HL 36: Materials and Devices for Quantum Technology II

Time: Wednesday 15:00–18:00 Location: H13

HL 36.1 Wed 15:00 H13

High aspect ratio wurtzite GaAs nanowires as a platform for hexagonal SiGe — •Marvin Marco Jansen[1], Wouter H.J. Peeters[1], Marcel A. Verheijen[1,2], and Erik P.A.M. Bakkers[1] — [1]Department of Applied Physics, Eindhoven University of Technology, Groene Loper 19, 5612AP Eindhoven, The Netherland — [2]Eurofins Materials Science BV, High Tech Campus 11, 5656 AE Eindhoven, The Netherlands

One of the most promising pathway to create a silicon based laser is the recently developed hexagonal silicon germanium (hex-SiGe) shells around wurtzite (WZ) gallium arsenide (GaAs) nanowires (NWs) for which efficient direct band gap emission was shown. However, studies have highlighted the limitations of the core/shell NW system. A main challenge is the recently discovered aspect ratio limitation in WZ GaAs NWs ascribed to a dynamic variation of the growth conditions. Here, we report on the crystal phase control of GaAs NWs down to the monolayer regime opening up new pathways for superlattices as well as high aspect ratios GaAs NWs. To achieve this, Ga pulses are executed by momentarily halting the As supply, leading to an accumulation of Ga atoms within the catalyst particle. This process leads to the increase of the contact angle of the catalyst particle enabling a controlled transition from the WZ phase to the zinc blende (ZB), and then back to the WZ phase. By using the ZB inclusion as a marker during the growth process, we successfully carried out a detailed investigation into the evolution of the NW growth, considering its diameter, length, and the pulse frequency.

HL 36.2 Wed 15:15 H13

Shaped pulses enable robust coherent control of quantum dots: perspectives for quantum technologies — •Vikas Remesh — Institute für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria

Shaped laser pulses have been remarkably effective in investigating and controlling various light-matter interactions in a broad area of research. In quantum technologies, the techniques to shape complex spatiotemporal waveforms have found renewed interest, for instance in coherent control of quantum dots [1]. In this talk, I will navigate through the impact of pulse shaping techniques in nanospectroscopy and how it enabled efficient preparation schemes in quantum dots, based on our recent works [2], including the pioneering off-resonant coherent control of quantum dots, compact plug-and-play method of exciting multiple quantum dots and accessing dark excitons in quantum dots for advanced entanglement generation. Afterwards, I will conclude with my vision on the future scope of nanophotonics-assisted-quantum technology roadmap. [1] Photonic Quantum Technologies: Science and Applications 1, 53 (2023) [2] Nano Letters 22, 6567 (2022), Materials for Quantum Technology 3, 025006 (2023), APL Photonics 8, 101301 (2023), npj Quantum Information 10, 17 (2024), Advanced Quantum Technologies, 2300352 (2024), arXiv:2409.13981, arXiv:2406.07097, arXiv:2404.10708

HL 36.3 Wed 15:30 H13

Single-Electron Shuttling for Scalable Silicon Quantum Computers: Modeling, Simulation and Optimal Control — •Lasse Ermoneit[1], Burkhard Schmidt[1], Thomas Koprucki[1], Jürgen Fuhrmann[1], Tobias Breiten[2], Arnau Sala[3], Nils Ciroth[3], Ran Xue[3], Lars R. Schreiber[3,4], and Markus Kantner[1] — [1]Weierstrass Institute, Berlin, Germany — [2]Technical University Berlin, Germany — [3]JARA-FIT Institute for Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Germany — [4]ARQUE Systems GmbH, Aachen, Germany

While spin qubits in gate-defined Si/SiGe quantum dots provide excellent prospects for scalability, the lithographic processing, signal routing and wiring of large qubit arrays at a small footprint pose a significant challenge. A potential solution is to divide the qubit register into compact, dense qubit arrays linked by an interconnecting quantum bus shuttle, that allows for coherent transfer of quantum information by physically moving electrons along a channel. Limitations in qubit shuttling fidelity arise from the interaction of the electron with material defects within the channel that can cause non-adiabatic transitions to excited orbital states. Since those have an altered effective g-factor, this leads to a spin precession with an indeterministic phase. In this contribution, we theoretically explore the capabilities for bypassing defect centers using optimally engineered control signals that allow for a quasi-adiabatic passage of the electron through the channel without reducing the shuttling velocity. Our approach is based on quantum optimal control theory and Schrödinger wave packet propagation.

HL 36.4 Wed 15:45 H13

Spectral Hole linewidths and donor-acceptor dynamics in ultra-pure 28-Si:P — •Nico Eggeling[1], Finja Tadge[1], N.V. Abrosimov[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Leibniz Universität Hannover, Germany — [2]IKZ Berlin, Germany

Donor-bound excitons in ultra-pure silicon show significant inhomogeneous broadening, which can be studied in detail using spectral hole burning[1]. Surprisingly, for decreasing pump intensities, the linewidth of these holes does not approach the natural transition linewidth, resulting from the dominating Auger effect at low temperatures[2]. Instead, time-dependent experiments show that the width and decay of the spectral holes change significantly with temperature and magnetic field, which an intricate model including donor-acceptor pair recombination can explain.

[1] J. J. Berry, et al. Appl. Phy. Lett. **88**, 061114, (2006).
[2] Yang, et al. Appl. Phy. Lett. **95**, 122113, (2009).

HL 36.5 Wed 16:00 H13

The Kitaev transmon qubit: design, readout and operation — •Tobias Kuhn and Monica Benito — Augsburg University, Augsburg, Germany

Fermionic-parity qubits are very stable but cannot be operated in isolation. Coupling two parity qubits allows us to construct parity-spin qubit states within one global parity [1]. Its degeneracy and non-locality should improve T_2 and T_1 times [2]. A parity qubit can be realized in a double quantum dot connected via a common superconducting lead, where elastic cotunneling t as well as crossed Andreev reflection Δ preserve parity. This minimal Kitaev chain possesses degenerate distinct-parity states at the sweetspot $\Delta = t$[1]. Weakly coupling two minimal Kitaev chains inside a transmon loop introduces an additional Josephson potential which is a consequence of the emerging parity-spin qubit [3]. This hybrid device combines the advantages of both quantum dots and transmons to promise a high-fidelity qubit device we call Kitmon (Kitaev transmon). We theoretically analyze even and odd global parity subspaces of the Kitaev junction and show that flux spectroscopy in a circuit QED implementation [4] determines global parity. Additionally, we derive an effective Hamiltonian depending on the transmon excitation state, which is useful for single qubit operations and qubit readout. [1] M. Leijnse and K. Flensberg, Phys. Rev. B **86**, 134528 (2012) [2] G.-L. Guo, H.-B. Leng, and X. Liu, New J. Phys. **26**, 063005 (2024) [3] D. M. Pino, R. S. Souto, and R. Aguado, Phys. Rev. B **109**, 075101 (2024) [4] L. Peri, M. Benito, C. J. B. Ford, and M. F. Gonzalez-Zalba, npj Quantum Inf **10**, 1 (2024)

HL 36.6 Wed 16:15 H13

Towards the goal of reliably storing single-photons from a quantum dot — •Ioannis Caltzidis[1], Patricia A. Kallert[1], Chase Wallace[2], Sean Keenan[3], Nicolas Claro-Rodríguez[1], Santiago Bermúdez-Feijóo[1], Sonja Barkhofen[1], Margherita Mazzera[3], Eden Figueroa[2], and Klaus D. Jöns[1] — [1]Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP) and Department of Physics, Paderborn University, Germany — [2]Quantum Memories Group, Heriot-Watt University, Edinburgh, Scotland, United Kingdom — [3]Department of Physics and Astronomy, Stony Brook University, Stony Brook, NY, USA and Brookhaven National Laboratory, Upton, NY, USA

In quantum networks, precise single-photon arrival times are crucial for effective entanglement swapping protocols. Therefore, quantum memories are curcial to store photons until read out simultaneously and synchronously routed to further processing, e.g. Bell measurements. To operate a varm vapor memory in our laboratories we present initial results demonstrating our ability to generate short optical pulses in the desired frequency domain optimized for the atomic transitions of rubidium. We further probe the interaction of short pulses with the atomic medium in the presence or absence of different supsidiary light-fields. This series of experiments aims to probe the parameter space of our system with the goal of storing single photons fom quantum dots in a rubidium based EIT Memory.

15 min. break

HL 36.7 Wed 16:45 H13

Stability of Majorana modes in disordered topological insulator nanowires — •Leonard Kaufhold — Institute for theoretical physics, Cologne, Germany

The possibility of Majorana bound states (MBS) in nanowire hybrid devices has sparked great interest over the past decade due to their potential application in quantum computing. In this talk, we evaluate theoretically the possibility to realize MBS in topological-insulator (TI) nanowires proximity-coupled to an s-wave superconductor with regards to one main obstacle: disorder, be it from charged impurities within the bulk of the TI or short ranged surface defects. Based on extensive numerical investigation of screening effects as well as the resulting surface states, we demonstrate, that Majorana modes can be achieved under realistic conditions.

HL 36.8 Wed 17:00 H13

Signature of topological transitions in Na-Sb-Bi alloys via Compton scattering — •Aki Pulkkinen[1], Veenavee Kothalawala[2], Kosuke Suzuki[3], Bernardo Barbiellini[2,4,5], Hiroshi Sakurai[3], Ján Minár[1], and Arun Bansil[4,5] — [1]New Technologies-Research Centre, Pilsen, Czech Republic — [2]School of Engineering Science, LUT University, Finland — [3]Graduate School of Science and Technology, Gunma University, Japan — [4]Department of Physics, Northeastern University, USA — [5]Quantum Materials and Sensing Institute, Northeastern University, USA

We investigate the topological transition in Na-Sb-Bi alloys using x-ray Compton scattering experiments, combined with first-principles modeling of the electronic structure. A robust signature of the semiconductor-to-Dirac semimetal transition is identified in the spherically averaged Compton profile. We demonstrate the evolution of the electronic structure across the topological transition as a function of Bi concentration using the coherent potential approximation (CPA) within the fully relativistic, full potential Korringa-Kohn-Rostoker (KKR) method implemented in the SPRKKR package. Spherically averaged Compton profiles are estimated by averaging over directional profiles over a set of special directions within the KKR method. We demonstrate how the number of electrons involved in the topological transition can be estimated, providing a new descriptor to quantify the strength of the spin-orbit coupling driving the transition. Our study also highlights the sensitivity of the Compton scattering technique in capturing the spillover of Bi 6p relativistic states onto Na sites.

HL 36.9 Wed 17:15 H13

Circular photonic crystal grating design for charge-tunable quantum light sources in the telecom C-band — •Chenxi Ma[1], Jingzhong Yang[1], Pengji Li[1], Eddy Rugeramigabo[1], Michael Zopf[1], and Fei Ding[1,2] — [1]Leibniz University Hannover, Institute of Solid State Physics, Hannover, Germany — [2]Leibniz University Hannover, Laboratory of Nano and Quantum Engineering, Hannover, Germany

Efficient generation of entangled photon pairs at telecom wavelengths is a key ingredient for long-range quantum networks. While embedding semiconductor quantum dots into hybrid circular Bragg gratings has proven effective, it conflicts with p-i-n diode heterostructures which offer superior coherence. We propose and analyze hybrid circular photonic crystal gratings, incorporating air holes to facilitate charge carrier transport without compromising optical properties. Through numerical simulations, a broad cavity mode with a Purcell factor of 23 enhancing both exciton and biexciton transitions, and exceptional collection efficiency of 92.4

HL 36.10 Wed 17:30 H13

Control of NV centre generation in pulsed plasma chemical vapor deposition (CVD) grown diamonds — •Ravi Teja Aditya[1], Felix Hoffmann[1], Patrik Stranak[1], Volker Cimalla[1], and Rüdiger Quay[1,2] — [1]Fraunhofer Institute for Applied Solid State Physics, Tullastraße 72, D-79108 Freiburg, Germany — [2]Department for Sustainable Systems Engineering INATECH, University of Freiburg, 79108 Freiburg, Germany

Nitrogen vacancy (NV) centres in diamond have emerged to be an integral part in many quantum computing and quantum sensing applications. High and precise NV density is required especially for quantum sensing applications. There is a need for control of nitrogen incorporation and NV yield without compromising crystal quality and growth rate. Although higher power levels ensure higher nitrogen incorporation, it is often limited by temperature. Investigating pulsed plasma chemical vapor deposition (CVD) for this purpose proved to be beneficial to control the NV generation. A pulsed plasma generator was used to reach higher power levels while maintaining an appropriate temperature by adjusting the duty cycle accordingly. Time resolved optical emission spectroscopy (OES) was used to observe the plasma composition during microwave pulses. A pulse length dependent activation of CN radicals was observed which led to a variation in NV densities in grown films. We present the results of variation of NV densities in diamond films caused by variation in pulse length, MW power and duty cycle.

HL 36.11 Wed 17:45 H13

Charge-tunable quantum dot single photon sources for quantum repeater experiments — •Peter Gschwandtner, Quirin Buchinger, Constantin Krause, Sebastian Krüger, Silke Kuhn, Tobias Huber-Loyola, and Sven Höfling — Julius-Maximilian-Universität Würzburg, Physikalisches Institut, Lehrstuhl für Technische Physik, Germany

Semiconductor quantum dots (QD) are promising candidates for entangled photon sources (SPS) for quantum network purposes [1]. Single charge spins in QDs could serve as the quantum memory in the quantum repeater [2] or as a local entangler to create a photonic state for a memory-free quantum repeater [3].

In this talk, we present our experimental results for electrically contacted charge-tuneable p-i-n InAs QDs embedded in a circular Bragg grating (CBG). The cavity design enables us to control the charged exciton states of the quantum dots. The CBG exhibits high Purcell enhancement in a broad wavelength range. A novel labyrinth design of the CBG allows for electrical contacting without impeding other performance characteristics [4].

[1] D. Vajner et al., Adv. Quantum Technol. (2022), 10.1002/qute.202100116 [2] H.-J. Briegel, W. Dür, J. I. Cirac and P. Zoller, Phys. Rev. Lett. 81, 5932*5935 (1998), 10.1103/PhysRevLett.81.5932 [3] K. Azuma, K. Tamaki and H.-K. Lo, Nature communications 6, 6787 (2015)., 10.1038/ncomms7787 [4] Q. Buchinger et al., Appl. Physics Letters (2023), 10.1063/5.0136715