Q 57: Quantum Information (Quantum Repeater)

Time: Friday 11:00–13:00 Location: e001

Group Report Q 57.1 Fri 11:00 e001

Resource Efficient One-way Quantum Repeater — •Tim Schröder — Humboldt-Universität zu Berlin — Ferdinand-Braun-Institut, Berlin

Towards the realisation of a 'one-way' quantum repeater, we show progress on theoretical concepts and experimental implementation. While to date 'one-way' quantum repeater proposals rely on a relatively large number of stationary and flying qubit resources, we introduce a scheme that is based on photonic tree cluster states and that requires only one single photon emitter and two ancilla qubits per communication node, reducing the resource requirements by orders of magnitude. We analyse achievable quantum communication rates for different repeater parameters, and simulate that about 70 kHz quantum bit rate over a distance of 1000 km can be achieved. Moreover, we show that the implementation of such a quantum repeater is almost accessible with today's technology, and we introduce physical modules that allow for its experimental realisation. Towards the implementation of such modules we show our experimental progress with spin-photon interfaces based on defect centres in diamond nanostructures.

Q 57.2 Fri 11:30 e001

Towards a Suburban Quantum Network Link — •Tim van Leent[1], Robert Garthoff[1], Matthias Bock[2], Kai Redeker[1], Florian Fertig[1], Derya Taray[1], Matthias Seubert[1], Wei Zhang[1], Wenjamin Rosenfeld[1,3], Christoph Becher[2], and Harald Weinfurter[1,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany — [2]Fachrichtung Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Quantum repeaters will allow scalable quantum networks, which is essential for large scale quantum communication and distributed quantum computing. Yet, still missing on the road towards a quantum repeater, is to achieve entanglement between quantum memories over long distances.

Here we present results demonstrating distribution of atom-photon entanglement at the telecom wavelength over 20 km optical fiber with a fidelity of >79% [1]. For this purpose, we use polarization-preserving quantum frequency conversion, where the photon at 780 nm is mixed with a strong pump field at 1600 nm inside a nonlinear waveguide crystal. Implementing frequency conversion for the second atom and employing the entanglement swapping protocol [2] in the telecom will enable the next important milestone, i.e., generating atom-atom entanglement on a suburban scale.

[1] T. van Leent et al., arXiv:1909.01006 (2019)
[2] W. Rosenfeld et al., Phys. Rev. Lett. **119**, 010402 (2017)

Q 57.3 Fri 11:45 e001

Optimized cavity-enhanced down-conversion source in interferometric configuration — •Jan Arenskötter, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, Campus E2.6, 66123 Saarbrücken

An efficient resource of entanglement in atom-photon-based quantum networks are polarization-entangled photon pairs generated by type-II spontaneous parametric down-conversion (SPDC). Previously, we presented a cavity-enhanced SPDC source in interferometric configuration, which is tailored to match the $P_{3/2}$ to $D_{5/2}$ transition of $^{40}Ca^+$ at 854 nm [1].

Here we show improvements and optimizations of this photon pair source. We changed the cavity geometry from a bow-tie to a triangle configuration which resulted in a shortening of the cavity length. By this we improve the scaling of the signal-to-background ratio due to an increased bandwidth of the photons. The photons coming from the new source are non-degenerate but still show polarization entanglement with a fidelity of at least 97.9% to the Ψ^--Bell state. The locking scheme of the cavity and the interferometer have also been improved for better signals and higher stability.

[1] DPG Verhandlungen Q2.7, Mainz 2017

Q 57.4 Fri 12:00 e001

A passive, heralded quantum memory with crossed optical fiber cavities — •Dominik Niemietz[1], Manuel Brekenfeld[1], Joseph D. Christesen[1,2], and Gerhard Rempe[1] — [1]MPQ, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]NIST, Boulder, Colorado 80305, USA

The impossibility to clone quantum information renders quantum communication secure, but also prevents quantum information from being amplified, causing processes that are subject to losses become probabilistic. In many cases, finite success probabilities can be coped with a herald [1] that indicates the successful completion of a process without touching the underlying quantum information. This applies, in particular, to the propagation of photons in quantum networks [2] where photon loss in optical fibers can be remedied using quantum repeaters [1]. In this talk, we present a promising candidate for a node in such a network: A heralded quantum memory for photonic polarization qubits based on single rubidium atoms trapped at the crossing point of two optical fiber cavities, one for the qubit, the other for the herald. Our high-fidelity quantum memory features fully passive storage, requiring neither amplitude- and phase-critical control fields nor error-prone feedback loops. With these properties, our system can be an important contribution to the current quest for a quantum repeater and for the realization of hybrid quantum systems.

[1] Briegel, Dür, Cirac and Zoller, Phys. Rev. Lett. **81**, 5932-5935 (1998)
[2] Ritter et al., Nature **453**, 1023-1030 (2012)

Q 57.5 Fri 12:15 e001

Space-borne quantum memories for quantum communication and fundamental physics: prospects and challenges — •Mustafa Gündoğan[1], Dennis Rätzel[1], Janik Wolters[2], Daniel Oi[3], and Markus Krutzik[1,4] — [1]Institut für Physik, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Optical Sensor Systems, 12489 Berlin, Germany — [3]SUPA Department of Physics, University of Strathclyde, John Anderson Building, Glasgow, G4 0NG, UK — [4]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany

Storing quantum information in material systems, i.e. in quantum memories (QM), is a key requirement for quantum information tasks in which probabilistic events have to be synchronized. Among the first applications of QMs is to extend the distance over which a quantum entangled state could be shared as nodes in a quantum repeater. In this work we compare performances of space-based quantum communication architectures without and with the help of QMs and quantify advantages that are brought by QMs.

Another potential use of space-based QMs is to store quantum information in curved space-times for extended period of times. In this context, we discuss novel experiments that would be enabled by QMs to probe general relativistic proper time in quantum mechanics.

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Q 57.6 Fri 12:30 e001

Stabilization of a high-finesse cavity with an Erbium doped crystal in a closed-cycle cryostat — •Alexander Ulanowski[1], Benjamin Merkel[1], and Andreas Reiserer[1,2] — [1]MPI of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität München, München, Germany

Cryogenic optical resonators are promising for the implementation of quantum repeaters based on dopants in solid-state systems. Due to mechanical vibrations in a closed-cycle cryostat, such resonators require elaborate passive and active stabilization. The presence of mechanical resonances and anti-resonances in the resonator mount can however limit the bandwidth of active feedback when using ordinary controllers, e.g. a proportional-integral-derivative controller (PID).

We overcome this limitation by using a Finite Impulse Response (FIR) filter realized digitally on a field-programmable gate array device to cancel out these mechanical resonances and increase the unity gain frequency. [1] In combination with passive stabilization of our high-finesse resonator ($\mathcal{F} \approx 10^5$), we achieve a sub-pm stability at a temperature of 2K. This allows us to observe emission of erbium ions, doped into a crystal that is embedded in the resonator, with a Purcell enhancement factor of several hundreds.

[1] Ryou and Simon, Rev. Sci. Instrum. 88, 013101 (2017)

Q 57.7 Fri 12:45 e001

Resonant spectroscopy of erbium dopants in silicon nanophotonic waveguides — •Florian Burger[1,2,3], Lorenz Weiss[1,3], Andreas Gritsch[1], Johannes Früh[1,4], Laura Zarraoa[1,5], and Andreas Reiserer[1,3] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Technical University of Munich, Germany, Department of Physics — [3]Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität München, Germany — [4]University of Applied Sciences Munich, Germany — [5]Technical University of Denmark, Copenhagen, Denmark

Silicon photonics has developed into a mature technological platform that allows for rapid development cycles using standardized tools. Integrating coherent optical emitters into this platform would open unique possibilities towards implementing a scalable platform for quantum repeaters. In this context, we explore the use of erbium dopants that feature a coherent optical transition at a wavelength close to 1.5 μm, where the loss in both optical fibers and silicon waveguides is minimal. Previous experiments, targeted at laser development, used high implantation doses and off-resonant excitation by a focused laser. In contrast, the use of low-loss nanowire waveguides allows us to perform resonant spectroscopy. At cryogenic temperatures, we observe narrow optical resonances, suggesting that the erbium dopants are integrated into the crystal lattice at well-defined sites. We will present the current status of the experiment and our progress towards coherent control of individual erbium spins in silicon by embedding them into photonic crystal waveguides and cavities.