TUE 1: QIP Implementations: Photons III

Time: Tuesday 14:15–16:00 Location: ZHG001

TUE 1.1 Tue 14:15 ZHG001

Bose-Einstein Condensation of Photons in Lattice Potentials — •Andreas Redmann, Christian Kurtscheid, Niels Wolf, Frank Vewinger, Julian Schmitt, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, Germany

Thermalization of radiation by contact to matter is a well-known concept, but the application of thermodynamic methods to complex quantum states of light remains a challenge. Using a controlled mirror surface delamination technique to imprint micro-wells in different lattice geometries [1,2], we study thermalization of light in a dye-filled microcavity at room temperature in variable trapping potentials.

In recent work, we have demonstrated Bose-Einstein condensation of photons in a four-site quantum ring [3]. We observe macroscopic accumulation of photons in the ground state with no phase winding above a critical photon number. In other work, we have thermalised photons in a double well system, realizing the textbook-character problem of N bosons populating a two-state system.

[1] C. Kurtscheid et al., Science 366, 894-897 (2019)
[2] C. Kurtscheid et al., EPL 130, 54001 (2020)
[3] A. Redmann et al., Phys. Rev. Lett. 133, 093602 (2024)

TUE 1.2 Tue 14:30 ZHG001

Hollow-core light cages: Towards scalable multiplexed quantum memories — •Esteban Gómez-López[1], Dominik Ritter[1], Jisoo Kim[2], Harald Kübler[3], Markus A. Schmidt[2,4], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Leibniz Institute of Photonic Technology, Jena, Germany — [3]Universität Stuttgart, Stuttgart, Germany — [4]Otto Schott Institute of Material Research, Jena, Germany

Quantum memories play a fundamental role in synchronizing quantum network nodes. Using electromagnetically induced transparency (EIT) in hot atomic vapors provides easy-to-handle systems capable of storing light for up to seconds [1]. Employing a novel photonic structure -a nanoprinted hollow-core light cage (LC)- can enhance the effects of EIT when interfaced with Cs vapor, offering the advantage of faster atomic diffusion inside the core compared to other hollow-core structures [2]. In this work, we show the storage of faint coherent light pulses in the atomic medium confined within the core of the LC for hundreds of nanoseconds. The intrinsic efficiency of the memory was optimized by performing a parameter scan on the signal bandwidth and control power driving the memory [3]. This paves the way towards an on-chip integrated module for quantum memories and as a platform for coherent interaction of light and warm atomic vapors. [1] Katz, O. and Firstenberg, O., Nat. Commun. 9, 2074 (2018). [2] Davidson-Marquis, F., et al., Light. Sci. Appl. 10, 114 (2021). [3] Gómez-López, E., et al., Preprint: arXiv:2503.22423 (2025).

TUE 1.3 Tue 14:45 ZHG001

Storage of single photons from a semiconductor quantum dot in a room-temperature atomic vapor memory with on-demand retrieval — •Benjamin Maass[1,2], Avijit Barua[2], Norman Vincenz Ewald[1], Elizabeth Jane Robertson[1], Kartik Gaur[2], Suk In Park[3], Sven Rodt[2], Jin-Dong Song[3], Stephan Reitzenstein[2], and Janik Wolters[1,2,4] — [1]Institute of Space Research, German Aerospace Center (DLR), Germany — [2]Institutes of Physics, Technische Universität Berlin, Germany — [3]Korean Institute of Technology, Seoul, Republic of Korea — [4]Einstein Center Digital Future (ECDF), Berlin, Germany

On-demand storage and retrieval of single photons in coherent light-matter interfaces is a key requirement for distributing quantum information. Here, we demonstrate storage of single photons from a semiconductor quantum dot device in a room-temperature atomic vapor memory and their on-demand retrieval [1]. A deterministically fabricated InGaAs quantum dot light source emits single photons at the cesium D1 transition wavelength (895 nm) with a linewidth of 5.1(7) GHz which are subsequently stored in a low-noise ladder-type cesium vapor memory. We show control over the interaction between the single photons and the atomic vapor, allowing for variable retrieval times of up to 19.8(3) ns and a maximum internal efficiency of $\eta_{\text{int}} = 0.6(1)\%$. This QD-memory interface provides an unprecedented level of control over the temporal mode of the single-photon emitter and represents a step towards heterogeneous platforms for quantum network nodes.

[1] B.Maaß et al. arXiv:2501.15663 (2025)

TUE 1.4 Tue 15:00 ZHG001

Stark Effect Limitations in Optical Addressing of Phosphorus Donors in Si-28 — •Nico Eggeling[1], Jens Hübner[1], Michael Oestreich[1], and N.V. Abrosimov[2] — [1]Leibniz Universität Hannover, Germany — [2]IKZ Berlin, Germany

Phosphorus donors in isotopically pure Si-28 serve as powerful qubits in electrical measurements. Combining these donors with optical methods seems highly promising[1]. However, surprisingly, spectral hole-burning experiments have not yet achieved Fourier-limited line shapes, a crucial requirement for efficient optical addressing[2]. For the first time on Si-28, we employ time-resolved spectral hole-burning spectroscopy to demonstrate that the primary cause is a random quadratic Stark-Effect, rooted in the formation of ionized donor-acceptor pairs. Monte Carlo simulations validate that the unavoidable acceptor background doping in silicon is responsible for this limitation and open a method to suppress the influence of these acceptors efficiently. This approach not only improves the optical performance of phosphorus-doped Si-28 but also paves the way for the further advancement of solid-state qubits.

[1] Sauter et al., Phys. Rev. Lett. **126**, 137402 (2021)
[2] Yang et al., Appl. Phys. Lett. **95**, 122113 (2009)

TUE 1.5 Tue 15:15 ZHG001

Experimental quantum metrology for fast-varying systems — •Lukas Rückle[1,2] and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Universitity of Stuttgart, 70569 Stuttgart, Germany

The use of quantum states for metrology tasks has been proven to surpass classical limits on the precision of estimating parameters. Recently, the framework of probably approximate correct (PAC) metrology has been introduced. It not only enables the estimation of a parameter in an arbitrarily big parameter space without prior knowledge, but also gives bounds for few- and single-shot metrology settings. It thus bridges the rather theoretical case of performing infinitely many measurements and practical metrology tasks.

Here, we present experimental results in a photonic metrology setting. We show how to use different states and measurements and how for each case to optimize the prediction strategy of the parameter that shall be estimated. Our work shows how to implement the given new framework of PAC metrology and thus helps improving the precision of applications that only allow for a few measurements, e.g. when measuring fast varying systems.

TUE 1.6 Tue 15:30 ZHG001

Hetero-integration of diamond nanostructures on AlGaN-based photonic circuits — •Domenica Romina Bermeo Alvaro[1,2], Sinan Gündogdu[1,2], Lea M. Rektorschek[2], Pascal Frehle[2], Marco E. Stucki[1,2], Maarten H. van der Hoeven[2], Julian M. Bopp[2,1], Tim Kolbe[2], Sylvia Hagedorn[2], Markus Weyers[2], Tommaso Pregnolato[1,2], and Tim Schröder[2,1] — [1]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [2]Department of Physics, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany

Spin-photon interfaces are crucial for the development of large quantum networks. A highly efficient spin-photon interface can be achieved when diamond color centers are embedded in photonic crystal cavities, which enhance the light-matter interaction and boost the emission rate of photons generated by the coherent zero-phonon-line transition. While the diamond substrate allows for the nanofabrication of such devices, achieving a monolithic platform that will take advantage of those photonic crystal cavities on a large scale remains a challenge. To overcome these limitations, we propose the hetero-integration of diamond nanostructures into AlGaN-based photonic circuits. By embedding diamond nanostructures within AlGaN-based circuits, we aim to create highly efficient, scalable spin-photon interfaces. Our approach involves the design, fabrication and characterization of a low-loss coupling section between diamond and AlGaN waveguides. Finally, we show the first integration on an AlGaN-based photonic circuit of a Sawfish cavity, our newly proposed photonic crystal cavity.

TUE 1.7 Tue 15:45 ZHG001

Experimental Quantum Strong Coin Flipping using a Deterministic Single-Photon Source — •Koray Kaymazlar[1], Daniel Vajner[1], Fenja Drauschke[2], Lucas Rickert[1], Martin von Helversen[1], Shulun Li[3], Zhichuan Niu[3], Anna Pappa[2], and Tobias Heindel[1] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin, Germany — [2]Electrical Engineering and Computer Science Department, Technische Univeristät Berlin, Germany — [3]Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China

Strong coin flipping (SCF) is a fundamental cryptographic protocol allowing two distrustful parties to agree on randomly generated bit. In this work, we report the first implementation of a quantum strong coin flipping protocol that yields a quantum advantage compared to both its classical counterpart and an implementation using weak coherent pulses [1]. The quantum advantage is enabled by employing a state-of-the-art deterministic single-photon source based on a quantum dot embedded in a high-Purcell microcavity. Using a fiber-based electro-optic modulator (EOM) we realize fast dynamic, random polarization-state encoding at 80 MHz clock-rate. Our QSCF implementation enables a coin flipping rate of 1.5 kHz and an average quantum bit error ratio (QBER) below 3%, sufficient to realize a quantum advantage.

[1] D. A. Vajner, K. Kaymazlar, F. Drauschke, L. Rickert, M. von Helversen, H. Liu, S. Li, H. Ni, Z. Niu, A. Pappa, T. Heindel, Single-Photon Advantage in Quantum Cryptography Beyond QKD, arXiv:2412.14993 (2024)