QI 45: Quantum Technologies (Solid State Systems) (joint session Q/QI)

Time: Friday 14:30–16:30 Location: HS I

QI 45.1 Fri 14:30 HS I

Low Temperature Spectroscopy of hBN Quantum Emitters — •Mouli Hazra[1], Manuel Rieger[2], Anand Kumar[1], Mohammad Nasimuzzaman Mishuk[1], Tjorben Matthes[1], Viviana Villafane[2,3], Jonathan J. Finely[2], and Tobias Vogl[1] — [1]Department of Computer Engineering, TUM School of Computation Information and Technology, Technical University of Munich, 80333 Munich, Germany — [2]Walter Schottky institute, School of Natural Sciences and MQST, Technical University of Munich, 85748 Garching, Germany. — [3]Walter Schottky Institute, School of Computation, Information and Technology and MQST, Technical University of Munich, 85748 Garching, Germany

Hexagonal boron nitride (hBN) hosts a large range of high quality single-photon emitters (SPEs) making it promising candidate for quantum technology applications. The practical integration of these emitters requires precise control of emission wavelengths, spatial localization, and directionality of those emitters. In this work, we have created localized, spectrally stable SPEs using electron beam irradiation without any pre- or post-treatment. To understand their chemical nature, we performed cryogenic experiments to minimize thermal broadening and gain insights into their optical and structural characteristics. We studied how excitation wavelength and temperature influence the emission. This work marks a significant step toward deterministic, high-quality SPEs in hBN, advancing integrated quantum photonic technologies.

QI 45.2 Fri 14:45 HS I

Towards on-chip microwave to telecom transduction using erbium doped silicon — •Daniele Lopriore and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences and Munich Center for Quantum Science and Technology, 85748 Garching

The development of a device that converts microwave to optical photons at telecommunication wavelengths would be a key enabler for communication between remote quantum computers and would pave the way for the entanglement of distant superconducting qubits. We investigate ensembles of erbium dopants that exhibit coherent microwave [1] and optical transitions [2]. They can be used as a nonlinear medium mediating an efficient Raman conversion process [3]. High efficiencies require enhancing both the microwave and the telecom transitions with high quality factor resonators. We will present our progress towards low-loss manufacturing and measurements of the spin properties in erbium-doped silicon waveguides, and give an outlook towards the transduction efficiencies achievable with our approach. [1] A. Gritsch, et al. arXiv:2405.05351 (2024). [2] A. Gritsch, et al. Phys.Rev.X 12, 041009 (2022). [3] C. O'Brien, et al. Phys.Rev.Lett. 113, 063603 (2014).

QI 45.3 Fri 15:00 HS I

Hybrid Nanophotonic Spin-Photon Interface of Si_3N_4 Photonics and Silicon Vacancy Centers in Nanodiamonds — •Lukas Antoniuk[1], Niklas Lettner[1,2], Anna P. Ovvyan[3,5], Daniel Wendland[3], Viatcheslav N. Agafonov[4], Wolfram H.P. Pernice[3,5], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Germany — [3]Institute of Physics and Center for Nanotechnology, University of Münster, Germany — [4]Universite F. Rabelais, 37200 Tours, France — [5]Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Color centers in diamond have shown promising internal properties to be harnessed for quantum networks, secure quantum communication and distributed quantum computing. These applications require exchanging quantum information between stationary qubits and flying qubits, thus an efficient interface between them is needed. We base such an interface on negatively charged silicon vacancy centers (SiV^-) in nanodiamonds [1] and one-dimensional silicon nitride photonic crystal cavities. We present our progress on this hybrid platform which are access to the SiV^- qubit space [2] and control of optical coupling via nanomanipulation [3].

[1] Klotz et al., arXiv:2409.12645 [2] Lettner et al., ACS Photonics, 11(2):696-702 [3] Antoniuk et al., Physical Review Applied, 21(5):054032

QI 45.4 Fri 15:15 HS I

Deterministic preparation and retrieval of the dark state population in a quantum dot — •René Schwarz[1], Florian Kappe[1], Yusuf Karli[1], Thomas Bracht[2], Saimon Covre da Silva[3], Armando Rastelli[3], Vikas Remesh[1], Doris Reiter[2], and Gregor Weihs[1] — [1]Institute of Experimental Physics, University of Innsbruck, Innsbruck, Austria — [2]Condensed Matter Theory, Department of Physics, TU Dortmund, Dortmund, Germany — [3]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Linz, Austria

Semiconductor quantum dots are arguably the most promising platform for future quantum technologies. Due to the confinement of charge carriers, a variety of photon states can be generated, making them a highly adaptable quantum platform. While state-of-the-art optical excitation methods target the so-called bright excitons or biexcitons, quantum dots also accommodate optically dark excitons, which are not directly accessible via optical excitation methods. The dark exciton states exhibit significantly slower decay rates compared to their bright counterparts, making them potential candidates for application in quantum information protocols that require control of quantum coherence over long time scales [1]. In this work, we perform a full magneto-optical characterization (in-plane magnetic field) as well as a deterministic preparation and retrieval of the dark exciton state population in a single GaAs/AlGaAs quantum dot emitting at ~ 800 nm using a combination of a magnetic field and chirped laser pulses [2]. [1] Phys. Rev. Lett. 94, 030502 (2005). [2] arXiv, 2404.10708 (2024)

QI 45.5 Fri 15:30 HS I

Spectroscopy and coherent manipulation of REI-based organic molecular systems for quantum information applications. — •Vishnu Unni C.[1], Evgenij Vasilenko[1], Nicholas Jobbitt[1], Xiaoyu Yang[1], Barbora Brachnakova[1], Senthil Kuppusamy[1], Timo Neumann[2], Mario Ruben[1], Michael Seitz[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]University of Tübingen, Tübingen, Germany

A europium-based molecular complex has recently shown [1] competing optical coherence time as that of europium-doped crystals. This opens the possibility of tailoring ligand fields to improve optical and spin properties to realize optically addressed spin qubits. We measure an improved photon echo coherence time of 3 μs at 4K, a narrow optical linewidth of 120 kHz, and a spin lifetime longer than an hour at 150 mK using spectral hole burning (SHB) in the complex reported in [1]. We measure spin inhomogeneous lines of the hyperfine transitions of the ground states. Simultaneously, we screen many organic complexes with improved branching ratios of up to 1.3% and characterize their hyperfine splittings of ground and excited states and optical coherence times. The self-assembly of molecular complexes into high-quality crystals is exploited to integrate them into fiber-based microcavities[2] which enhances emission rates by the Purcell effect. These results are important steps towards single ion experiments to realize optically addressable spin qubits.

[1] Serrano et al., Nature, 603, 241-246 (2022)
[2] Hunger et al., New J. Phys 12, 065038 (2010)

QI 45.6 Fri 15:45 HS I

Hybrid integration of silicon carbide color centers into photonic integrated circuitry — •Jan Riegelmeyer, Gerben Timmer, Keyuan Fang, Maurice van der Maas, Elena Volkova, Kees Koot, Ryoichi Ishihara, Tim Taminiau, and Carlos Errando Herranz — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft 2628 CJ, Netherlands

Color centers in the solid-state are promising qubit candidates for quantum information processing, but scaling to practical systems requires significantly increasing the number of qubits within a single processing unit. A solution to this challenge is integrating color centers into photonic integrated circuits (PICs) for efficient and miniaturized photon collection, manipulation, and detection. However, traditional color center host materials like silicon carbide (SiC), lack well-established PIC technology, limiting scalability. Here, we address this limitation via the hybrid integration of SiC chiplets into silicon nitride (SiN) PICs using micro transfer printing. The chiplets are suspended structures fabricated from 4H-SiC-on-insulator containing photonic waveguides and cavities designed for the V2 color center. We optimized the geometry of chiplet and PIC to ensure reliable transfer printing and efficient optical transmission and demonstrate successful hybrid integration. While optimized for SiC color centers, our approach applies to other color center host materials.

QI 45.7 Fri 16:00 HS I

Building a weakly coupled nuclear spin register using the V2 color center in Silicon Carbide — •Pierre Kuna[1], Erik Hesselmeier-Hüttmann[1], Wolfgang Knolle[2], Florian Kaiser[3,4], Nguyen Tien Son[5], Misagh Ghezellou[5], Jawad Ul-Hassan[5], Vadim Vorobyov[1], and Jörg Wrachtrup[1,6] — [1]3rd Institute of Physics, IQST, and Research Center SCoPE, University of Stuttgart, Stuttgart, Germany — [2]Department of Sensoric Surfaces and Functional Interfaces, Leibniz-Institute of Surface Engineering (IOM), Leipzig, Germany — [3]Materials Research and Technology (MRT) Department, Luxembourg Institute of Science and Technology (LIST), 4422 Belvaux, Luxembourg — [4]University of Luxembourg, 41 rue du Brill, L-4422 Belvaux, Luxembourg — [5]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden — [6]Max Planck Institute for solid state physics, Stuttgart, Germany

The V2 color center in Silicon Carbide is a promissing candidate for scalable quantum networks due to its long coherence time, electrical compatibility, hosting two different and individually addressable nuclear spin baths[1].

In this work, we resolve the nuclear spin environment of a single color center using Electron DOuble Nuclear Spin Resonnance (ENDOR) spectroscopy showing over ten addressable nuclear spins and demonstrate their individual initialisation and control. We furthermore show first results on the entanglement of two weakly coupled nuclear spins.

[1] Erik Hesselmeier et al. Phys. Rev. Lett. 132, 180804-May, 2024

QI 45.8 Fri 16:15 HS I

Purcell enhancement of single defects in silicon carbide coupled to a a fiber-based Fabry-Pérot microcavity — •Jannis Hessenauer[1], Jonathan Körber[2], Jawad Ul-Hassan[3], Georgy Astakhov[4], Wolfgang Knolle[5], Jörg Wrachtrup[2], and David Hunger[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Germany — [2]3rd Institute of Physics, University of Stuttgart, Germany. — [3]Department of Physics, Chemistry and Biology, Linköping University, Sweden. — [4]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany. — [5]Leibniz-Institute of Surface Engineering (IOM), Germany.

The negatively charged silicon vacancy center (V2) in silicon carbide (SiC) has recently emerged as a promising realization of a solid-state spin-photon interface. Remarkably, it exhibits narrow optical linewidths, even when integrated into nanostructures, and at temperatures up to 20 K. However, only a small fraction of the light is emitted into the coherent zero-phonon line. An optical microcavity can be used to enhance this fraction via the Purcell effect. In this work, we integrate a three micron thin membrane of SiC containing color centers into a cryogenic fiber-based Fabry-Pérot-resonator. We study the cavity-membrane system and find excellent agreement with our model and minimal losses introduced by the membrane. We observe Purcell enhancement of the zero-phonon line, manifesting itself in a lifetime shortening and a strong zero-phonon line emission. Utilizing the spectral selectively of the cavity allows us to address individual defects in a spatially dense sample, which results in a high single photon purity.