MON 8: Quantum Sensing and Decoherence: Contributed Session to Symposium I

Time: Monday 14:15–15:45 Location: ZHG009

MON 8.1 Mon 14:15 ZHG009

Diamond-based quantum processors - State-of-the-art and future challenges — Lukas Antoniuk[1], Gopi Balasubramanian[1], Priya Balasubramanian[1,2], Jan Binder[1], Jason Choudhury[1], Florian Frank[1], Matthias Gerster[1], •Julian Rickert[1], Janani Sevvel[1], and Mukesh Tripathi[1] — [1]XeedQ GmbH, Augustusplatz 1-4, D-04109 Leipzig, Germany — [2]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany

Engineered colour centres within diamond have demonstrated the potential for quantum sensing, communication, and computing. Coherent control of a few qubits has been demonstrated in group-IV- and NV-centres. Currently, NV systems are the only commercially available diamond quantum processors. State-of-the-art designs couple NV centres to nearby nuclear spins and directly to other NVs. Our work employs electron-beam lithography and focused ion beam implantation to fabricate high-purity diamond chips with tailored defects. We characterize these chips by benchmarking qubit coherence, single- and two-qubit NV gate operations, NV-nuclear spin control protocols, and NV-NV entanglement. Our efforts deliver comprehensive quantum control beyond existing lab demonstrations. However, scaling beyond a few qubits is complicated by material quality, fabrication precision, and nanoscale addressability. We are working on overcoming engineering, integration, and control challenges to enable scalable networks of interlinked NV centres.

MON 8.2 Mon 14:30 ZHG009

Towards Hyperpolarization at the Solid Surface - A Progress Report — •Konstantin Herb and Christian Degen — Department of Physics, ETH Zurich, Switzerland

Traditionally, nuclear magnetic resonance (NMR) spectroscopy suffers from intrinsically low sensitivity due to the relatively weak coupling of nuclear spins to an external magnetic field. To significantly enhance the sensitivity of NMR spectroscopy, electron spins may be used as a polarizing source. Transferring nuclear spin polarization from the Nitrogen-Vacancy (NV) center to its surrounding is a long-standing goal in field. In this talk, I will present our recent progress towards achieving hyperpolarization at the solid surface. We explore the possibilities and limits of transferring polarization from NV centers to the surface of diamond. We will discuss the challenges we face in this process, including the need for efficient transfer mechanisms and the optimization of experimental conditions.

MON 8.3 Mon 14:45 ZHG009

Height Calibration of Nitrogen Vacancy Diamond Tips Using Current-Carrying Wires — Robin Abram, •Ricarda Reuter, Alexander Fernández Scarioni, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Scanning Nitrogen Vacancy Microscopy (SNVM) is a measurement technique capable of resolving the spatial distribution of magnetic stray fields with nanometer and microtesla resolution, respectively. It combines optical field detection with a scanning probe-like approach, where the key component is a diamond scanning tip containing a single NV center. While magnetic field measurements are quantum-calibrated with respect to the position of the NV center, precise knowledge of the distance to the sample is required to also consider the height dependence. Unfortunately, the latter can currently only be estimated with an uncertainty of up to several nanometers, most commonly from a calibration based on the stray field detection of ferromagnetic microstructures. We propose an improved height calibration based on SNVM studies of the current-induced Oersted field in Pt wires by Lee et al.. The out of plane field component is extracted from the raw data taken along the NV spin axis, following the approach first established by Schendel et al. and later applied to SNVM by Dovzhenko et al., and fitted to a numerical model. Compared to the calibration with ferromagnets, this approach is highly adaptable in terms of both magnetic and spatial resolution, thus contributing to fully exploiting the potential of the NV center as a quantum-based magnetic field sensor.

MON 8.4 Mon 15:00 ZHG009

Exploring non-Markovian dynamics in microwave spin control of group-IV color centers coupled to a phononic bath — •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 well-established technique for driving the electronic spin of diamond color centers. In our earlier work [1], we demonstrated that optimizing the orientation of the static magnetic field lifting the spin degeneracy and the polarization of the microwave field driving the spin, is essential for achieving efficient control conditions in a low strain environment. Expanding on this, we now incorporate the phononic bath, which introduces decay and decoherence to the qubit's quantum state. We examine the system dynamics using both Markovian and non-Markovian master equations, revisiting the interplay between magnetic and microwave field orientations and applied strain, with a focus on their impact on the qubit decay and decoherence times. We interpret our simulation results and compare them with the most recent experimental results. Finally, we assess the validity of the Born-Markov approximation and investigate how bath memory effects impact quantum state evolution.

[1] G. Pieplow, M. Belhassen, T. Schröder, Phys. Rev. B 109, 115409

MON 8.5 Mon 15:15 ZHG009

Nonlocal metasurface coupled to a single-photon emitter for on-chip applications — •Amitrajit Nag and Jaydeep Kumar Basu — Department of Physics, Indian Institute of Science, Bangalore, India-560012

Solid-state single-photon emitters (SPE) are indispensable in the emerging applications for qubits and photonic communications due to their higher quantum yield, spectral tunability, and scalability. All-dielectric guided mode resonant metasurfaces (GMR-MSR) are interesting photonic systems with low losses, waveguiding, and asymmetric Fano resonance features. The near-field coupling between an SPE and a GMR-MSR brings up interesting features like the resonance linewidth narrowing, directional emission, long-range photon transport, etc. In this work, we emphasize the field nonlocality property of a GMR-MSR, which controls and tunes the overall partial coherence of the coupled SPE-MSR system.

$$\mathbf{E}(\mathbf{r}_D,\omega) = \int \mathbf{G}(\mathbf{r}_D,\mathbf{r}'_d,\omega)\cdot\frac{\mathbf{P}(\mathbf{r}',\omega)}{\epsilon_0}d^3r' \quad (1)$$

The in-plane component of this defined Green's function of the SPE-MSR system quantifies this nonlocal field behavior. Our experimental results on SPEs integrated to GMR-MSR, capable of showing field nonlocality along with an appreciable antibunching property, makes the coupled system emerge as a new platform to efficiently generate directional, high spectral purity photons with precision control parameters, and the waveguiding gives the system an additional leap as a viable platform for on-chip integrated photonic applications.

MON 8.6 Mon 15:30 ZHG009

Non-destructive characterization of ceramics using mid-infrared optical coherence tomography with undetected photons — •Felipe Gewers[1], Fabian Wendt[2], Gunnar Blume[3], Emma Pearce[1], Martin Laurowski[4], Ivan Zorin[5], Bettina Heise[5], Katrin Paschke[3], Helen Chrzanowski[1], and Sven Ramelow[1,6] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Fraunhofer-Institut für Lasertechnik ILT, Aachen, Germany — [3]Ferdinand-Braun-Institut (FBH), Berlin, Germany — [4]NELA, Lahr, Germany — [5]Research Center for Non-Destructive Testing GmbH, 4040 Linz, Austria — [6]IRIS Adlershof, Berlin, Germany

Optical coherence tomography (OCT) is a non-destructive imaging technique widely used in industry and biomedicine. However, imaging ceramic micro-components is challenging due to their strong light scattering. Mid-infrared (mid-IR) wavelengths (2-4μm) can reduce scattering, but conventional OCT systems in this range are expensive, complex, and noisy.

We present a compact, low-cost OCT system based on undetected photons. Using a nonlinear interferometer and a 660nm laser, entangled photon pairs are generated: the sample is probed with mid-IR field (3.3-4.3μm), and detection occurs in the near-infrared (780-820nm) using a standard silicon spectrometer.

Our system accurately measures ceramic thickness and refractive index, and resolves subsurface structures, demonstrating its potential for affordable imaging of highly scattering materials.