Q 41: Quantum Information (Quantum Communication and Quantum Repeater) I

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

Group Report Q 41.1 Thu 11:00 e001

Photonic qubit memories for quantum networks — •Olivier Morin, Stefan Langenfeld, Matthias Körber, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

The storage of qubits is an extremely important capability for the implementation of numerous protocols in quantum information technology. In the context of quantum networks the qubits are transported from one node to another via the exchange of photonic states. Here, we will report on our progress on photonic memories using single 87Rb atoms in a high finesse cavity.

First, one important figure of merit is the storage time. By using different atomic states we have extended the coherence time beyond 100ms [1]. The second important figure of merit is the efficiency of the memory. This latter does not only rely on minimizing optical losses but also on the accurate control of the temporal shape of the photons that carry the qubits [2]. Last but not least, in order to be used in advanced applications like quantum repeaters, pairs of memories that can interact with each other are desired. We have recently shown that we can have two individual atoms in the same optical cavity mode and use them as Random Access Quantum Memories for more than 10 qubits with high fidelity and low cross talk [3].

[1] M. Körber et al., Nat. Photonics 12, 18 (2018).
[2] O. Morin et al., Phys. Rev. Lett. 123, 133602 (2019).
[3] S. Langenfeld et al., in preparation (2019).

Q 41.2 Thu 11:30 e001

Single-Photon Distillation with an Atom-Cavity System — •Stephan Welte[1], Severin Daiss[1], Lukas Hartung[1], Emanuele Distante[1], Bastian Hacker[1,2], Lin Li[1,3], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Present address: Max-Planck-Institut für die Physik des Lichts, Staudtstr. 2, 91058 Erlangen — [3]Present address: School of Physics, Huazhong University of Science and Technology, Wuhan, China

Custom-shaped single photons are an indispensable tool for many applications in quantum communication. We distill them out of incoming weak optical pulses that are reflected from and entangled with an atom-cavity system [1]. A suitable measurement on the atom is used to herald the suppression of undesired photon-number contributions. Additionally, the temporal mode profile of the generated photons can be tailored. Out of vacuum-dominated coherent pulses, we distill single photons with a fidelity of 66%. Applying our protocol to state-of-the-art fiber cavities [2] would allow one to reach single-photon fidelities of up to 96%.

[1] S. Daiss, S. Welte, B. Hacker, L. Li, G. Rempe, PRL **122**, 133603 (2019)
[2] M. Uphoff, M. Brekenfeld, G. Rempe, S. Ritter, New J. Phys. **17**, 013053 (2015)

Q 41.3 Thu 11:45 e001

Development of Single Photon Quantum Frequency Conversion for Quantum Computing Networks — •Marcel Hohn and Simon Stellmer — Physikalisches Institut der Universität Bonn, Nussallee 12, 53115 Bonn

In recent years, numerous physical implementations of qubit systems, ranging from trapped ions to solid state quantum dots, have been realized. For reliable long-distance transport of quantum information between quantum systems, the usage of single photons as so-called flying qubits is the most convenient choice. The development of a hybrid quantum network permits to incorporate the benefits of different systems. This requires a means to convert the frequencies of these single photons between the operation frequencies of the respective platforms while preserving the quantum correlations, which is accomplished by quantum frequency conversion (QFC) via sum- and difference frequency generation (SFG/DFG) in a nonlinear material. Here we report on the development of a quantum frequency conversion setup between the Yb^+ dipole transition at 369.5 nm and InGaAs quantum dots at about 850 nm using a waveguide in periodically poled potassium titanyl phosphate (PPKTP).

Q 41.4 Thu 12:00 e001

Spin-controlled indistinguishable and distinguishable photon emission from colour centres in silicon carbide — •Florian Kaiser, Naoya Morioka, Roland Nagy, Izel Gediz, Erik Hesselmeier, Charles Babin, Matthias Niethammer, Roman Kolesov, Durga Dasari, Rainer Stöhr, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart and IQST, Stuttgart, Germany

The silicon carbide (SiC) platform has recently shown extremely promising advancements for scalable quantum information applications [1]. To foster the platform's full potential, entanglement generation is crucial, which may be efficiently mediated through photonic interference [2].

Here, we show that the silicon vacancy (VSi) centre in SiC provides the necessary spin-optical interface. First, we show high quality Hong-Ou-Mandel interference experiments. Then, we show how we control the photonic interference pattern via coherent electron spin control.

Our results clearly demonstrate that VSi centres in SiC are capable of generating photon-mediated spin-spin entanglement. This crucial step demonstrates the potential of the system for realising large-scale quantum networks.

[1] R. Nagy et al., Nat. Commun. 10, 1954 (2019)
[2] F. Rozpedek et al., Phys. Rev. A 99, 052330 (2019)

Q 41.5 Thu 12:15 e001

Photon entanglement distribution using a single trapped ion as quantum memory — •Martin Steinel, Matthias Kreis, Jan Arenskötter, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

The generation of remote entanglement at long distances is a fundamental component in quantum networks. To achieve long distance entanglement through a fiber network, quantum repeaters [1] operating on quantum memories (QM) must be employed. Focusing on trapped ions as QMs [2-4] in a quantum repeater cell [5] we compare several protocols quantitatively with numerical simulations in terms of qubit rate and background contributions. Implemented as a finite state machine, we simulate an emission protocol for a single qubit QM consecutively emitting two entangled photons, and an absorption protocol. In the latter, two entangled photon pairs are generated by SPDC and one partner of each pair is absorbed consecutively by the QM. The necessary Bell state measurement is performed by projection of heralds of absorption and the final atomic state, that allows to distinguish all four Bell states. The simulations are compared with two qubit QM schemes in terms of efficiencies and experimental parameters of our existing setup and possible future developments.

[1] H.-J. Briegel et al., Phys. Rev. Lett. **81**, 5932 (1998)
[2] C. Kurz et al., Nat. Commun. **5**, 5527 (2014)
[3] C. Kurz et al., Phys. Rev. A **93**, 062348 (2016)
[4] M. Bock et al., Nat. Commun. **9**, 1998 (2018)
[5] C. Panayi et al., New J. Phys. **16**, 043005 (2014)

Q 41.6 Thu 12:30 e001

Integrated photonics for quantum communications in space — Ömer Bayraktar[1], •Jonas Pudelko[1], Winfried Boxleitner[2], Christoph Pacher[2], Gerd Leuchs[1], and Christoph Marquardt[1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Austrian Institute of Technology, Vienna, Austria

The limited range of quantum key distribution (QKD) in fiber based systems led to several projects aiming for the development of a satellite based QKD infrastructure. Photonic integrated circuits (PICs) are a convenient way to implement all necessary optical functions, while meeting the stringent demands on size, weight and power in satellite missions.

In this work, we present our payload designed for the demonstration of integrated quantum communication technology in space and its first tests. It is based on two Indium-Phosphide PICs implementing a source for modulated weak coherent states as well as a quantum random number generator (QRNG) based on homodyne measurements of the quantum mechanical vacuum state. The whole system is implemented on a 10 cm x 10 cm PCB including all electronics and processing units, while also being compatible to the CubeSat standard.

These developments will be tested as part of the CubeSat mission

QUBE.

Q 41.7 Thu 12:45 e001

Orchestrating parametric down conversion temporal modes
— •Jano Gil Lopez, Vahid Ansari, Benjamin Brecht, and Christine Silberhorn — Paderborn Universität, Warburgerstr. 100 33098 Paderborn

Photon temporal modes (TM) are a powerful tool for quantum information science (QIS). They span a high-dimensional Hilbert space, which is compatible with spatially single-mode fibres. QIS can benefit from such high-dimensional spaces; they provide an increase in the security of quantum key distribution as well as in the information capacity of photons, while allowing for the utilisation of off-the-shelf telecommunication components. These advantages can be improved further, if the distribution of TMs is tailored to be equally distributed over a controlled number of effective modes, thereby producing maximally entangled states. We implement an engineered parametric down conversion source of controlled TM bi-photon states with equally-weighted mode distribution. The states are characterised through joint spectral intensity and second order correlation measurements. We demonstrate the generation of maximally entangled states in up to six dimensions, where the dimensionality is limited only by experimental imperfections.