Q 68: Quantum information: Photons and nonclassical light II

Time: Friday 14:00–16:00 Location: F 142

Q 68.1 Fri 14:00 F 142

Interfacing UV and telecommunication wavelengths — •Helge Rütz, Hubertus Suche, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

While trapped ions and other promising candidates for stationary qubit systems in quantum information applications can only be addressed in the UV and visible spectral region, efficient long distance photonic state transfer is restricted to telecommunication wavelengths. This spectral gap can however be bridged by Frequency Conversion.

Here, we focus on a coherent Frequency Conversion interface for quantum states of light between trapped ions at 369.5 nm and telecommunication wavelengths around 1310 nm. A single-pass quasi-phasematched second-order nonlinear interaction with a strong cw-pump field at 515 nm in a periodically poled waveguide allows for the upconversion of infrared- as well as the downconversion of UV-light. Conceptual and experimental details of this interface are given and its potential for quantum information technology is discussed.

Q 68.2 Fri 14:15 F 142

Click statistics of strongly illuminated systems of on-off detectors — •Johannes Kröger[1], Thomas Ahrens[1], Jan Sperling[2], Boris Hage[3], and Heinrich Stolz[1] — [1]AG Halbleiteroptik, Institut für Physik, Universität Rostock — [2]AG Theoretische Quantenoptik, Institut für Physik, Universität Rostock — [3]AG Experimentelle Quantenoptik, Institut für Physik, Universität Rostock

We present experimental results from measurements with systems of on-off detectors, i. e. an array of single photon detectors (SPDs), where the examined intensities of the incident coherent light field include mean photon numbers per SPD being significantly higher than one. Thus probabilities for multiple photon events on one SPD become eminent. This is contrary to the common method of preparing the experimental setup in a way that the probability of detecting one photon per single detector is $\ll 1$. We compare the obtained click statistics, which include up to 80 distinguishable simultaneous clicks, with the theoretically predicted click statistics, based on the calculations of J. Sperling, W. Vogel and G.S. Agarwal, for the case of a coherent light field. These calculations and our experimental verification render it possible to obtain useful information about the state of a light field, while the detector system is strongly illuminated, thus minimizing undesired effects due to attenuation of the intensity.

Q 68.3 Fri 14:30 F 142

A Versatile Photon Pair Source for Quantum Circuits — •Vahid Ansari, Georg Harder, Benjamin Brecht, and Christine Silberhorn — Applied Physics, University of Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

Efficient generation of indistinguishable single photons in pure quantum states is key to many applications in quantum information processing. We present an ultrafast pulsed parametric down conversion (PDC) source based on a degenerate type-II PDC in a PP-KTP waveguide at telecommunication wavelengths. As such, our highly efficient source generates close to perfect single-mode photon pairs with indistinguishable mode properties. As a measure of indistinguishability we observe Hong-Ou-Mandel interference between signal and idler with a visibility of 95.6%, without narrow-band filtering. We further demonstrate the purity of signal and idler by HOM interference between signal/idler and a weak coherent field. The results are in excellent agreement to the spectral and modal characterization as well as to theory.

Q 68.4 Fri 14:45 F 142

Phase-locked indistinguishable flying qubits from a quantum dot — •Carsten H. H. Schulte, Clemens Matthiesen, Martin Geller, Claire Le Gall, Jack Hansom, Zhengyong Li, and Mete Atatüre — Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

Optically active spins in self-assembled InAs quantum dots (QDs) represent one of many promising qubit candidates for quantum information processing. The entanglement of individual spins constitutes the smallest unit of a distributed quantum network and can be realised through quantum interference of flying qubits, i.e. photons emitted by the QD. For this, ideally indistinguishable photons from separate QDs are needed, the generation of which has proved challenging due to dephasing of the used optical QD transitions. Resonance fluorescence in the Heitler regime circumvents environment-induced dephasing and delivers single photons with a coherence well above the Fourier transform limit of the QD transition, the spectral shape of the photons being solely tailored by the excitation laser [1]. Using optical heterodyning, we demonstrate that QD photons and exciting laser field are phase-locked on a timescale exceeding 3 seconds. Exploiting this degree of mutual coherence we spectrally shape the emitted photons by modulating the excitation laser. Finally, successively emitted photons generated phase-locked to the excitation laser are proven to be fundamentally indistinguishable in Hong-Ou-Mandel interferometry [2].

[1] Matthiesen *et al.*, Phys. Rev. Lett. **108**, 093602 (2012).
[2] Matthiesen *et al.*, arXiv:1208.1689 [quant-ph] (2012).

Q 68.5 Fri 15:00 F 142

Quantification of nonclassicality — •Melanie Mraz, Jan Sperling, Werner Vogel, and Boris Hage — Universität Rostock, Institut für Physik, Rostock, Deutschland

At the beginning of the 20th century the discussion on physics beyond the classical regime started. This was the hour of birth of quantum physics and, with Einstein's description of the photoelectric effect, of quantum optics. Even the physicists had problems to understand nonclassical quantum phenomena, because of its non-intuitive properties. So, why further struggling?

Nonclassical states have an advantage over classical states for various applications. Only one example is the quantum teleportation which would be unthinkable without nonclassical states. Hence, it is of a fundamental interest to study properties of nonclassical quantum states. It is already possible to say if a state is nonclassical or not, but how can we decide how much nonclassicality is in our system?

We propose a degree of nonclassicality being a nonclassicality measure. It is determined by the decomposition of a quantum state into superpositions of coherent states. On the one hand, coherent states resembles the behavior of a classical harmonic oscillator most closely. On the other hand, the more quantum superpositions of coherent states are needed, the more quantum interferences arise. A method for such a decomposition of quantum states is presented and the degree of nonclassicality is determined for different states. We apply our method to typical nonclassical states, such as the compass state and the squeezed vacuum state.

Q 68.6 Fri 15:15 F 142

Entangling photons via the quantum Zeno effect — •Nicolai ten Brinke, Andreas Osterloh, and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

The quantum Zeno effect describes the inhibition of quantum evolution by frequent measurements. In this talk, we propose a scheme for entangling two given photons based on this effect. We consider a linear-optics set-up with an absorber medium whose two-photon absorption rate $\xi_{2\gamma}$ exceeds the one-photon loss rate $\xi_{1\gamma}$. In order to reach an error probability $P_{\rm error}$, we need $\xi_{1\gamma}/\xi_{2\gamma} < 2P^2_{\rm error}/\pi^2$ [1], which is a factor of 64 better than previous approaches, e.g., [2]. Since typical media have $\xi_{2\gamma} < \xi_{1\gamma}$, we discuss mechanisms for enhancing two-photon absorption as compared to one-photon loss. In particular, we present a mechanism which envisages three-level systems where the middle level is meta-stable (Λ-system). In this case, $\xi_{1\gamma}$ is more strongly reduced than $\xi_{2\gamma}$ and thus it should be possible to achieve $\xi_{2\gamma}/\xi_{1\gamma} \gg 1$. In conclusion, although our scheme poses serious experimental challenges, we find that a two-photon gate with an error probability $P_{\rm error}$ below 25% might be feasible using present-day technology [3].

[1] N. ten Brinke, A. Osterloh, and R. Schützhold, Phys. Rev. A **84**, 022317 (2011).
[2] J. D. Franson, B. C. Jacobs, and T. B. Pittman, Phys. Rev. A **70**, 062302 (2004).
[3] N. ten Brinke, A. Osterloh, and R. Schützhold, arXiv:1212.1309.

Q 68.7 Fri 15:30 F 142

Entanglement distribution by separable states — •Daniela Schulze[1], Christina E. Vollmer[1], Tobias Eberle[1], Vitus Händchen[1], Jaromír Fiurášek[2], and Roman Schnabel[1] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover

and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany — [2]Department of Optics, Palacký University, 17. listopadu 50, 77200 Olomouc, Czech Republic

Distribution of entanglement between two parties - Alice and Bob - is an essential step for most quantum information protocols. Usually, entanglement is distributed directly by exchanging entangled subsystems between the individual parties. However, it has been shown in [1] that it is possible to establish entanglement between two parties by exchanging an ancilla mode C, which is neither entangled with Alice's mode A, nor with Bob's mode B. We report on the experimental realization of a scheme for entanglement distribution by separable states on the basis of continuous variables. Our scheme relies on a specific three-mode Gaussian state where parts of the entanglement structure are initially hidden by correlated noise and later restored via quantum interference.

[1] T. Cubitt, F. Verstraete, W. Dür, and J. Cirac. Separable States Can Be Used To Distribute Entanglement. Physical Review Letters, 91(3):1-4, July 2003.

Q 68.8 Fri 15:45 F 142

Efficient Reconstruction of Qudit Entangled States — •Daniel L. Richart[1,2], Christian Schwemmer[1,2], Wieslaw Laskowski[1,2,3], and Harald Weinfurter[1,2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str.1 D-85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstr. 4, D-80797 München, Germany — [3]Instytut Fizyki Teoretycznej i Astrofizyki, Uniwersytet Gdánski, PL-80-952 Gdánsk, Poland

Qudit states offer significant advantages with respect to qubit states regarding their application in the field of quantum communication and computation. However, the measurement effort necessary to tomographically reconstruct their quantum states scales with $4^{log(d)/log(2)}$ with d denoting the dimension of the qudit state. Here, we present experimental results on the efficient tomographic reconstruction of qudit entangled states with dimensions up to 2x8 using the energy-time degree of freedom [1,2]. Two different methods based on low rank quantum state tomography [3] and on correlation complementarity [4] are compared regarding their efficiency.

[1] J.D. Franson et al., PRL 62, 2205 (1989) [2] D. Richart et al., Appl. Phys. B 106, 543 (2012) [3] D. Gross et al., PRL 105 150401 (2010) [4] W. Laskowski et al., PRL 108, 240501 (2012)