Q 69: Quantum Information: Quantum Computing and Communication IV

Time: Friday 14:30–16:00 Location: e214

Q 69.1 Fri 14:30 e214

Quantum correlations in microwave frequency combs —

•Thomas Weissl[1], Erik Tholén[2], Daniel Forchheimer[1,2], and David B. Haviland[1] — [1]KTH- Royal Institute of Technology, 106 91 Stockholm, Sweden — [2]Intermodulation Products AB, 823 93 Segersta Sweden

Multipartite entangled states in frequency combs have possible application as a universal resource for continuous wave quantum computation. In the optical frequency range, bipartite entanglement between different frequencies in frequency combs generated by parametric down-conversion has been demonstrated [1,2]. In comparison with optical systems, superconducting microwave circuits can be designed with much stronger coupling strength between (artificial) atoms and the electromagnetic field, as well as much stronger non-linearity that couple the various tones of a frequency comb. We present a method to create and to measure quadrature response of a microwave frequency comb, based on up- and down-conversion of a digitally synthesized and digitally demodulated low-frequency comb. The method works with as many as 42 frequencies. When a non-linear superconducting resonator is pumped with the GHz comb, the tones in the comb become correlated due to the strong non-linearity. We show preliminary results on the analysis of these correlations. [1] J. Roslund et al., Nature Photonics 8, 109-112 (2014) [2] M. Chen et al., PRL 112, 120505 (2014)

Q 69.2 Fri 14:45 e214

A two-photon quantum gate —

•Bastian Hacker, Stephan Welte, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Optical photons are excellent carriers of quantum information with well established technologies for their creation, manipulation and detection. For the purpose of photonic quantum information processing, it is essential to achieve non-linear interactions between them. Unfortunately, the non-linearities in conventional optical materials are too weak for this at the low light powers of single photons. A way to mediate strong interactions is to use a single atom inside a high-finesse cavity, which couples to the light field of impinging photons. According to an old but not yet implemented proposal [1] this can be employed to realize a two-photon quantum gate between successively reflected photons. Our current setup is well-suited to achieve this long-standing goal. We will discuss a potential implementation in our setup and will report on the current status of the experiment.

[1] L.-M. Duan and H. J. Kimble, Phys. Rev. Lett. 92, 127902 (2004)

Q 69.3 Fri 15:00 e214

Higher-efficiency lower-noise Raman quantum memory —

Sarah Thomas[1,2], Joseph Munns[1,2], •Benjamin Brecht[1], Patrick M. Ledingham[1], Dylan J. Saunders[1], Joshua Nunn[1], and Ian A. Walmsley[1] — [1]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [2]QOLS, Blackett Laboratory, Imperial College London, London SW7 2BW, UK

Raman quantum memories in warm atomic vapour promise excellent applicability in future quantum networks, owing to their experimental simplicity and large time-bandwidth product. However, they suffered from intrinsic four-wave noise and moderate efficiencies, which ultimately limited their usefulness.

Here, we report on experimental progress that allowed us to demonstrate on the one hand high noise suppression with only 0.015 noise photons per pulse, and on the other hand high memory efficiency of up to 60% in a warm Cs vapour Raman memory. These steps facilitate the future realization of a genuine quantum memory operating on single photons.

Q 69.4 Fri 15:15 e214

A quantum repeater scheme with single atoms in telecom-wavelength cavities —

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Single atoms in optical cavities are a promising system to implement a quantum repeater, which can overcome the limitations arising from the exponential decrease of transmission with distance in optical fibers. For such a repeater to be useful, the entanglement generation between remote nodes must be mediated by photons at a telecom wavelength. Unfortunately, the ground states of easily laser cooled atoms show no suitable transitions at these wavelengths. As a solution, we propose a scheme for entanglement generation between a single atom and a telecom photon based on cascaded transitions from higher excited states of alkali atoms [1]. Owing to a modification of the atomic emission by means of crossed cavities, the telecom photons are heralded and highly indistinguishable. This is essential for a high-fidelity photonic Bell state measurement performed to provide entanglement between remote nodes. We will also discuss the prospects of extending this scheme to a simple quantum repeater that can generate entangled pairs faster than using direct transmission using state-of-the-art technology.

[1] Uphoff *et al.*, arXiv:1507.07849 (2015)

Q 69.5 Fri 15:30 e214

A two-color polarization-entangled photon pair source for applications in hybrid quantum architectures —

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Entangled photon pairs can be exploited to realize a quantum repeater [1] which is crucial for a long distant quantum communication. However, entangled photon pairs can also be used for establishing entanglement between dissimilar systems to create quantum hybrid structures.

We set up a two-color polarization-entangled parametric down conversion source in a folded-sandwich geometry [2] to create entangled photon pairs. This setup can generate highly non-degerate photons with wavelengths at the Cs D1 line (894.3 nm) and the telecom O-band (1313.1 nm), while obtaining an entanglement fidelity of $F = (75 \pm 2)\%$ [3].

The long term goal is to establish a hybrid quantum interface where the photon pair source is used to demonstrate teleportation [1] of the electronic state of a semiconductor quantum dot [4] to photons at telecom wavelength.

[1] Bussières F., et al. Nature Photonics 8, 775-778 (2014)
[2] Steinlechner F., et al. Optics Express 21, 11943 (2013)
[3] Dietz O., et al. Applied Physics B accepted
[4] Gao W.B., et al. Nature Comm. 4, 2744 (2013)

Q 69.6 Fri 15:45 e214

Parsing Squeezed Light into Polarization Manifolds —

•Christian R. Müller[1,2,3], Lars S. Madsen[3], Andrei Klimov[4], Luis L. Sánchez-Soto[5,1,2], Gerd Leuchs[1,2], Christoph Marquardt[1,2,3], and Ulrik L. Andersen[3,1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany. — [2]Department of Physics, University of Erlangen-Nuremberg (FAU), Germany. — [3]Department of Physics, Technical University of Denmark, Lyngby, Denmark. — [4]Departamento de Física, Universidad de Guadalajara, Mexico. — [5]Departamento de Óptica, Facultad de Física, Universidad Complutense, Madrid, Spain.

We investigate polarization squeezing in squeezed coherent states with different amplitudes [1]. In contrast to the traditional characterization based on the full Stokes parameters [2,3], we experimentally characterize the polarization properties of each photon number manifold individually. This method provides a substantially richer description and allows to investigate the otherwise separate regimes of spin squeezing, of quadrature squeezing as well as of the intermediate regime in a single experiment. Intuitive insight into the nature of the different regimes is given via the Husimi Q function [4,5] of the polarization states with different coherent amplitudes.

[1] C. R. Müller et al., arXiv:1511.03553 [quant-ph] (2015)
[2] Ch. Marquardt et al., Phys. Rev. Lett. 99, 220401 (2007)
[3] C. R. Müller et al., New J. Phys. 14, 085002 (2012)
[4] L. L. Sánchez-Soto et al., J. Phys. B 46, 104011 (2013)
[5] P. de la Hoz et al., Phys. Rev. A 88, 063803 (2013).