Q 24: Quanteninformation: Repeater und Speicher

Time: Tuesday 10:30–12:30 Location: V7.02

Group Report Q 24.1 Tue 10:30 V7.02

Hybrid quantum communication and computation — •Peter van Loock — Institute of Theoretical Physics I, Univ. Erlangen-Nuremberg, Erlangen, Germany — OQI Group, MPL, Erlangen, Germany

We give an overview of our group's investigations into optical hybrid approaches to quantum communication and information processing, in which discrete and continuous degrees of freedom are exploited at the same time. These include various notions and applications such as hybrid entanglement, hybrid quantum repeaters for long-distance quantum communication, and small-scale quantum logic using hybrid resources. Our most recent emphasis is on the issue of imperfect memories in a quantum repeater and the choice between entanglement distillation and quantum error correction, as well as on the possibility of implementing nonlinear gates using both Gaussian and non-Gaussian resource states.

Q 24.2 Tue 11:00 V7.02

Measurement-based quantum repeaters — •Michael Zwerger[1], Wolfgang Dür[1], and Hans Briegel[1,2] — [1]Institut für theoretische Physik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation der österreichischen Akademie der Wissenschaften, Innsbruck, Österreich

We present a measurement-based implementation of the quantum repeater. We envision special purpose processors at each repeater node, which integrate entanglement swapping and purification into a single step. This measurement-based integration leads to significantly improved noise thresholds. It is shown that one or two purification steps per repeater level are sufficient and that with seven levels in total one can reach the international scale.

Q 24.3 Tue 11:15 V7.02

Long distance continuous-variable quantum communication — •Imran Khan[1,2], Christoffer Wittmann[1,2], Nitin Jain[1,2], Nathan Killoran[3], Norbert Lütkenhaus[3], 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, Erlangen — [3]Institute of Quantum Computing, Waterloo CA

Quantum correlations are at the heart of all quantum communication. In experimental data, such correlations can be investigated using the concept of effective entanglement [1, 2]. In a former experiment, we have witnessed the distribution of effective entanglement over a 2 km fiber channel [3]. We now present our results on the quantification of effective entanglement over a 40 km fiber channel. This long distance sets, to our knowledge, a new record for continuous-variable quantum communication.

In our system, non-orthogonal quantum states are sent through a fiber-based quantum channel. The signal is detected using simultaneous homodyne detection of conjugate quadratures. By analyzing the excess noise and the received signal amplitudes , we are able to estimate the amount of distributed effective entanglement [4], which provides insight into the limits of our experimental setup.

[1] J. Rigas et al., Phys. Rev. A 73, 012341 (2006) [2] H. Häseler et al., Phys. Rev. A 77, 032303 (2008) [3] C. Wittmann et al., Opt. Express 18, 4499 (2010) [4] N. Killoran et al., Phys. Rev. A 83, 052320 (2011)

Q 24.4 Tue 11:30 V7.02

Quantum Interference of Photons from Two Independent Single-Atom Quantum Memories — •Christian Nölleke, Carolin Hahn, Andreas Reiserer, Andreas Neuzner, Eden Figueroa, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Neutral atoms trapped in optical cavities are capable of fully controlled single photon generation and storage, making them universal nodes in large-scale quantum networks. One way to distribute quantum information among the entire network is to make use of interference between photons from different nodes. Fundamentally, two indistinguishable single photons combined on a beam splitter will coalesce and leave the beam splitter from the same output port. This quantum interference effect is at the heart of quantum information protocols like linear optical quantum-computing, generation of remote-entanglement and quantum teleportation. We demonstrate interference of single photons emitted from two independently operated atom-cavity systems at remote locations. We characterize the two-photon interference in a time-resolved manner and present prospects towards teleportation of quantum states between neutral atoms.

Q 24.5 Tue 11:45 V7.02

Electromagnetically induced transparency (EIT) in a realistic atomic quantum memory for light — •Oxana Mishina[1], Michael Scherman[1], Pietro Lombardi[1,3], Alberto Bramati[1], Alexandra Sheremet[2], Dmitriy Kupriyanov[2], Julien Laurat[1], and Elisabeth Giacobino[1] — [1]Laboratoire Kastler Brossel, Université Pierre et Marie Curie, Ecole Normale Supérieure and CNRS, Paris, France — [2]Department of Theoretical Physics, State Polytechnic University, St.-Petersburg, Russia — [3]European Laboratory for Non-Linear Spectroscopy, University of Florence, Sesto-Fiorentino (Firenze), Italia

In this work we identify a process detrimental for the EIT based quantum memory in alkali gases. Our main tool is a theoretical model we developed for the EIT in a Lambda scheme with more than one excited level. Such a multiple Lambda-type interaction arises due to the hyperfine splitting typical for the alkali atoms and rare earth ions currently used for quantum memory experiments. Using this model we show that the presence of extra excited states may strongly damage the EIT if inhomogeneous broadening is comparable with the excited level spacing. We also proposed a method to enhance the EIT in an alkali vapor and successfully demonstrated it experimentally showing a good agreement with theoretical predictions. Furthermore we apply our theory to optimize a quantum memory performance in a cold atomic cloud. We believe our theory captures the general phenomena ruling the efficiency of EIT based quantum memories and it could be adapted to improve the performance of other EIT based systems.

Q 24.6 Tue 12:00 V7.02

Efficient, Narrowband PPKTP Source for Polarization Entangled Photons — •Siddarth.K. Joshi[1], Chen Ming Chia[1], Felix Anger[3], and Christian Kurtsifer[1,2] — [1]Center for Quantum Technologies, Singapore — [2]Physics Dept., National University of Singapore, Singapore — [3]Ludwig-Maximilians-Universität, München

The underlying protocols behind many applications often require a complete detection of almost all entangled photons to outperform their classical counterparts. While photodetectors have come close to unit detection efficiency (>95%) [1], photon pair sources seem to be the current bottleneck in applications requiring a high efficiency.

We present a high efficiency photon pair source which addresses this issue. A pump laser (λ= 405 nm) is focused into a type II PPKTP crystal, where it undergoes spontaneous parametric down-conversion into signal and idler modes collinear with the pump mode, maximizing the mode overlap between the target modes. To obtain polarization entangled photons, we pump the crystal from both directions and interferometrically combine the two downconverted paths in a Sagnac interferometer. We experimentally optimized the focusing parameters for a maximal efficiency and we observe uncorrected efficiencies > 35%. This efficiency is the value obtained from uncorrected count rates from Silicon Avalanche Photo Diodes (Si APDs) of 49.7% $\pm$ 2% and 48.1% $\pm$2% connected directly to the single mode fibers supporting the downconverted photons. No corrections are applied. Our source efficiency (71%) thus starts to reach the threshold for a loophole free Bell test.

[1] A.E. Lita, A.J. Miller, S.W. Nam,Opt. Express 16, 3032 (2008)

Q 24.7 Tue 12:15 V7.02

Demonstration of QKD with a compact and mobile single photon source based on defect centers in diamond — Matthias Leifgen, Tim Schröder, •Robert Riemann, and Friedemann Gädeke — HU Berlin, Inst. für Physik, AG Nano-Optik, Newtonstr. 15, 12489 Berlin

Quantum key distribution (QKD) is an absolute secure way of distributing keys for secure data encryption. Experimental realizations have become much more mature recently. Mostly, attenuated laser pulses are used as light source rather than true single photons, which would be the obvious choice theoretically. This is due to various difficulties of producing single photons efficiently. Single photons, if produced efficiently and at a high rate, would be the light source of choice for QKD. Furthermore, they provide inherent security from the so-called photon number splitting attack of an eavesdropper. Here we demonstrate QKD with single photons from a single nitrogen-vacancy center inside a nanodiamond. The overall efficiency of the single photon source we use, taking only detected photons per excitation pulse into consideration, is about 2% and relatively high photon rates can be achieved. This efficiency is comparable to attenuated laser pulses (without decoy states), which have to be attenuated strongly to provide security. We implement the BB84 protocol and use the polarization of the photons for encryption. The setup is designed to account for the relatively broadband single photons (FWHM 100nm) generated by the NV centers. The compact and mobile single photon source is ready to use and can easily be integrated into the QKD setup.