Q 68: Quantum Technologies (Color Centers and Ion Traps) II (joint session Q/QI)

Time: Friday 11:00–13:00 Location: HS Botanik

Invited Talk Q 68.1 Fri 11:00 HS Botanik

Multi-color excitation of quantum emitters — •Thomas Bracht — TU Dortmund, 44227 Dortmund, Germany

On-demand photon generation is essential for reliable quantum communication. Solid state quantum emitters have emerged as a promising platform, offering excellent photon properties and controllability.

In this talk, I introduce the Swing-UP of quantum EmitteR (SUPER) scheme, which enables excitation of a quantum emitter using two pulses of different colors, allowing for completely off-resonant, red-detuned excitation. This novel multi-color approach is advantageous as spectral filtering can be used to suppress the excitation laser, boosting the total photon yield. In a completely quantized picture, it corresponds to a two-photon process [1]. After its theoretical prediction [2], the SUPER scheme has been experimentally demonstrated in quantum dots [3] and other systems.

As an outlook, I show how this technique can be used to generate highly entangled photon pairs, which are an important building block in quantum information technology.

[1] Richter et al., arXiv:2405.20095 (2024) [2] Bracht et al., PRX Quantum 2, 040354 (2021) [3] Karli et al., Nano Lett. 22, 6567 (2022)

Q 68.2 Fri 11:30 HS Botanik

Measuring MHz charge dynamics in diamond with a tin-vacancy color center — •Charlotta Gurr[1], Cem Güney Torun[1], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut gGmbH, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

Color centers in diamond are influenced by electric noise from their diamond host material [1]. Free charge carriers being trapped and released from charge traps in the diamond lattice create a fluctuating electric field environment, shifting the color center's energy levels. The optical transitions are therefore rendered unstable, to the detriment of applications that require a source of indistinguishable photons. Little is known about the nature of the charge traps. Here, we develop a technique to investigate the charge process dynamics of single charges in diamond with MHz resolution, using a tin-vacancy color center. We find charge capture and release rates spanning two orders of magnitude within Hz and kHz, possibly revealing two different effects influencing the charge processes. Furthermore, we find that 520 nm illumination of the diamond sample influences the charge release rates more strongly than more energetic 445 nm illumination. We believe this to be caused by a two-step process leading to the release of charges from charge traps. These findings expand our understanding of charge traps in diamond as well as the processes responsible for capturing and releasing single charges.

[1] Pieplow, Torun et al., *Quantum Electrometer for Time-resolved Material Science at the Atomic Lattice Scale*, arXiv:2401.14290, 2024

Q 68.3 Fri 11:45 HS Botanik

Integration of group IV color centers in nanodiamonds in a tunable Fabry-Perot microcavity — •Selene Sachero, Robert Berghaus, Florian Feuchtmayr, and Alexander Kubanek — Institute for Quantum Optics, Ulm University, 89081 Ulm, Germany

Quantum repeater are essential building block to create a large scale quantum communication network. An ideal quantum repeater nodes efficiently link a quantum memory with photons serving as flying qubits. By coupling group IV vacancy defect centers in nanodiamonds (NDs) to an open Fabry-Perot cavity, such an interface can be created. As such a platform, we propose a fully tunable cavity composed by two Bragg mirrors which allows short cavity lengths down to $\approx 1\ /mu$m, and provides efficient coupling of the quantum emitter at liquid helium temperatures.

Here, we show the good optical properties of a single group IV emitter and its transfer, via nanomanipulation, to a Fabry-Perot cavity. The coupling of the emitter into the resonator is achieved maintaining an high finesse.

Moreover, we perform PL measurement at cryogenic temperatures and observe a lifetime reduction due to the Purcell factor.

Q 68.4 Fri 12:00 HS Botanik

Entanglement by path identity based on engineered photon pairs — •Richard Bernecker[1,2], Baghdasar Baghdasaryan[3], and Stephan Fritzsche[1,2] — [1]Institute for Theoretical Physics, Friedrich Schiller University Jena, 07743 Jena, Germany — [2]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [3]Institute of Applied Physics, Friedrich Schiller University Jena, Albert-Einstein-Str. 6, 07745 Jena, Germany

Entangled photon pairs are essential for applications in quantum communication and distributed quantum computing. A convenient approach for entanglement generation is to coherently superimpose photon pairs created in multiple nonlinear crystals via spontaneous parametric down-conversion (SPDC). The entanglement emerges because no information is available about which crystal created the pair, provided the propagation paths of the photon pairs are overlapped. This path identity approach was experimentally demonstrated by overlapping separable orbital angular momentum modes using three nonlinear crystals and spiral phase plates. However, the number of nonlinear crystals governs the dimensionality of the entangled state, posing challenges for generating entanglement in large Hilbert spaces. Recently, we explored the direct generation of maximally entangled states via pump and crystal shaping in SPDC. In this contribution, we combine pump shaping techniques with the path identity approach to engineer high-dimensional entangled states. A key advantage of this method is the potential for increasing the scalability of the entanglement dimensionality without requiring additional crystals in the setup.

Q 68.5 Fri 12:15 HS Botanik

Enhanced atom-photon interactions based on integrated waveguides immersed in hot atomic vapor — •Annika Belz[1], Benyamin Shnirman[1,2], Xiaoyu Cheng[1], Harald Kübler[1], Hadiseh Alaeian[3], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany — [3]Departments of Electrical & Computer Engineering and Physics & Astronomy, Purdue University, West Lafayette, USA

The combination of thermal atomic vapor with nanophotonic structures provides a unique platform for the manipulation of atom-photon and light induced atom-atom interactions and can exhibit large optical non-linearities, even at the few photon level.

We can further enhance these non-linearities via an enlarged Purcell factor using slot waveguides. We observe saturable repulsive interactions of the atoms within the slot as an intensity dependent blue shift. In order to verify the nature of the non-linearity in more detail we incorporate an integrated Mach-Zehnder interferometer to access also the non-linear phase shift.

Q 68.6 Fri 12:30 HS Botanik

Cavity-Enhanced Spin-Photon Interface for Single Tin-Vacancy Centers in Diamond — •Andras Lauko[1], Kerim Köster[1], Julia Heupel[2], Philipp Fuchs[3], Michael Kieschnick[4], Michael Förg[5], Thomas Hümmer[5], Cyril Popov[2], Jan Meijer[4], Christoph Becher[3], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität Kassel — [3]Universität des Saarlandes — [4]Universität Leipzig — [5]Qlibri GmbH

Building a long-distance quantum network is one of the big challenges in the field of quantum communication, which requires the development of a quantum repeater.

Tin-vacancy centers in diamond are a rising candidate among color centers in diamond, having higher operating temperatures than silicon-vacancy centers and less prone to phonon-coupling relative to nitrogen-vacancy centers.

In our experiment, we integrate a diamond membrane into an open access fiber-based Fabry-Perot microcavity to attain emission enhancement in a single well-collectable mode. We present our fully tunable, cryogenic cavity platform operating in a tabletop dilution cryostat, and we achieve a picometer mechanical stability. The platform also allows for integration of a superconducting DC magnet and microwave antenna for spin manipulation.

We observe cavity-enhanced fluorescence signal of single, shallow-implanted tin-vacancy centers in diamond, showing Purcell-enhancement and thus higher emission rates and reduced excited state lifetimes.

Q 68.7 Fri 12:45 HS Botanik

Optimal Control for Quantum Technology with NV-Centers in Diamond — •Matthias Müller — Peter-Grünberg-Institute of Quantum Control (PGI-8), Forschungszentrum Jülich GmbH

Diamond-based quantum technology is a fast-emerging field with both scientific and technological importance. The performance relies on unique features like superposition and entanglement and depends on sophisticated mechanisms of control to perform the desired tasks. Quantum Optimal Control (QOC) has proven to be a powerful tool to accomplish this task. I will give a brief overview on the use of QOC for NV-centers in diamond [1], the CRAB algorithm for Optimal Control [2], the optimal-control software QuOCS [3] and report on recent applications toward quantum sensing and quantum computing [4,5,6].

[1] P. Rembold et al., AVS Quantum Sci. 2, 024701 (2020) [2] M. M. Müller et al., Rep. Prog. Phys. 85 076001 (2022) [3] M. Rossignolo et al. Comp. Phys. Comm. 291, 108782 (2023) [4] N. Oshnik et al., Phys. Rev. A 106, 013107 (2022) [5] N. Grimm et al., arXiv:2409.06313 (2024) [6] P. Vetter et al., npj Quantum Information 10 (1), 96 (2024)