Q 25: Quantum Information: Quantum Communication I

Time: Wednesday 10:30–12:30 Location: E 214

Q 25.1 We 10:30 E 214

Atmospheric quantum communication with continuous polarization variables — •Bettina Heim[1,2], Dominique Elser[1,2], Claudia Dürr[1,2,3], Tim Bartley[1,2,4], Christoffer Wittmann[1,2], Denis Sych[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Erlangen — [2]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg — [3]Hochschule für Angewandte Wissenschaften - FH München — [4]Clarendon Laboratory, University of Oxford

We present experimental work on the demonstration of free space quantum communication using continuous polarization variables. In a prepare-and-measure setup, binary-encoded coherent polarization states are transmitted through an atmospheric quantum channel of 100m. The signal states are measured using homodyne detection with the help of a local oscillator (LO) occupying the same spatial mode as the signal. Thus, the interference of signal and LO is excellent. Additionally, the LO acts as spatial and spectral filter, which allows for unrestrained daylight operation. Currently, we are working on expanding the link distance to 1.6km in an urban environment. Influences of the turbulent atmosphere resulting in spatial beam jitter could cause attenuation as well as intensity noise at the detector [1]. We investigate these potentially harmful effects and present methods to compensate for them.

[1] B. Heim et al., Applied Physics B, published online http://dx.doi.org/10.1007/s00340-009-3838-8

Q 25.2 We 10:45 E 214

Coherent optical memory with GHz bandwidth — •Klaus Reim[1], Joshua Nunn[1], Virginia Lorenz[2], Ben Sussman[3], Ka Lee[1], Nathan Langford[1], Dieter Jaksch[1], and Ian Walmsley[1] — [1]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [2]Department of Physics, University of Delaware, Newark, DE 19716, USA — [3]National Research Council of Canada, Ottawa, Ontario K1A 0R6, Canada

Quantum memories, capable of controllably storing and releasing a light pulse, are a crucial component for quantum computers and quantum communications. So far, quantum memories — either ensemble based or single absorbers — have operated with bandwidths of kHz or MHz. Robust, higher bandwidth (faster) quantum memories operating with very short laser pulses are a prerequisite for reliable and broadband quantum technology devices that allow for high-speed quantum processing and high data transfer rates in completely secure quantum networks. Here we report the coherent storage and retrieval of subnanosecond low intensity light pulses with spectral bandwidths exceeding 1 GHz in cesium vapor. The memory interaction takes place via a far off-resonant two-photon transition in which the memory bandwidth is dynamically generated by the strong control field. This makes the memory robust to environmental noise and allows an increase of speed by a factor of almost 1000 compared to existing quantum memories. The memory works with a total efficiency of 15 % and its coherence is demonstrated by directly interfering the stored and retrieved pulses.

Q 25.3 We 11:00 E 214

Entanglement properties of optical coherent states under amplitude damping — •Ricardo Wickert[1,2], Nadja Kolb Bernardes[1,2], and Peter van Loock[1,2] — [1]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light — [2]Institute of Theoretical Physics I, Universität Erlangen-Nürnberg

Quantum Error Correction (QEC) codes aim to protect the information in fragile quantum states by encoding them into a larger Hilbert space; Entanglement Purification (EP) protocols aim to distill higher entanglement from a number of identically prepared copies of lower entanglement. It is known that QEC codes can be recast as EP schemes and vice-versa [1]. Through concurrence, we characterize the distillation capabilities of a known error correcting code for the amplitude damping channel [2]. An upper bound is established considering the non-orthogonality of the coherent-state basis [3].

[1] C. Bennett et al., Phys. Rev. A 54, 3824 (1996)
[2] S. Glancy et al., Phys. Rev. A 70, 22317 (2004)
[3] R. Wickert at al., in preparation (2009)

Q 25.4 We 11:15 E 214

Hybrid quantum repeater with imperfect memories — •Nadja Kolb Bernardes[1,2] and Peter van Loock[1,2] — [1]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light — [2]Institute of Theoretical Physics I, Universität Erlangen-Nürnberg

We discuss the efficiency of quantum error correction (QEC) codes for quantum repeaters based on atomic qubit-entanglement distribution through optical coherent-state communication (hybrid quantum repeater [1]). In particular, we consider nonlocal distributions of two-qubit entangled memory pairs based on unambiguous discrimination measurements of coherent states [2]. The conditionally prepared, entangled states will be subject to local memory dephasing, which is to be suppressed by means of QEC codes. For this realistic case of imperfect memories, we explore the regimes in which the encoding pays off and where it does not. Our model gives the minimum requirements on the local memories, unencoded or encoded,in order to outperform direct transmissions or quantum relay approaches.

[1]P. van Loock, T. D. Ladd, K. Sanaka, F. Yamaguchi, Kae Nemoto, W. J. Munro, and Y. Yamamoto, Phys. Rev. Lett. 96, 240501 (2006).
[2]P. van Loock,N. Lütkenhaus, W. J. Munro, Kae Nemoto,Phys. Rev. A 78, 062319 (2008).

Q 25.5 We 11:30 E 214

Displacement Controlled Photon Number Resolving Detector for Optical Coherent States. — •Christoffer Wittmann[1,2], Ulrik L. Andersen[1,2,3], Masahiro Takeoka[4], Denis Sych[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University of Erlangen-Nuremberg, Erlangen, Germany — [3]Department of Physics, Technical University of Denmark, Lyngby, Denmark — [4]National Institute of Information and Communications Technology (NICT), Tokyo, Japan

Optimal discrimination of non-orthogonal quantum states is one of the fundamental tasks in quantum detection theory. For weak coherent states, the standard detection schemes are not able to achieve error free sensitivity in principle. We propose and experimentally realize a novel detection strategy for the discrimination of two optical coherent states [1]. The scheme is then extended for probabilistic discrimination by accepting also inconclusive measurement outcomes. We show that our discrimination strategy based on an optimized displacement and a photon number resolving measurement, allows for smaller error rates than the homodyne strategy [2] and demonstrate this experimentally [3]. [1] C. Wittmann et al., Phys. Rev. Lett. 101, 210501 (2008) ; [2] C. Wittmann et al., Jour. Mod. Opt., published online (arXiv:0905.2496v1 [quant-ph]), (2009); [3] C. Wittmann et al., arXiv:0906.2859 [quant-ph], (2009).

Q 25.6 We 11:45 E 214

Quantum Random Numbers Based on the Vacuum State — •Christian Gabriel[1,2], Christoffer Wittmann[1,2], Denis Sych[1,2], Ruifang Dong[1,2], Wolfgang Mauerer[3], Ulrik L. Andersen[1,2,4], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Siemens AG, Corporate Technology, Otto-Hahn-Ring 6, 81739 Munich, Germany — [4]Department of Physics, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

We present a random number generator (RNG) based on the measurement of a quadrature amplitude of a pure quantum state, namely the vacuum state. By determining the entropy of the system and applying a suitable one-way function it can be assured that the random numbers originate from quantum noise solely and classical noise sources have no influence on the generated bit sequences. As quantum mechanics postulates completely random measurement outcomes, the generated numbers are truly random. The optimized information capacity of the system is determined, leading to increased bit generation speeds. Furthermore, the random numbers are assured to be unique, i.e. they cannot be known by an adversary. This is guaranteed by the measurement of a pure state. This feature makes our RNG advantageous to many earlier generators as it offers not only a truly random but also a secure generation of bits.

Q 25.7 We 12:00 E 214

Experimental results for quantum state discimination — •Gesine Steudle, Sebastian Knauer, Ulrike Herzog, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nano-Optik

The discrimination of quantum states [1,2] is a fundamental part of quantum communication and quantum crytography. Particularly, the discrimination of two non-orthogonal quantum states can performed unambiguously only at the expense of admitting inconclusive results. In this contribution we present an experimental setup for optimal unambiguous discrimination between two non-orthogonal mixed states [3,4]. We show experimental results of state discrimination on the single photon level. A first approach utilizes attenuated light from a laser light source whereas a second approach will implement a true single photon source. The latter is based on Stranski-Krastanow-grown InAs dots which are embedded in a pin-junction to establish electrical pumping [5].

[1] J. A. Bergou et al., Lect. Notes Phys. 649, 417 (2004)
[2] S. M. Barnett and S. Croke, Adv. Opt. Photon. 1, 238 (2009)
[3] U. Herzog, Phys. Rev. A 75, 052309 (2007)
[4] U. Herzog and O. Benson, J. Mod. Opt. 56, 1362 (2009)
[5] A. Lochmann et al., Electron. Lett. 42, 774 (2006)

Q 25.8 We 12:15 E 214

Concentration of Phase Information — •Christian Müller[1,2], Mario Usuga[3,1], Christoffer Wittmann[1,2], Petr Marek[4], Radim Filip[4], Ulrik L. Andersen[3,1], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Bau 24, 91058 Erlangen, Germany — [2]Institute of Optics, Information und Photonics, University of Erlangen-Nuremberg, Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Department of Physics, Technical University of Denmark, Building 309, 2800 Kgs. Lyngby, Denmark — [4]Department of Optics, Palacký University, 17. Listopadu 50, Olomuc 77200, Czech Republic

The phase of coherent states is a degree of freedom that plays an important role in the field of quantum information and communication. The accessible phase information suffers under the influence of attenuation and it is hence desirable to be able to amplify phase information. Linear amplifiers fail to fulfill this task [1], so that more sophisticated schemes are needed . Previous proposals [2] had the drawback of relying on single photon sources and high interferometric stability, making implementation hardly feasible. We show in theory [3] and experiment, that a novel probabilistic scheme is capable of increasing the phase information. It is based purely on the addition of thermal noise and subsequent heralding, conditioned on the result of a photon number resolving detector.

[1] H.A. Haus and J.A. Mullen Phys. Rev. 128.2407 (1962)
[2] T.C. Ralph and A.B. Lund (2008) arXiv:0809.0326 [quant-ph]
[3] P. Marek and R. Filip (2009) arXiv:0907.2402[quant-ph]