FM 18: Quantum Networks: Interfaces & Hybrid Systems

Time: Monday 16:30–18:30 Location: 1015

Invited Talk FM 18.1 Mon 16:30 1015

Generation of strongly correlated photons using nanofiber-coupled atoms — Adarsh Prasad[1], Jakob Hinney[1], Klemens Hammerer[2], Sahand Mahmoodian[2], Samuel Rind[1], Philipp Schneeweiss[1,3], Anders S. Sørensen[4], Jürgen Volz[1,3], and •Arno Rauschenbeutel[1,3] — [1]Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria — [2]Institute for Theoretical Physics, Institute for Gravitational Physics (Albert Einstein Institute), Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Department of Physics, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [4]Center for Hybrid Quantum Networks (Hy-Q), Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen, Denmark

Typical schemes for generating correlated states of light require a highly nonlinear medium strongly coupled to an optical mode. Such approaches are often impaired by unavoidable dissipative processes which reduce the nonlinearity and cause photon loss. Here, we experimentally demonstrate the opposite approach, where a highly dissipative, weakly coupled medium can be harnessed to generate and study strongly correlated states of light. Specifically, we show that light transmitted through an ensemble of atoms that weakly couple to the optical mode of an optical nanofiber exhibits antibunched or bunched photon statistics depending on the optical depth of the atomic ensemble. This opens a new avenue for generating nonclassical states of light and for exploring photon correlations in non-equilibrium systems using a mix of nonlinear and dissipative processes.

FM 18.2 Mon 17:00 1015

Towards a Suburban Quantum Network Link — •Tim van Leent[1], Robert Garthoff[1], Kai Redeker[1], Matthias Bock[2], 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 on observing atom-photon entanglement between a Rubidium 87 atom and a telecom photon over 10 km optical fiber with a fidelity of 85%. For this purpose, we use quantum frequency conversion, where the spontaneously emitted photon at 780 nm is mixed with a strong pump field at 1600 nm inside a nonlinear waveguide crystal in a Sagnac-type interferometer configuration [1,2]. The atomic coherence time is extended to hundreds of μs by suppressing magnetic field fluctuations with a guiding field. Installing frequency conversion for the second atom will allow to generate atom-atom entanglement on a suburban scale [3].

[1] M. Bock et al., Nat. Comm. **9**, 1998 (2018)
[2] R. Ikuta et al., Nat. Comm. **9**, 1997 (2018)
[3] W. Rosenfeld et al., Phys. Rev. Lett. **119**, 010402 (2017)

FM 18.3 Mon 17:15 1015

Device-indepedent certification of quantum network link — •Xavier Valcarce[1], Jean-Daniel Bancal[1], Kai Redeker[2], Pavel Sekatski[1], Wenjamin Rosenfeld[3,2], and Nicolas Sangouard[1] — [1]Quantum Optics Theory Group, Universität Basel, CH-4056 Basel, Switzerland — [2]Department fur Physik, Ludwig-Maximilians-Universität, 80797 Munchen, Germany — [3]Max-Planck-Institut fur Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, German

Device-independent characterization, also known as self-testing, provides a certification of devices from the result of a Bell test that is suitable for a wide range of applications. We here show advantages and recently derived limits of CHSH self-test, as well as how it can be used in an elementary link of a quantum network. Being based on a Bell test free of detection and locality loopholes, our certification is fully device-independent, that is, it does not rely on a knowledge of how the devices work. This guarantees that our link can be integrated in a quantum network for performing long-distance quantum communications with security guarantees that are independent of the details of the actual implementation.

FM 18.4 Mon 17:30 1015

grAl SQUID resonators for magnetomechanical coupling — •Christian Markus Florian Schneider[1,2], Mathieu Juan[2], David Zöpfl[1,2], and Gerhard Kirchmair[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Innsbruck, Austria

Granular Aluminum (grAl) has been proven to be an ideal material for magnetic coupling. The high critical field of this dirty superconductor allows operation in 100 - 500 mT magnetic fields. Recent experiments have further demonstrated high coherences of grAl resonators and qubits. We implement a superconducting quantum interference device (SQUID) made out of grAl constriction junctions to construct a flux sensitive grAl resonator. By placing a ferromagnetic cantilever on top of the SQUID loop, we achieve a strong magnetomechanical coupling. This approach could allow us to enter the strong single photon coupling regime between a macroscopic mechanical system and superconducting circuits - a milestone in the field of cavity optomechanics.

FM 18.5 Mon 17:45 1015

Simple smooth pulses for fast dispersive cavity and network measurements — •Felix Motzoi[1,2], Lukas Buchmann[1], and Christian Dickel[3] — [1]Aarhus University — [2]Forschungszentrum Jülich, Peter Grünberg Institute — [3]Kavli Institute of Nanoscience, Delft University of Technology,

We demonstrate a quantum non-demolition measurement pulse shaping technique that allows for arbitrarily fast dispersive, single-quadrature measurements using cavities and quantum networks. For single-qubits, current cQED measurements are limited to the 99% fidelity range due to relaxation for long durations, traded off with cavity leakage at shorter times. These effects can be suppressed using simple smooth readout shapes, related to unitary DRAG transmon pulses. Here, an exact open-system solution is found for arbitrarily many measurement modes, network elements, and mea- sured states. It also generalizes to any linear measurement apparatus, and maximizes efficiency by retaining information in a single field quadrature. Beyond single cavities, the technique generalizes to more complex networks, such as using Purcell filter cavities (where depopulating is a major chal- lenge), cascaded cavity systems (e.g for fast remote entanglement generation), continuous-variable field operations, or (non-dispersive) single-photon networks.

FM 18.6 Mon 18:00 1015

Quantum synchronization — •Christoph Bruder — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel

Experimental progress in optomechanical systems, in trapped-ion setups, and in superconducting circuit-QED architectures has motivated the study of synchronization in *quantum systems*. This gives rise to a number of conceptual questions, like the relation between quantum synchronization and the generation of entanglement, and leads to paradoxial phenomena like the quantum synchronization blockade [1]. Recently, we have addressed the question what is the smallest possible system that can be synchronized. We have shown that whereas qubits cannot be synchronized due to the lack of a limit cycle, a single spin 1 can be phase-locked to a weak external signal of similar frequency and exhibits all the standard features of the theory of synchronization [2]. We have also studied synchronization in a two-node spin-1 network and have shown that phase locking between these quantum oscillators can be achieved even for limit cycles that cannot be synchronized to an external semi-classical signal [2]. Finally, we have explored the relation between quantum synchronization and the generation of entanglement.
[1] N. Lörch, S.E. Nigg, A. Nunnenkamp, R.P. Tiwari, and C. Bruder, Phys. Rev. Lett. **118**, 243602 (2017). [2] A. Roulet and C. Bruder, Phys. Rev. Lett. **121**, 053601 (2018); *ibid.*, 063601 (2018).

FM 18.7 Mon 18:15 1015

A SiO2 Photonic Platform for the On-Chip Integration of Quantum Emitters — •Florian Böhm[1], Niko Nikolay[1], Christoph Pyrlik[2], Jan Schlegl[2], Andreas Thies[2], Andreas Wicht[2], and Oliver Benson[1] — [1]AG Nanooptik & IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

An important prerequisite for future nanophotonic devices is the scalable on-chip integration of single photon emitters.

Here we present the deterministic integration of a single solid-state qubit, the nitrogen-vacancy (NV) center, with a photonic platform consisting exclusively of SiO2 grown thermally on a Si substrate. The platform stands out by its ultra-low fluorescence and the ability to produce various passive structures such as high-Q microresonators and mode-size converters [1].

An numerically optimized structure for the efficient coupling of a dipole emitter to the guided mode was integrated with a preselected NV emitter using an atomic force microscope. We then could demonstrate the on-chip excitation of the quantum emitter as well as the coupling of single photons to the guided mode of the integrated structure [2].

Our approach shows the potential of this platform as a robust nanoscale interface of on-chip photonic structures with solid-state qubits.

[1] Pyrlik, C. et al., IEEE Phot. Technol. Lett. (2019): 31 479-82
[2] Böhm, F. et al., New Journal of Physics 21.4 (2019): 045007.