Q 43: Color Centers III

Time: Thursday 11:00–13:00 Location: Aula

Q 43.1 Thu 11:00 Aula

Long-lived quantum network memories using spin qubits in isotopically engineered diamond — •Kai-Niklas Schymik[1], Benjamin van Ommen[1], Conor Bradley[2], Takashi Yamamoto[1], and Tim Hugo Taminiau[1] — [1]QuTech an Kavli Institute of Nanoscience Delft, Delft University of Technology, 2628 CJ Delft, The Netherlands — [2]Pritzker School of Molecular Engineering, University of Chicago, Chicago, IL 60637, USA

Optically active spin qubits in solid-state materials, such as the NV center in diamond, are a promising platform for quantum computation distributed over a network. To increase the size and circuit depth of such a quantum network, e.g. beyond the state-of-the-art of three nodes, long-lived quantum memories in each node are desired. Recent work has identified Carbon-13 spin qubits in isotopically purified diamond as a promising candidate. In this work, we demonstrate control over isotope concentration in (111) CVD-grown diamond. At the targeted concentration of 0.05%, we show that memory qubits with kHz couplings can be addressed and measure long coherence times of the spin qubits. With a memory decoherence rate lower than possible entanglement rates between remote NV centers, these devices show promise for distributed computations using more than one entangled Bell pair.

Q 43.2 Thu 11:15 Aula

Photonic multipartite entangled state generation with group-IV color centers — •Gregor Pieplow[1], Yannick Strocka[1], Mariano I. Monsalve[2], Joseph H. D. Munns[3], and Tim Schröder[1] — [1]Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]University of Innsbruck, 6020 Innsbruck, Austria — [3]PsiQuantum, 94304 California Palo Alto, USA

In this work, we analyze the generation of large entangled photonic states, specifically multiphoton Greenberger-Horne-Zeilinger (GHZ) states and cluster states (CS) using group-IV color centers. These states are an essential resource in photonic quantum information applications, for example in measurement-based quantum computing and one-way quantum repeaters. Our research aims at providing a comprehensive analysis of the coherent control operations that are required for the creation of these resource states. The fidelity of these operations is critical; any compromise leads to a rapid degradation in the quality of the state. In particular, our work focuses on an optical Raman control scheme and microwave control. Both types of control operations enable single and two-qubit gates, which are crucial for the deterministic generation of resource states. Additionally, the study introduces a novel quality measure, which highlights the significance of fast, high-fidelity control techniques.

Q 43.3 Thu 11:30 Aula

Investigation of microwave spin control of unstrained negatively charged group-IV color centers in diamond — •Mohamed Belhassen[1], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

Microwave control is a standard technique for manipulating the electronic spin of diamond color centers owing to its advantages when implementing complex control sequences. For microwave control, a *dc* magnetic field is used to lift the spin degeneracy. An *ac* microwave pulse drives the system. Aligning the *dc* field parallel to the color center's symmetry axis and the *ac* field perpendicular to it has been commonly used in previous works. This configuration, although working well for the light color centers, has been shown to require high strain or large microwave powers for heavier ions, such as the tin- and lead-vacancy center. In addition to providing the theoretical framework to explain the requirement of strain for heavy defects in the above field configuration, we study the dependence of the Rabi frequency on the *dc* and *ac* fields orientations and strain. We provide analytical expressions and exact numerical simulations of the impact of strain and field orientations on microwave control. We find that strain can be rendered obsolete, while simultaneously producing higher Rabi frequencies for an alternative setup, where the *dc* field is aligned perpendicular to the color center symmetry axis and the *ac* field is aligned parallel to it. We show that this configuration is also efficient for the spin's optical initialization, readout and analyse resulting gate fidelities.

Q 43.4 Thu 11:45 Aula

Optically Detected Magnetic Resonance in Microdiamonds Embedded in Polymer Waveguides — •Marina Peters[1,2], Jonas Homrighausen[1], Tim Buskasper[2], Shqiprim Adrian Abazi[2], Daniel Wendland[2], Carsten Schuck[2], and Markus Gregor[1] — [1]Department of Engineering Physics, FH Münster University of Applied Sciences, Germany — [2]Department for Quantum Technology, University of Münster, Germany

Nitrogen vacancy centers in diamond hold great potential for quantum sensing applications. The challenge of integration can be addressed by using integrated photonics based on modern nanofabrication techniques. Here, we present optically detected magnetic resonance measurements from deterministically embedded microdiamonds with NV centers in polymer waveguides on silicon substrates. In combination with electrically conductive microstructures for microwave supply, this method of optical access provides the basis for scaling up to highly integrated on-chip sensors with excellent spatial magnetic resolution and sensitivity.

Q 43.5 Thu 12:00 Aula

Microscale NMR of hyperpolarized nuclei with NV centers in diamond — Luca Troise[1], •Nicolas Staudenmaier[2], Christoph Findler[2,3], Kirstine Berg-Sørensen[1], Fedor Jelezko[2], and Jan Henrik Ardenkjaer-Larsen[1] — [1]Department of Health Technology, Technical University of Denmark, 2800, Kongens Lyngby, Denmark — [2]Institute of Quantum Optics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [3]Diatope GmbH, Buchenweg 23, 88444 Ummendorf, Germany

We present a groundbreaking approach that combines nitrogen-vacancy (NV) center ensemble based quantum sensing with dynamic nuclear polarization to perform nuclear magnetic resonance (NMR) spectroscopy of picoliter samples. Traditional NMR spectroscopy suffers from poor sensitivity and requires larger sample volumes, typically in the milliliter range. However, the introduction of NV centers in diamond for NMR spectroscopy has revolutionized the field, enabling the analysis of unprecedented sample volumes. In our study, we utilize the dissolution dynamic nuclear polarization (dDNP) technique to hyperpolarize carbon nuclei, thereby overcoming previous sensitivity limitations and providing a pathway to high-resolution spectroscopy on molecules in dilute solutions. By integrating dDNP into NV-based NMR spectrometers, we not only promise to extend the capabilities of mass-limited NMR spectroscopy but also open up new avenues for research at the picoliter scale, including drug discovery, catalysis research, and single-cell studies.

Q 43.6 Thu 12:15 Aula

Laser noise compensation to enable high fidelity spin-photon gates — •Mara Brinkmann[1], Lennart Manthey[1], Donika Imeri[1,2], Rikhav Shah[1], Timo Eikelmann[1], Konstantin Beck[1], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Current research areas in quantum communication entail quantum networks, consisting of optically connected nodes, which can efficiently distribute entanglement. We use silicon-vacancy (SiV) color centers in diamond, which show great potential for optically coupled quantum processors. To address the probes at millikelvin temperature and achieve high fidelities for spin-photon quantum gates, we rely on pulsed weak laser light. Sideband-noise, such as relaxation oscillations, can result in off-resonant scattering, reducing the gate fidelity. Here we present our approach to optimize the temporal and spectral properties of the laser light, employing mode cleaner cavities. The spin-photon gates can subsequently be used to create high-fidelity entanglement between remote quantum processors.

Q 43.7 Thu 12:30 Aula

Optimization of nuclear spin control with germanium vacancy centre in diamond at mK temperatures — •Nick Grimm, Katharina Senkalla, Philipp Vetter, and Fedor Jelezko — Institute for Quantum Optics, Ulm University

Long-distance quantum communication requires a platform which allows to collect, store and process quantum information. Promising candidates for such quantum nodes are the negatively charged group-IV defects in diamond as they provide an efficient spin-photon interface with high photon flux, long coherence times and high-fidelity single qubit gates. Moreover, addressing of proximal nuclear spins can be used for computational purposes or act as memory qubits. Here we demonstrate for the first time the coherent control of a hybrid register of a negatively charged germanium vacancy centre (GeV) electron spin and a strongly coupled single ^{13}C nuclear spin with excellent coherence properties at mK temperatures. We show initialisation and readout of the nuclear spin using a SWAP gate with the optically addressable GeV electron spin. Applying optimized microwave and radiofrequency pulses on the electron and nuclear spin, respectively, allows to reach increased fidelities. The realization of this fully controlled two-qubit register is laying the groundwork for the implementation of quantum repeaters.

Q 43.8 Thu 12:45 Aula

Spin-phonon entanglement in SiC optomechanical quantum oscillators — •Ruoming Peng[1], Xuntao Wu[2], Durga Dasari[1], and Joerg Wrachtrup[1] — [1]3. Physikalisches Institut, University of Stuttgart, 70569 Stuttgart, Germany — [2]Pritzker School of Molecular Engineering, University of Chicago, Chicago IL 60637, USA

Scaling up quantum systems, especially solid-state spins, presents a significant challenge in the field of quantum information science. In this study, we propose a hybrid spin-phonon architecture based on spin-embedded optomechanical crystal (OMC) cavities. This architecture combines integrated photonic and phononic accesses, allowing for the entanglement of multiple spins. Remarkably, this hybrid spin-optomechanical system can offer a coupling of the spin to the vibration mode of simulated Silicon Carbide OMC cavities approaching MHz in a Raman-facilitated mechanism, enabling a fast and efficient spin-phonon entanglement with fidelity of 98%. By incorporating the Stimulated Raman Adiabatic Passage (STIRAP) protocol into the coupled tripod-phonon system, a two-qubit Controlled-Z gate with 97% fidelity is implemented by engineering the non-vanishing geometry phase in a strongly coupled spin-phonon dark state basis, which is robust against the dominant loss from the excited state and allow for full connection of spins through the cavity phonon. Our work establishes a crucial platform for exploring the spin entanglement with potential scalability in addition to the optical link, which opens the path to investigate quantum acoustics in hybrid solid-state systems