Q 80: Quantum Technologies – Color Centers III

Time: Friday 14:30–16:15 Location: P 5

Q 80.1 Fri 14:30 P 5

Spectral diffusion and spin signatures of quantum emitters in hexagonal Boron Nitride — •Alexander Pachl[1], Sajedeh Shahbazi[1], and Alexander Kubanek[1,2] — [1]1Institut for Quantum Optics, University Ulm, 89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, 89081 Ulm, Germany

Single-photon emitters hosted in hexagonal boron nitride (hBN) are, due to their bright and narrow zero-phonon lines (ZPLs) and their two-dimensional host material, promising candidates for integration into upcoming quantum optical technologies. Mechanically decoupled emitters have even shown Fourier-transform-limited linewidths up to room temperature [1,2]. However, these emitters typically suffer from fast spectral diffusion and have so far not shown any spin signatures. In our most recent work, we address these limitations and report observed spin signatures together with an investigation of the fast sprecral diffusion properties.

[1] A. Dietrich et al., Physical Review B, Vol. 98 (2018)
[2] A. Dietrich et al., Physical Review B, Vol. 101 (2020)

Q 80.2 Fri 14:45 P 5

Electron spin-1/2 mediated nuclear-spin entanglement in diamond — •Marco Klotz, Andreas Tangemann, David Opferkuch, and Alexander Kubanek — Institute for Quantum Optics, University Ulm, Germany

Quantum networks will rely on photons entangled to robust, local quantum registers for computation and error correction. We demonstrate control of and entanglement in a fully connected three-qubit 13C nuclear spin register in diamond. The register is coupled to a quasi-free electron spin-1/2 of a silicon-vacancy center (SiV). High strain leads to a ground-state splitting of 1.8 THz and decouples the SiVs electron spin from spin-orbit interaction reducing the susceptibility to phonons at 4 Kelvin. We leverage continuously decoupled microwave and direct radio frequency driving to implement a nuclear-spin conditional phase-gate on the electron spin to mediate bipartite entanglement. This approach presents an alternative to dynamically decoupled nuclear spin entanglement, not limited by the electron spin's 1/2 nature, opening up new avenues to an optically-accessible, solid-state quantum register. [1] M. Klotz et al., https://arxiv.org/pdf/2508.05255, (2025) [2] M. Klotz et al., npj Quantum Inf. 11, 91 (2025)

Q 80.3 Fri 15:00 P 5

Detection and control of a nuclear spin register coupled to a spin-1/2 — •Andreas Tangemann[1], Marco Klotz[1], David Opferkuch[1,2], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany

Solid-state spin defects, such as color centers in diamond, are among the most promising candidates for scalable and integrated quantum technologies. In particular, the good optical properties of negatively-charged silicon-vacancy centers (SiV) in diamond, combined with naturally occurring and exceptionally coherent nuclear spins, serve as a building block for quantum networking applications. We demonstrate detection and control of a nuclear spin register coupled to a highly strained SiV at four Kelvin. Moreover, we measured the interconnectivity of the register with spin-echo double resonance.

[1] M. Klotz et al., https://arxiv.org/pdf/2508.05255, (2025)
[2] M. Klotz et al., npj Quantum Inf. 11, 91 (2025)

Q 80.4 Fri 15:15 P 5

High-fidelity gates in a multi-qubit diamond quantum processor — •Margriet van Riggelen, Jiwon Yun, Hendrik Benjamin van Ommen, and Tim Hugo Taminiau — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft, The Netherlands

Solid-state color centers are a promising platform exploring a range of quantum technologies such as distributed quantum computing and quantum communication. Examples using the nitrogen-vacancy center in diamond include the fault-tolerant operation of a logical qubit [1] and the creation of entanglement on a metropolitan scale [2]. To perform quantum error correction in future algorithms, high-quality quantum control will be needed. Recently, a high-fidelity two-qubit gate was demonstrated on an isolated two-qubit system in purified diamond [3]. However, high-fidelity quantum gates for a multiqubit register based on solid-state color centers have so far remained elusive.

Here, we demonstrate high-fidelity control of six nuclear spins surrounding a nitrogen-vacancy center in diamond using the dynamical decoupling radiofrequency gate. We characterize and benchmark the gates using gate set tomography and find an average of 99.18(2)% for the two-qubit gates in the register. We use the characterized gates in a variational quantum eigensolver algorithm to calculate the ground-state energy of molecular hydrogen and lithium hydride.

[1] Stolk, A.J. et al., Sci. Adv. 10 (2024) [2] Abobeih, M.H. et al., Nature 606 (2022) [3] Bartling, H.P. et al., Phys. Rev. App. 23 (2025)

Q 80.5 Fri 15:30 P 5

10-Second Spin Coherence and Near-Lifetime Optical Linewidths in Isotopically Engineered Diamond — •Hendrik Benjamin van Ommen[1], Takashi Yamamoto[1], Kai-Niklas Schymik[1], René Vollmer[2], and Tim Hugo Taminiau[1] — [1]Qutech, Delft University of Technlogy — [2]Netherlands Organisation for Applied Scientific Research (TNO)

Solid-state spin defects are a promising platform for next-generation quantum technologies, but their performance is fundamentally limited by the quality of the host material. Here we present the growth and characterisation of high-purity, isotopically engineered diamond, grown along the <111> axis, hosting NV centres with excellent spin and optical properties [1]. The reduced ^{13}C concentration results in a spin-echo coherence time of 6.8(1) ms, which is extended beyond 10 s by using up to 24000-pulse dynamical decoupling, both record times for solid-state spins. We observe a strong effect from 50 Hz mains noise, which is mitigated using a real-time feedforward scheme. While it has remained difficult to combine isotopic purification with good optical coherence, we observe a homogeneous optical linewidth of 17.8(4) MHz, near the lifetime limit. We investigate the optical coherence in further depth using a recently introduced diffusion measurement scheme [2]. These results show that our high-purity and isotopically engineered diamond is a promising candidate for future defect-centre-based quantum technologies.

[1] van Ommen et al., in preparation;
[2] van de Stolpe et al., npj Quantum Inf 11, 31 (2025)

Q 80.6 Fri 15:45 P 5

Coherent Control of a Coupled Three-Electron Spin Quantum Register in Diamond — •Fabian Müller[1], Tobias Spohn[1], Philipp J. Vetter[1], Timo Joas[1], Samuele Brambilla[1], Florian Ferlemann[2], René Wolters[2], Tommaso Calarco[2], Matthias M. Müller[2], Shinobu Onoda[3], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Peter Grünberg Institute-Quantum Control (PGI-8), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany — [3]Takasaki Advanced Radiation Research Institute, National Institutes for Quantum Science and Technology (QST), Takasaki, Gunma 370-1292, Japan

High-fidelity gates between coupled electron spins at room temperature were recently demonstrated using molecularly implanted nitrogen-vacancy (NV) centers in diamond. In addition to NV centers, the implantation process can also create dark spins, providing further scalability for the system.

In this work, we characterize a coupled NV–NV pair and a nearby dark spin (a P1 center) that together form a three-electron spin quantum register at room temperature. We demonstrate coherent interactions among all three spins and probe their coherence properties.

Controlling the P1 center at room temperature is challenging due to the strong hyperfine interaction between its electron and nuclear spin. We present methods such as DEER spectroscopy and double-channel PulsePol to address, coherently control, and read out the P1 center using the nearby NV center. Our work expands the scalability of room-temperature electron spin quantum registers in diamond.

Q 80.7 Fri 16:00 P 5

Influence of strain on the metastable state dynamics of silicon vacancy centers in 4H Silicon Carbide — •Maximilian Hollendonner[1], Fedor Hrunski[1], Durga B. R. Dasari[2], Maximilian Schober[3], Michel Bockstedte[3], and Roland Nagy[1] —

[1]Friedrich-Alexander University Erlangen-Nürnberg, Institute of Applied Quantum Technologies (AQuT.), Germany — [2]3rd Institute of Physics, ZAQuant, IQST, University of Stuttgart, Germany — [3]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria

Currently color centers in semiconductors are among the most promising platforms for quantum technology. Especially the negatively charged cubic silicon vacancy center (VSi) in 4H silicon carbide (SiC) stands out due to its exceptional spin and optical properties [1] and can be integrated into semiconductor structures [2]. It is therefore an ideal candidate for quantum memory nodes [3,4]. The VSi can exhibit significant strain when integrated into nanophotonic structures. How this influences spin properties is currently not fully understood. For this reason, we developed pulse sequences which allow the measurement of metastable state transition rates [5]. In my talk I will discuss the changed rates and present the underlying physical mechanisms. [1] R. Nagy et al., Nat Commun 10, 1954 (2019) [2] D. Scheller et al., Phys. Rev. Applied 24, 014036 (2025) [3] S. K. Parthasarathy et al., Phys. Rev. Applied 19, 034026 (2023) [4] R. Nagy et al., Appl. Phys. Lett. 118, 144003 (2021) [5] D. Liu et al., npj Quantum Inf 10, 72 (2024)