Q 76: Nanophotonics II

Time: Friday 14:30–16:30 Location: WP-HS

Q 76.1 Fri 14:30 WP-HS

Towards a versatile Silicon-Carbide-on-Insulator Platform for Quantum Nanophotonics with Optically Active Spins — •Leonard K.S. Zimmermann[1,2], Flavie Davidson-Marquis[1,2], Jonah Heiler[1,2], Samuel C. Eserin[3], Stephen K. Clowes[3], Benedict N. Murdin[3], Stephan Kucera[1], and Florian Kaiser[1,2] — [1]Luxembourg Institute of Science and Technology (LIST), Esch-sur-Alzette, Luxembourg — [2]University of Luxembourg, Esch-sur-Alzette, Luxembourg — [3]Advanced Technology Institute, University of Surrey, Guildford, United Kingdom

Colour centres offer promising properties for quantum technologies, including controllable generation, processing, and tuning. Silicon carbide (SiC) is a promising material for a scalable nanophotonics platform, given its mature device technology. Recent demonstrations show color centers in SiC with good preserved spin-optical coherence and effective spin-photon interaction in nanophotonic devices. This allows SiC to combine multiple functionalities on a single chip, such as small quantum processors with quantum memories. The next steps are further developing the Silicon-Carbide-on-Insulator (SiCOI) platform on multiple fronts. Different insulator materials are investigated to increase the spin-photon interface efficiency and the first results from an ongoing implantation-annealing study to generate divacancy colour centres in 4H-SiC using a Helium-Neon-Focussed-Ion-Beam are shown.

Q 76.2 Fri 14:45 WP-HS

Nonlinear SnV-Based Electrometry for Material Science at the Atomic Lattice Scale — •Gregor Pieplow[1], Cem Güney Torun[1], Charlotta Gurr[1], Joseph H. D. Munns[1], Franziska M. Herrmann[1], Andreas Thies[2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Quantum probes embedded in solid-state materials offer new and technologically relevant insights for materials science. While nitrogen-vacancy (NV) centers in diamond are well-established as in situ magnetometers and electrometers, we propose a novel approach to electrometry using group-IV vacancies (G4V), specifically the negatively charged tin vacancy (SnV) in diamond [1]. Unlike NV centers, G4V centers exhibit reduced sensitivity to linear Stark shifts, making them less susceptible to noise from distant charges. This property enables the detection of electric fields generated by charges near the sensor, allowing for the localization of charge traps at the diamond lattice scale, even in the presence of significant noise. By employing a rapid spectroscopic method, our approach enables the monitoring of environmental dynamics and the identification and colocalization of multiple charge traps using a single sensor probe. Additionally, we quantify the impact of charge noise on the SnV's optical coherence, investigate critical material properties, and outline strategies for material optimization.

[1] Pieplow G., et al. (2024) arXiv:2401.14290v1

Q 76.3 Fri 15:00 WP-HS

Advanced waveguide structures for quantum communication and computing in SiC — •Jonas Schmid[1,2], Flavie Davidson-Marquis[1,2], Nien-Hsuan Lee[1,2], Sushree Swateepragnya Behera[1,2], Stephan Kucera[1], and Florian Kaiser[1,2] — [1]Luxembourg Institute for Science and Technology, Esch-sur-Alzette, Luxembourg — [2]University of Luxembourg, Esch-sur-Alzette, Luxembourg

Divacancies in silicon carbide (SiC) entail excellent quantum systems for quantum communication, based on the combination of quantum memories and photonic qubits. Significant challenges to overcome are the low efficiency of the optical interface and the integration into photonic chips. We address these issues through the optimization of the design in order to increase the efficiency of photonic circuits in SiC. Our approach involves SiC-on-insulator waveguide structures for the integration into photonic chips. With our designs, we ensure good coupling from the dipole emitter into the waveguide, as well as from the waveguide into the fiber. Further, robust and low-loss beam splitter designs are investigated. The successful implementation of this design will enable interference between divacancies on a quantum chip. This multiplexed spin-photon entanglement interface enables faster quantum communication rates.

Q 76.4 Fri 15:15 WP-HS

Controlling non-volatile shifts of high-Q resonances for nanobeam photonic crystal cavities — •Tim Buskasper[1,2,3], Mohammad Bilal Malik[1,2,3], David Lemli[1,2,3], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Heisenbergstr. 11, Münster, 48149, Germany — [2]CeNTech - Center for NanoTechnology, Heisenbergstr. 11, 48149 Münster, Germany — [3]SoN - Center for Soft Nanoscience, Busso-Peus-Straße 10, 48149 Münster, Germany

Nanobeam photonic crystal cavities are critical for applications in nanoscale sensing, nonlinear optics, and light-matter interaction. However, achieving high-quality (Q) factors typically requires free-standing devices, and precise resonance tuning often relies on active elements with limited scalability.

Here, we show an order-of-magnitude improvement of Q-factors for nanobeam cavities made from tantalum pentoxide to 1.36×10^5 at $\lambda = 773.2$ nm without the need of releasing the device from the substrate. Additionally, we demonstrate shifting of resonances by combining advanced nanophotonic design and high-resolution lithography with laser-assisted oxidation, thus achieving resonance overlap for a large number of resonators.

This approach is not restricted to tantalum pentoxide but can be adapted for other material platforms, like silicon-nitride-on-insulators. It paves the way for realizing large arrays of identical high-Q resonators.

Q 76.5 Fri 15:30 WP-HS

Telecom emitters in silicon slow-light waveguides — •Florian Burger[1,2], Stephan Rinner[1,2], Andreas Gritsch[2,1], Kilian Sandholzer[2,1], and Andreas Reiserer[2,1] — [1]Max Planck Institute of Quantum Optics, Quantum Networks Group, 85748 Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences and Munich Center for Quantum Science and Technology (MCQST), 85748 Garching, Germany

In ground-based quantum networks, photons are exchanged via optical fibers to create entanglement between distant network nodes. To scale up these networks, efficient light-matter interfaces, which map the quantum state of a photon to that of a stationary quantum mechanical system, are required. Yet, a physical system that combines telecom wavelength emission for low-loss fiber transmission with sufficiently long coherence times for global-scale quantum links and straightforward scalability remains elusive. Here we show that erbium dopants in silicon, which fulfill these criteria [1], can be addressed individually when integrated into a photonic-crystal slow-light waveguide. Due to the broadband nature of the the slow-light effect in the waveguide, no technically involved tuning of the nanostructure is required to ensure efficient coupling. We also show how the slow-light effect modifies the lifetime of the investigated optical transition. Erbium-doped silicon slow-light waveguides could thus be a platform for robust on-chip quantum memories operating at telcom wavelengths in future quantum networks.

[1] A. Gritsch et al., 2024, arXiv:2405.05351.

Q 76.6 Fri 15:45 WP-HS

Long-Range Self-Hybridized Exciton-Polaritons in Two-Dimensional Ruddlesden-Popper Perovskites — •Maximilian Black[1], Mehdi Asadi[2], Parsa Darman[2], Sezer Seçkin[3], Finja Schillmöller[1], Tobias A. F. König[3], Sara Darbari[1,2], and Nahid Talebi[1] — [1]Institute of Experimental and Applied Physics, Kiel University, Kiel, Germany — [2]Nano-Sensors and Detectors Lab., Tarbiat Modares University, Tehran, Iran — [3]Leibniz-Institut für Polymerforschung Dresden e.V., Dresden, Germany

Ruddlesden-Popper perovskites combine excellent photoluminescence efficiency and high synthetic versatility with a crystal structure of stacked quantum wells that induces two-dimensional quantum confinement in the bulk crystal. This makes them exciting platforms for the study of exciton-polaritons, mixed states of excitons and localized photons. In this work, we present proof of long-range propagating exciton-polaritons in the cavity formed by the crystal itself, a phenomenon called self-hybridization. Bright-field spectroscopy reveals excitonic splitting and polaritonic bending of Fabry-Pérot mode dispersion, while photoluminescence spectroscopy shows multiple thicknessdependent polariton branches. Strikingly, local optical excitation below the exciton energy couples light directly to in-plane polaritonic modes, which transfer energy to lower-energy polaritons. The exciton-polaritons exhibit directed long-range propagation, as confirmed by FDTD simulations. Thus, we demonstrate that mesoscopic 2D Ruddlesden-Popper perovskite flakes serve as an effective system for exploring exciton-polaritons at room temperature.

Q 76.7 Fri 16:00 WP-HS

Transient energy distributions for photo-catalysis in plasmonic heterostructures — •Mathis Noell, Felix Stete, Matias Bargheer, and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

We investigate the dynamics of heat energy transfer following photon absorption by a gold palladium core-shell nanoparticle. This hybrid structure combines a highly efficient plasmonic antenna with catalytically active material, making it a promising platform for light energy harvesting in view of light-driven catalysis. We analyze energy dissipation after single-photon absorption and sequences of photon pulses, bridging towards continuous-wave irradiation via stochastic Markov chains of individual absorption events. Employing two- and three-temperature models, we track the transient energy flow and demonstrate that the Pd shell, due to its strong electron-phonon coupling, momentarily reaches the highest local energy density. The influence of interfacial thermal conductivity and coupling to the surrounding medium is also evaluated.

Q 76.8 Fri 16:15 WP-HS

Limits for coherent optical control of a quantum emitter in hexagonal Boron Nitride (hBN) — •Michael K. Koch[1,2], Vibhav Bharadwaj[1,3], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, D-89081 Ulm, Germany — [3]Department of Physics, Indian Institute of Technology Guwahati, 781039 Guwahati, Assam, India

Single photon emitters are a crucial resource for upcoming quantum optic technologies. Hosted single photon emitters in hexagonal boron nitride (hBN) are ideal candidates for integration into hybrid quantum systems. One type of such emitter has demonstrated the remarkable property of Fourier transform-limited optical linewidth at cryogenic and even room temperature [1,2]. This characteristic is a manifestation of out-of-plane distorted emitters, which weakly couple to in-plane phonon modes. This results in the mechanical isolation of defect centers' orbitals [3], which enables coherent optical driving and the observation of optical Rabi oscillations at elevated temperatures [4].

[1] A. Dietrich et al., Physical Review B, Vol. 98 (2018)
[2] A. Dietrich et al., Physical Review B, Vol. 101 (2020)
[3] M. Hoese et al., Science Advances, Vol. 6 (2020)
[4] M. K. Koch et al., Communications Materials, Vol. 5 (2024)