nm and 1550 nm respectively. We investigated extensively the impact on performance of deviations in the fabrication using machine-learning algorithms, and show our recent progress in the experimental realization of directly fiber-coupled hCBG single photon sources.

30 min. break

HL 37.6 Thu 11:15 POT 251

X-ray nanobeam measurements of nanoscale elastic strain in electron shuttling devices — •Cedric Corley-Wiciak[1], Marvin H. Zoellner[1], Ignatii Zaitsev[1], Costanza L. Manganelli[1], Edoardo Zatterin[2], Ketan Anand[1], Agnieszka A. Corley-Wiciak[1], Felix Reichmann[1], Yuji Yamamoto[1], Michele Virgilio[3], Lars Schreiber[4], Wolfram Langheinrich[5], Carsten Richter[6], and Giovanni Capellini[1,7] — [1]IHP, Frankfurt(Oder), Germany — [2]ESRF, Grenoble, France — [3]Department of Physics, Università di Pisa, Italy — [4]JARA Institute, RWTH Aachen University, Germany — [5]Infineon Technologies Dresden GmbH und Co.KG, Germany — [6]IKZ, Berlin, Germany — [7]Dipartimento di Scienze, Universita Roma Tre, Italy

Recently, spin qubits housed in electrostatic quantum dots in epitaxial Si/SiGe heterostructures have evolved by the demonstration of multi-qubit algorithms. One key requirement for realizing arrays of qubits with shared gate control is highly homogenous lattice strain in the Si quantum well (QW) hosting the qubits. We leverage Scanning Xray Diffraction Microscopy (SXDM), performed at the beamline ID01/ESRF, to map the strain tensor around several fully CMOS compatible electron shuttling devices for qubit interconnection (QuBus). We observe local modulations of the lattice strain by several 10^{-4}, which are translated into spatially resolved profiles for the energy of the conduction band valley state, showing local fluctuations $>$ 1meV. Thus, our results demonstrate that material inhomogeneities must be considered in the design for scaled quantum processors.

HL 37.7 Thu 11:30 POT 251

Quantum optimal control for conveyor-mode single-electron shuttling in Si/SiGe — •Alessandro David[1], Veit Langrock[2], Julian D. Teske[3], Lars R. Schreiber[3], Hendrik Bluhm[3], Tommaso Calarco[1], and Felix Motzoi[1] — [1]Institute of Quantum Control (PGI-8), Forschungszentrum Jülich GmbH, Jülich, Germany — [2]Institute of Theoretical Nanoelectronics (PGI-2), JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH, Jülich, Germany — [3]JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Aachen, Germany

A quantum bus (QuBus) is a promising candidate for the scalability of spin-qubits quantum computers. We consider a gated Si/SiGe quantum well capable of shuttling electrons smoothly by a translating confining potential (conveyor-mode). Dephasing coupling with valley degree of freedom and geometry of the quantum well dictate a maximum shuttling speed to keep the electron state adiabatically in the ground state and avoid excitation of the valley state. In this work we use the position of the electron as a control parameter and we optimise the trajectory of the electron to show how the electron can be shuttled faster and with lower infidelity compared to the adiabatic regime.

HL 37.8 Thu 11:45 POT 251

Determination of optical dipole orientation of quantum emitters in monolayer MoS_2 — •Anna Herrmann, Katja Barthelmi, Lukas Sigl, Mirco Troue, Thomas Klokkers, Jonathan Finley, Christoph Kastl, and Alexander Holleitner — Walter Schottky Institut and Physics Department, Technische Universität München, Am Coulombwall 4a, Garching bei München, Germany

Single photon emitters in 2D materials are interesting for applications in quantum science and technology. Recently, we demonstrated that defect-based single photon emitters can be site-selectively generated in monolayer MoS_2 van der Waals heterostacks by a focused beam of helium ions with an overall positioning accuracy below 10 nm. The emitters show a luminescence with narrow emission lines around 1.75 eV. To determine the optical dipole orientation of the emitters we discuss the far-field photoluminescence intensity distribution of the defect emission in a back-focal plane geometry. The data is compared to simulations by an analytical model, which describes the dipolar emission pattern in the dielectric environment of the heterostructure. The demonstrated approach allows determining the relative contributions for in- and out-of-plane transition dipole moments of quantum emitters.

HL 37.9 Thu 12:00 POT 251

Interface control of valley splitting in Si-based heterostructures — •Jonas R F Lima[1,2] and Guido Burkard[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]Departamento de Física, Universidade Federal Rural de Pernambuco, 52171-900, Recife, PE, Brazil

The spin of electrons is a natural two-level system that works as an excellent qubit. The control of the spin of isolated electrons in silicon-based heterostructures is very promising for high performance and scalable qubits. To achieve this, it is very important to predict and control the valley splitting in this system, since a very fast qubit relaxation is obtained, for instance, when the valley splitting becomes equal to the qubit Zeeman splitting. For this reason, different works have investigated the valley splitting in silicon spin qubits, both experimentally and theoretically. In this work we used the effective mass theory, which enables us to obtain the electron envelope function, to predict the valley splitting of silicon-based heterostructures, where we consider fluctuations in the interfaces of the heterostructure. We obtain how the valley splitting can be tuned by the width of the interfaces and compare our results with results obtained by other methods.