A 8: Quantum Technologies: Color Centers (joint session Q/A/QI)

Time: Monday 17:00–19:00 Location: F342

A 8.1 Mon 17:00 F342

NMR-fingerprinting of biomolecules on the picoliter level — •Nico Striegler, Thomas Unden, Jochen Scharpf, Stephan Knecht, Christophoros Vassiliou, Jochen Scheuer, Michael Keim, John Blanchard, Martin Gierse, Mohammad Usman Qureshi, Ilai Schwartz, and Philipp Neumann — NVision Imaging Technologies GmbH

A standard method for diagnostics and analytics is nuclear magnetic resonance (NMR). Conventional NMR only function well for large enough samples and is inherently limited by the low thermal spin polarisation. The combination of nuclear spin hyperpolarisation with a microscale quantum sensor enables study of metabolism on the single-cell level. This can be used for evaluating the treatment effectiveness from tumor biopsies using only a few cells. In this study the combination of a Nitrogen-Vacancy-based quantum sensor and a hyperpolarized Fumarate solution enables heteronuclear magnetic resonance spectroscopy of liqudis in picoliter volumes. The NMR probe is based on an ensemble of negatively charged Nitrogen-Vacancy (NV) centers in a ten micrometer thick diamond layer. Hyperpolarization of the solution is based on parahydrogen induced polarization (PHIP) methods, which is done in house and then transferred to the detection volume of the quantum sensor. Microwave pulse sequences brings the NV electron spins into adjustable frequencies for detection of AC magnetic fields generated by the nuclear spins of interest.

A 8.2 Mon 17:15 F342

Impact of Charge Conversion on NV-Center Relaxometry — •Isabel Barbosa, Jonas Gutsche, and Artur Widera — Physics Department and State Research Center OPTIMAS, RPTU Kaiserslautern, Erwin-Schroedinger-Str. 46, 67663 Kaiserslautern, Germany

Relaxometry schemes employing nitrogen-vacancy (NV) centers in diamonds are essential in biology and physics to detect a reduction of the color centers' characteristic spin relaxation (T_1) time caused by, e.g., paramagnetic molecules in proximity. However, while only the negatively-charged NV center is to be probed in these pulsed-laser measurements, an inevitable consequence of the laser excitation is the conversion to the neutrally-charged NV state, interfering with the result for the negatively-charged NV centers' T_1 time or even dominating the response signal. In this work, we perform relaxometry measurements on an NV ensemble in nanodiamond combining a 520 nm excitation laser and microwave excitation while simultaneously recording the fluorescence signals of both charge states via independent beam paths. Correlating the fluorescence intensity ratios to the fluorescence spectra at each laser power, we monitor the ratios of both charge states during the T_1 measurement and systematically disclose the excitation-power-dependent charge conversion. Even at laser intensities below saturation, we observe charge conversion, while at higher intensities, charge conversion outweighs spin relaxation. These results underline the necessity of fluorescence normalization during the measurement to accurately determine the T_1 time and characterize paramagnetic species close to the sensing diamond.

A 8.3 Mon 17:30 F342

SiV center in nanodiamonds as a potential source for a hybrid quantum network node — •Marco Klotz[1], Richard Waltrich[1], Niklas Lettner[1], Lukas Antoniuk[1], Viatcheslav Agafonov[2], and Alexander Kubanek[1] — [1]Institut für Quantenoptik, Universität Ulm — [2]Universite Francois Rabelais de Tours

Combining conventional photonic systems with the good optical and spin properties of group IV defects in diamond puts a platform for quantum technologies into reach. Here, we present measurements of characteristic properties of SiV centers in nanodiamond in comparison with bulk diamond. This reveals key benefits of a nanostructured defect host for future integration into photonic-enhancing structures, e.g. cavities.

A 8.4 Mon 17:45 F342

Vector Magnetometry Based on Polarimetric Optically Detected Magnetic Resonance — Philipp Reuschel[1], Mario Agio[1,2], and •Assegid M. Flatae[1] — [1]Laboratory of Nano-Optics, University of Siegen, Siegen (Germany) — [2]National Institute of Optics (INO), National Research Council (CNR), Sesto Fiorentino (Italy)

Vector magnetometry has various applications in navigation systems, spintronics and life sciences. So far, different sensitive magnetic field sensors exist, for example, superconducting quantum interference devices and alkali vapor cells magnetometers. However, they suffer from high technical complexity and low spatial resolution. Recently, negatively charged nitrogen-vacancy (NV-) color centers in diamond have been developed as sensitive magnetic field sensors based on the optically detected magnetic resonance (ODMR). However, these approaches require knowledge of the crystal axes and need an external magnetic bias field or they rely on the use of single NV- centers. Recently, by combining ODMRs of ensembles of NV- color centers with polarimetry, we have been able to determine the magnitude and direction of an unknown magnetic field [1]. A longitudinal laser polarization component enables the unequivocal distinction of the four crystal axes containing NV- centers, allowing high sensitivity and robust vector magnetometry without a bias field. Our approach is general for other spin-1 color centers with C3v symmetry, and it is compatible with standard microscopy methods. Reference [1] P. Reuschel, M. Agio, A. M. Flatae, Adv. Quantum Technol. 2200077 (2022).

A 8.5 Mon 18:00 F342

Coherent optical spectroscopy on ensembles of Silicon-vacancy color centers in diamond — •Anna Fuchs and Christoph Becher — Universität des Saarlandes, Saarbrücken 66123, Germany

Spectral hole burning (SHB) and coherent population trapping (CPT) are important techniques both in spectroscopy to characterize an ensemble of emitters in terms of their coherence times and in coherent control experiments to realize e.g. quantum memories or sensors. Single negatively charged silicon-vacancy (SiV^-) color centers in diamond are of the leading candidates for qubit systems in quantum communication [1] based on their long spin coherence and narrow optical emission lines. In addition, ensembles of SiV centers show strong coherent light-matter interaction [2], enabling applications as Raman-based optical quantum memories or for realizing single photon nonlinearities. However, the spin coherence of SiV ensembles so far remains unexplored. In this talk, we report our results of SHB and CPT measurements on two different SiV^- ensembles in an external magnetic field. The SHB measurements reveal in both samples an additional narrow resonance of a few MHz linewidth, which we attribute to coherent population oscillations (CPO) due to the beat frequency between the two independent input laser fields. The CPT measurements allow us to determine the Zeeman splittings not resolvable in excitation or emission spectroscopy due to inhomogeneous line broadening.

[1] Stas et al., Science 378, 557 (2022)
[2] Weinzetl et al., Phys. Rev. Lett. 122, 063601 (2019)

A 8.6 Mon 18:15 F342

Probing the Orbital Coherence of a Tin-Vacancy Center in a Diamond Nanopillar via Coherent Population Trapping — •Cem Güney Torun[1], Joseph H. D. Munns[1], Franziska M. Herrmann[1], Gregor Pieplow[1], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Department of Physics, Berlin, Germany — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

Tin-vacancy color center in diamond (SnV) has gained much attention in recent years as a promising spin-photon interface. This is mainly due to its excellent optical properties resulting from the inhibited first-order coupling to external electric fields via DC Stark Shifts [1] and millisecond spin coherence through decreased phononic coupling by the large ground state splitting of 850 GHz [2]. Here, we analyze the coherence properties of the ground state orbital levels under zero magnetic field. This is implemented via a coherent population trapping experiment where two optical transitions in a lambda scheme are simultaneously driven and a reduction in the fluorescence signal is observed. Working in the spectral domain enables the extraction of a rapid 5 ps phononic decay time after analyzing the data; showing that the orbital degree of freedom is not particularly suitable for most quantum information processing applications. Finally, implications of orbital coherence times on the spin levels are considered. These experiments lay the basis for the coherent control of SnV spin states.

[1] J. Görlitz, et al. *npj Quan. Inf.* 8.1 (2022): 1-9.
[2] R. Debroux, et al. *Phy. Rev. X* 11.4 (2021): 041041.

A 8.7 Mon 18:30 F342

Optical Microcavity with Coupled Single SiV- Centers in a Nanodiamond for a Quantum Repeater Platform — •Robert Berghaus[1], Gregor Bayer[1], Selene Sachero[1], Andrea B Filipovski[1], Lukas Antoniuk[1], Niklas Lettner[1], Richard Waltrich[1], Marco Klotz[1], Patrick Maier[1], Viatcheslav Agafonov[2], and Alexander Kubanek[1] — [1]Institute for Quantum Optics, Ulm University, Germany — [2]Tours University, France

A quantum repeater node requires a long-lived memory that can be addressed coherently. Additionally, efficient writing and reading of quantum states with high rates are crucial. Optical cavities can be used as spin-photon platforms to accomplish such requirements. By coupling silicon vacancy defect centers (SiV-) in a nanodiamond to an open Fabry-Pérot cavity, our work paves the way for a light-matter interface with efficient coherent control. Our fully tunable cavity formed by two Bragg mirrors allows short cavity lengths down to $\approx 1\mu$m and provides efficient coupling of the quantum emitter at liquid helium temperatures.

Here, we perform photoluminescence measurements of SiV- centers and power-dependent photoluminescence excitation of single SiV centers by collecting the cavity modulated sideband. We observe spectrally stable emitters and measure a linewidth close to the Fourier limit below $\Delta\nu = 200$ MHz. With the Purcell-enhanced cavity signal we demonstrate coherent optical driving and access the electron spin all-optical in a strong external magnetic field. The electron spin can be initialized within 67 ns and a lifetime of 350 ns is reached.

A 8.8 Mon 18:45 F342

Entanglement in a disordered chain of coupled qubits — •Alexander Michael Minke[1], Edoardo Carnio[1,2], and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany

Nitrogen-Vacancy (NV) centers in diamond are promising candidates for quantum computation due to their long coherence times. However, the robust implementation of scalable quantum registers composed of suitably coupled NV centers remains a challenge, due to limited control of their assembly. We therefore investigate the entanglement properties of arrays of dipole-coupled NV centers, the robustness of these properties against positional disorder and the dependence of the registers' resilience on their size. We find that, for chains with an even number of components, some manifolds of eigenstates show resilient entanglement properties when scaling up the system.