Q 49: Quantum Communication, Networks, Repeaters, & QKD I

Time: Thursday 11:00–13:00 Location: P 10

Q 49.1 Thu 11:00 P 10

Optical quantum storage of cold atomic ensemble mediated by light-induced fictitious magnetic field — Liang Dong[1], Linyu Chen[1], Xingchang Wang[1], Xinyun Liang[1], •Ying Zuo[2], Georgios Siviloglou[2,3], and JieFei Chen[1,2] — [1]Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China — [2]International Quantum Academy, Shenzhen 518048, China — [3]Department of Physics, University of Crete, Heraklion, Greece

Optical quantum memory is a critical component in quantum computing, sensing, and communication. A major obstacle limiting practical quantum memory based on cold atomic ensemble is the reduced storage lifetime caused by spatiotemporal inhomogeneity in ambient magnetic fields along the elongated atomic cloud. To address this challenge, we demonstrate a method to prolong the storage lifetime of single-photon quantum states using a combination of optically induced virtual magnetic fields and DC bias field. By precisely tailoring the polarization, spatial distribution, and temporal waveform of the AC Stark beam, the generated virtual magnetic field compensates in real-time for spatial inhomogeneities and temporal fluctuations. This high-speed, high-spatial-resolution compensation technique overcomes the limitations of conventional current-coil methods, such as slow response and low spatial resolution, effectively suppressing decoherence in magnetically sensitive quantum states. Furthermore, we propose a scheme for storing time-bin entangled photon pairs prepared at two distinct time bins.

Q 49.2 Thu 11:15 P 10

Towards a spin-exchange collision-based optical quantum memory in noble-gas spins — •Alexander Erl[1,2], Norman Vincenz Ewald[1,2], Andrés Medina Herrera[2], Denis Uhland[3], Wolfgang Kilian[2], Jens Voigt[2], Ilja Gerhardt[3], and Janik Wolters[1,4] — [1]DLR, Institute of Space Research, Berlin — [2]PTB, 8.2 Biosignals, Berlin — [3]LUH, Institute of Solid State Physics, Hannover — [4]TUB, Institute of Physics and Astronomy, Berlin

A critical limitation on current room-temperature quantum memory systems [1] is the maximum achievable storage time on the order of a few μs, which must be extended for various quantum communication applications. We report on our first steps towards a long-lived quantum memory with an all-optical interface based on a mixture of ^{129}Xe noble gas and ^{133}Cs alkali metal vapor, both confined in a glass cell at near room temperature. The interface relies on EIT, implemented through a Λ-scheme in the Zeeman sublevels of the long-lived hyperfine ground states of ^{133}Cs, coupled to an excited state via the D_1 line at 895 nm [2]. A sufficiently long-lived Cs spin coherence is essential for entering the strong spin-exchange coupling regime, where collisions can efficiently transfer the stored quantum excitation from the alkali vapor to the noble-gas ensemble [3]. The coherence time of ^{129}Xe, which can extend up to several hours [4], offers the potential for long-term storage of quantum information in collective atomic excitations. [1] M. Jutisz et al., Phys. Rev. Applied 23, 024045 (2025); [2] G. Buser et al., PRX, 020349 (2022); [3] O. Katz et al., PRA 105, 042606 (2022); [4] C. Gemmel et al., EPJ D 57, 303-320 (2010)

Q 49.3 Thu 11:30 P 10

Exploring the nuclear spin environment of individual erbium emitters — Alexander Ulanowski, Olivier Kuijpers, Benjamin Merkel, Adrian Holzäpfel, •Noah Weinhold, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences, Physics Department and Munich Center for Quantum Science and Technology (MCQST), 85748 Garching, Germany

Nuclear spins in solids exhibit exceptional coherence times and present promising candidates for nuclear spin registers and robust quantum memories. In this work, we focus on the nuclear spin of ^{167}Er dopants, which feature an optical transition within the low-loss wavelength window of optical fibers. Using a high-finesse cryogenic Fabry-Perot cavity, we achieve all-optical control and readout of ^{167}Er dopants in a 10 μm thin yttrium orthosilicate crystal. We further implemented spectroscopy techniques to characterize the superhyperfine interaction with Y nuclear spins surrounding individual Er dopants [1]. This may be used as a resource in quantum technology e.g. enabling the entanglement of nuclear spins with emitted photons or targeting nearby nuclear spins for quantum memories.

[1] A. Ulanowski, O. Kuijpers, B. Merkel, A.Holzäpfel, and A. Reiserer, PRX Quantum 6, 020344 (2025)

Q 49.4 Thu 11:45 P 10

Characterization of Pulsed Entangled Photon Emission via SFWM in Warm Rubidium Vapors — •Giorgio De Pascalis[1], Ioannis Caltzidis[1], Ruben Kampel[1], Shane Andrewski[2], Mael Flament[2], Alexander N. Craddok[2], Sonja Barkhofen[1], Mehdi Namazi[2], and Klaus D. Jöns[1] — [1]Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP) and Department of Physics, Paderborn University, Paderborn, Germany — [2]Qunnect Inc, Brooklyn, USA

The development of robust sources capable of reliably emitting entangled photon pairs-compatible with both current communication systems and emerging quantum devices-is of paramount importance for quantum information applications [1,2]. Practical implementations in deployed quantum networks require both high emission rates and high state fidelity. Spontaneous four-wave mixing (SFWM) has emerged as a promising technique to use in a real telecommunication network [3]. Typically, these sources are driven using continuous-wave coupling and pump fields, a configuration that limits the possibility of controlled synchronized quantum network protocols. We present a comprehensive characterization of the source's emission properties, combining theoretical modeling and experimental measurements, including a CHSH measurement and quantum state tomography of the generated entangled photon pairs. [1] Yin, J. et al. Nature 582, 501-505 (2020) [2] Bennett C. H. et al. Phys. Rev. Lett. 68, 557 (1992) [3] M. Sena et al. arXiv: 2504.08927 [quant-ph]

Q 49.5 Thu 12:00 P 10

What can the experimentalist learn from Bell polytopes? — •Tom Hobbs and Ilja Gerhardt — light & matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Measurements on entangled systems can produce correlations which are stronger than those predicted by local theories of physics. For a particular experimental configuration, the set of outcomes allowed by local models forms a Bell polytope. Meanwhile, quantum theory allows for a larger outcome set, comprising the whole local polytope plus additional nonlocal correlations. For applications such as quantum key distribution (QKD) or randomness generation, it is important to know whether the measured correlations lie inside or outside the local region. This is typically done by checking if the correlations violate a particular Bell inequality.

In our work we investigate how experimental flaws, such as imperfect state preparation, detector noise, and mismatched measurement bases, affect the set of correlations that can be measured. We show how these correlations can be visualized, and how varying the experimental settings can move the measured correlations inside or outside the Bell polytope. We aim to link our results to a practical entanglement-based QKD scenario.

Q 49.6 Thu 12:15 P 10

Purcell-Enhanced Er^{3+} Dopants in Silicon Nanophotonics for Quantum Networks — •Francesca Molteni, Andreas Gritsch, Jakob Pforr, Benedikt Braumandl, Alexander Ulanowski, Arantza Pineda Gonzalez, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences, Physics Department and Munich Center for Quantum Science and Technology (MCQST), James-Franck-Straße 1, 85748 Garching, Germany

Erbium in silicon provides a promising route towards scalable quantum networks, offering telecom-band emission compatible with low-loss fibers and narrow transitions [1], while enabling the integration of quantum emitters into photonic circuits [2].

We investigate Er^{3+} dopants in a silicon-on-insulator platform, where on-chip photonic crystal cavities produce strong Purcell enhancement via high Q factors and sub-wavelength mode volumes. This enables fast spin initialization and optical single-shot readout [3].

Optical coherence is probed through Rabi oscillations and photon-echo measurements, revealing coherence times exceeding 80% of the lifetime limit and interference of sequentially emitted photons demonstrates high indistinguishability. We will present recent advances that allow for increased Purcell enhancement factors.

These results establish erbium in silicon as a highly promising and scalable platform for future quantum network architectures.

[1] Reiserer, Rev. Mod. Phys. 94, 041003 (2022); [2] Gritsch et al., Phys. Rev. X 12 (4), 041009 (2022); [3] Gritsch et al., Nat. Commun. 16, 64 (2025).

Q 49.7 Thu 12:30 P 10

Shot-noise limited discrete QAM signals for airborne quantum communication — Stefan Richter[1,2], •Hüseyin Vural[1,2], Thomas Dirmeier[2,1], Sheng-Hsuan Huang[1,2], and Christoph Marquardt[1,2] — [1]Chair of optical quantum technologies, Friedrich-Alexander- Universität Erlangen-Nürnberg, Erlangen — [2]Max Planck Institute for the Science of Light, Erlangen

To ensure continuity of operation in quantum communication networks when terrestrial fiber links are (temporarily) unavailable, methods to quickly (re-)establish secure links between access nodes are required. One promising approach is the deployment of airborne mobile nodes to bridge outages and extend secure connectivity. As part of the German QuNET initiative, such a scenario was investigated using a flying transmitter aboard a research aircraft of the German DLR and an optical ground station (OGS) operated by Fraunhofer IOF during two measurement campaigns in April and October 2025 in Erlangen.

Here, we report on our transmitter system and its deployment for testing the feasibility of continuous-variable (CV) QKD over such a dynamic free-space link. Our system is capable of generating discrete quadrature amplitude modulation (QAM) of coherent states required for CV-QKD protocols under the restrictive conditions of a flying platform, while the receiver is connected via fiber to the OGS. Our findings indicate the feasibility of CV-QKD in this harsh environment and over a strongly fluctuating link by successfully exchanging shot-noise-limited signals.

Q 49.8 Thu 12:45 P 10

Non classicality in frequency multiplexed quantum networks — •Theresa Keuter, Patrick Folge, Abhinandan Bhattacharjee, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonics Quantum Systems (PhoQS), Warburger Str. 100

Linear optical quantum networks are a key building block for many quantum technologies, such as Gaussian Boson Sampling. However, previous implementations based on spatial encoding are difficult to scale. We propose a new system, which operates on modes of different frequencies. By employing a dispersion-engineered sum-frequency generation (SFG) process, interactions between these frequency modes can be mediated, enabling a fully programmable, frequency-encoded quantum network within a single spatial and polarization mode. Quantum input states for this network are provided by the strong frequency entanglement of a type-0 parametric down-conversion (PDC) source. In this work, we investigate signatures of non-classicality in such systems as an essential step toward assessing their quantum properties.