QI 33: Quantum Networks II (joint session QI/Q)

Time: Thursday 14:30–16:30 Location: F428

QI 33.1 Thu 14:30 F428

A quantum interface between NV center matter qubits and Thulium rare-earth ion quantum memory compatible light
— •M.C. Roehsner[1], M. Iuliano[1], A.J. Stolk[1], M. Sholkina[1], N. Alfasi[1], T. Chakraborty[1], W. Tittel[1,2], and R. Hanson[1] — [1]QuTech & Kavli Institute of Nanoscience, Delft University of Technology — [2]Department of Applied Physics, University of Geneva & Schaffhausen Institute of Technology, Geneva

Quantum networks promise to enable applications ranging from secure communication to fundamentally new kinds of computation. However, the individual components of quantum networks may be realized with different kinds of physical systems, requiring specialized interfaces. Here we present our work towards interfacing a diamond Nitrogen Vacancy (NV) center, well suited as a local quantum processing network node [1], with light compatible with Tm-based rare-earth ion quantum memories, well suited for long-range quantum repeaters [2]. We demonstrate two-photon quantum interference between photons emitted from an NV center with weak coherent light resonant with a Tm-based memory, probing the indistinguishability of the photons created by these disparate sources, using a low noise two-step quantum frequency conversion process. Furthermore, we present latest results towards teleporting a memory-compatible time-bin qubits into the NV center. With this quantum interface between different physical systems, we aim to bridge the gap between two key network components.
[1] Hermans, S.L.N. et al. Nature 605 (2022) [2] Davidson J.H. et al. Phys. Rev. A 101 (2020)

QI 33.2 Thu 14:45 F428

Space-borne quantum memories for global quantum networking
— •Mustafa Gündoğan[1], Jasminder Sidhu[2], Daniel Oi[1], and Markus Krutzik[1] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]University of Strathclyde

Exponential losses in optical fibres limit the transmission of quantum information to around few hundred kilometres. Quantum repeaters based on the heralded storage of entangled photon pairs were proposed to increase this direct transmission limit. Nevertheless, these architectures are still limited to around few thousand kilometres.

In this talk I will present our proposal for placing quantum memories on board orbiting satellites to enable quantum networking at a truly global scale. The first idea relies on building a network of satellites equipped with QM with storage times of <1s. One can then create a quantum repeater in space to cover global distances [1]. The second idea is to use a single orbiting satellite equipped with two QMs: one with long (∼h) and the other short (∼ms) storage times. Quantum information is then shuttled across the globe in a time-delayed quantum repeater fashion. This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) due to an enactment of the German Bundestag under grant number 50WM2055.

[1] M. Gündoğan *et. al.*, npj Quantum Information **7**, 128 (2021)

QI 33.3 Thu 15:00 F428

Towards remote entanglement of single erbium dopants
— •Alexander Ulanowski[1], Fabian Salamon[1], Benjamin Merkel[1], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]TU München and Munich Center for Quantum Science and Technology, 85748 Garching, Germany

In a future quantum internet, coherent emitters will exchange quantum states over global distances, preferably using optical fibers to establish entanglement between remote spins. To this end, erbium dopants are a promising platform due to the optical transition in the telecom band enabling low-loss distribution of photons. To realize an efficient spin-photon interface for single dopants, we embed a thin erbium doped crystal into a tuneable high-finesse Fabry-Perot resonator. In our experiment we achieve up to 110-fold Purcell enhancement while the coherence is preserved up to the lifetime limit by avoiding proximal interfaces [1]. Using spectral multiplexing gives us access to hundreds of individual dopants which exhibit a low spectral diffusion (< 0.2 MHz) currently limited by the nuclear spin bath [2]. To further improve the spectral stability and enable entanglement generation via photon interference, we thus investigate spin-free ^{29}Si crystals as a possible host material [3]. Furthermore, we expect considerable stability improvement by applying real-time feedback on the emitter frequency. This opens perspectives for long-distance entanglement at kilohertz rates.

[1] B. Merkel et al., Phys. Rev. X 10, 041025 (2020).
[2] A. Ulanowski et al., Sci. Adv. 8, eabo4538 (2022).
[3] Y. Liu et al., Journ. Cryst. Growth, 126733 (2022).

QI 33.4 Thu 15:15 F428

Hong-Ou-Mandel Interference in LNOI
— •Silia Babel, Laura Bollmers, Marcello Massaro, Kai Hong Luo, Michael Stefszky, Federico Pegoraro, Philip Held, Harald Herrmann, Christof Eigner, Benjamin Brecht, Laura Padberg, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

A quantum computer can be built solely using single photons sources, linear optics and single photon detectors. For the realisation of a photonic quantum computer, a particular interest has been devoted to the study of integrated networks since these offer many advantages such as stability, the possibility of compact devices and high efficiency, and thus provide scalability. The foundation of these integrated networks are directional couplers and interference between single photons.
A interesting platform for this purpose is Lithium Niobate on Insulator (LNOI) since it combines the advantages of conventional lithium niobate, such as a wide transparency window and high nonlinear coefficients, with a high integration density. To show that this material is suited for the realisation of integrated quantum networks, we demonstrate Hong-Ou-Mandel interference (HOMI) of telecom photons on a balanced directional coupler. We designed and fabricated the coupler in-house and achieve a raw HOMI visibility of (93.5±0.7)%. Our work demonstrates a crucial building block for integrated quantum networks based on LNOI.

QI 33.5 Thu 15:30 F428

Portable warm vapor memory
— •Martin Jutisz[1], Elisa Da Ros[1], Alexander Erl[2,3], Leon Messner[1,3], Luisa Esguerra[3,2], Janik Wolters[3,2], Mustafa Gündoğan[1], and Markus Krutzik[1,4] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Deutsches Zentrum für Luft- und Raumfahrt, Berlin, Germany — [4]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Warm vapor memories have seen significant progress in terms of efficiency and storage time in recent years. Their low complexity makes them a promising candidate for operation in non-lab environments including space-based applications. As necessary element of quantum repeaters, memories operating in space could advance global quantum communication networks [1].

We will present the overall status of integration and test of a portable rack-mounted system. The implementation of the optical memory is based on electromagnetically induced transparency on the Cesium D1 line at 894 nm. Three lasers are frequency stabilized to provide pump, signal and control pulses. Automated locking is realized via a FPGA-based tool for laser frequency stabilization. The storage platform is provided by a heated Cesium vapour cell in a three-layer magnetic shield. Possibilities of micro integration are also being investigated.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWK) under grant number 50RP2090.

[1] M. Gündoğan et. al., npj Quantum Information 7, 128 (2021)

QI 33.6 Thu 15:45 F428

Single erbium dopants in nanophotonic resonators
— •Jakob Pforr[1,2], Andreas Gritsch[1,2], Alexander Ulanowski[1,2], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]TU München and Munich Center for Quantum Science and Technology, 85748 Garching, Germany

Single erbium dopants in nanophotonic resonators are promising for the realization of quantum networks owing to their outstanding optical and spin coherence properties [1] and their large spectral multiplexing potential [2]. Previous experiments used yttrium-based host crystals, in which erbium is integrated in well-defined sites. However, these crystals are not compatible with established nanofabrication techniques, which hinders scalable integration into on-chip photonic circuits. To address this challenge, we have spectroscopically studied ensembles of erbium dopants in silicon nanostructures. After optimizing the erbium implantation procedure, we have observed two well-defined lattice sites with narrow inhomogeneous broadening ($<$ 1 GHz), narrow homogeneous linewidths ($<$ 0.01 MHz) and optical lifetimes of 0.2 ms [3]. In one-dimensional photonic crystal resonators ($Q > 10^4$, $V \sim \lambda^3$), we observe single dopants with a 60-fold Purcell-enhanced emission. We will present studies of the optical coherence, spectral diffusion, spin properties and spectral multiplexing capability of these devices.

References:
[1] Merkel et. al. 2020. PRX 10(4): 041025.
[2] Ulanowski et. al. 2021. SciAdv 8(43): eabo4538.
[3] Gritsch et. al. 2021. PRX 12(4): 041009.

QI 33.7 Thu 16:00 F428

High fidelity single-shot readout of telecom emitters in a Fabry-Perot resonator — •Fabian Salamon[1,2], Alexander Ulanowski[1,2], Johannes Früh[1,2], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]TU München and Munich Center for Quantum Science and Technology, 85748 Garching, Germany

Erbium dopants are prime candidates for the realisation of extended quantum networks, as they combine second-long ground state coherence with a coherent optical transition in the telecommunication window, where loss in optical fibers is minimal [1].

To implement quantum information processing in this novel platform, we perform single-shot readout of the spin state by resonantly driving the optical transition and detecting the subsequently emitted photons. We overcome the challenge that erbium lacks a cycling transition [2] by using a Fabry-Perot resonator with a narrow linewidth (50 MHz) [3] in order to selectively enhance the readout transition.

Combined with our recent advances in spectral multiplexing [4], the successful implementation of high-fidelity single-shot readout is a key step towards high-rate entanglement of distant erbium dopants.

[1] A. Reiserer, arXiv:2205.15380 (2022).
[2] M. Raha et al., Nat. Commun. 11, 1605 (2020).
[3] B. Merkel, A. Ulanowski & A. Reiserer, Phys. Rev. X 10, 041025 (2020).
[4] A. Ulanowski, B. Merkel & A. Reiserer, Sci. Adv. 8, eabo4538 (2022).

QI 33.8 Thu 16:15 F428

Electromagnetically Induced Transparency in hollow-core light-cages: Simulation tool and experimental preparation — •Dominik Ritter[1], Esteban Gómez-López[1], Jisoo Kim[2], Markus Schmidt[2,4], Harald Kübler[3], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Leibniz Institute of Photonic Technology, 07702 Jena, Germany — [3]University of Stuttgart, 70569 Stuttgart, Germany — [4]Otto Schott Institute of Material Research, 07743 Jena, Germany

Quantum repeaters and memories are needed to overcome efficiently the losses of long-distance quantum networks [1]. A promising system to host a quantum memory is atomic vapours, which can be enhanced with guiding photonic structures [2].

We will present a simulation program and experimental measurements for enhanced light matter interaction in hollow-core light-cages (LC) inside a warm cesium vapor cell. The program calculates the absorption spectra of alkali vapors under Electromagnetically Induced Transparency (EIT). Propagation of light pulses through the bare atomic vapor and the LC are simulated, where a linear loss model is assumed. This use of the LC would lead towards controllable time delay of photons in an easy to use and easy to implement device and eventually a reliable platform for a quantum memory for single photons using the EIT-storage scheme [3].

[1] P. v. Loock et al., Adv. Quantum Technol. 3, 1900141 (2020). [2] K. F. Reim et al., Phys. Rev. Lett. 107, 053603 (2011). [3] J. Wolters et al., Phys. Rev. Lett. 119, 060502 (2017).