Q 54: Quantum information: Photons and nonclassical light I

Time: Thursday 14:00–16:00 Location: E 001

Group Report Q 54.1 Thu 14:00 E 001

Ultrafast multi-mode quantum optics — •Andreas Christ[1], Benjamin Brecht[1], Georg Harder[1], Vahid Ansari[1], Kaisa Laiho[1], Andreas Eckstein[2], and Christine Silberhorn[1] — [1]Applied Physics, University of Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]Equipe DON, Laboratoire Matériaux et Phénomènes Quantiques, Université Paris Diderot-Paris 7

Ultrafast single-mode quantum states of light constitute a basic building block for quantum enhanced applications. For quantum networking applications, people usually consider the combined use of several distinct sources to enlarge the available Hilbert space. As an alternative we harness the intrinsic multi-mode structure of high dimensional ultrafast quantum states, which, for example, enables multiplexed quantum communication protocols.

As a first step, we present the creation of multi-mode pulsed quantum states of light, based on ultrafast waveguided parametric downconversion (PDC). Engineering the PDC process enables us to excite a tuneable number of ultrafast modes.

Secondly, in order to characterize the number of emitted modes and to benchmark our sources we introduce broadband correlation function measurements and show how they are able to resolve the multi-mode nature of the created quantum states.

Finally, it is essential for further applications to individually address the different pulse modes. Here we discuss quantum pulse gates, based on engineered ultrafast frequency conversion processes, which are able to separate individual pulse modes from multi-mode quantum states.

Q 54.2 Thu 14:30 E 001

Realization of quantum up-conversion of squeezed light from 1550 nm to 532 nm — •Petrissa Zell[1], Christina E. Vollmer[1], Christoph Baune[1], Aiko Samblowski[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

Frequency conversion of non-classical light provides a considerable amount of applications in the field of quantum information and quantum metrology. An example of quantum metrology is the sensitivity enhancement of gravitational wave detectors using squeezed vacuum states of light as it was recently accomplished in GEO 600 at a wavelength of 1064 nm. In principle, reducing the detector's wavelength to the optical regime yields a further enhancement of its sensitivity. Here we report on the generation of a continuous-wave squeezed vacuum state at 532 nm via frequency up-conversion of a squeezed vacuum state at 1550 nm. The up-conversion is realized by means of a doubly resonant optical parametric oscillator, exploiting a strong 810 nm pump field. With this method we achieved a non-classical noise reduction of 1.5 dB at 532 nm, and introduce the possibility to up-convert entangled states as well as single photons.

Q 54.3 Thu 14:45 E 001

Near-Unity Collection Efficiency of Single Photons from a Solid-State Emitter — Thomas J.K. Brenner, •Xiao-Liu Chu, Stephan Götzinger, and Vahid Sandoghdar — Max Planck Institut für die Physik des Lichts, Erlangen, Germany

Recently, we described a theoretical method for constructing a planar metallo-dielectric antenna that exhibits 99% collection efficiency. The antenna design consists of a multilayer architecture with stepwise change in the refractive index across the structure. Single photons emitted by a quantum emitter sandwiched in between the high and low refractive index layers are channeled into the middle layer (n2), from where they leak down into the high refractive index substrate (sapphire, n1=1.78) at angles determined by arcsin(n2/n1). The emitted photons are then collected by using a conventional microscope objective. Here we report on the experimental realization of this proposal using single colloidal quantum dots (CdS/CdSe) as sources of single photons. This system serves as a stable and ultra-bright source of single photons that is highly desirable for a variety of applications such as quantum communication, quantum cryptography, shot-noise-free detection and spectroscopy.

Q 54.4 Thu 15:00 E 001

Wavelength tunability of a triply resonant whispering gallery optical parametric oscillator — •Gerhard Schunk, Michael Förtsch, Josef Fürst, Dmitry Strekalov, Florian Sedlmeir, Harald Schwefel, Christoph Marquardt, and Gerd Leuchs — Max Planck Institute for the Science of Light, Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Erlangen, Germany

Lithium Niobate whispering gallery mode resonators (WGMR) offer high finesse and small mode volume leading to strong field enhancement for all wavelengths within the transparency window of the medium. Hence, optical parametric oscillators (OPO) based on WGMRs offer high efficiency as well as high stability and control over wavelength and bandwidth.

The process of parametric down conversion (PDC) has been demonstrated in a z-cut WGMR near the degenerate emission at 1064 nm [1,2,3]. The ongoing project aims for the analysis of wavelength tuning in this triply resonant OPO for applications in quantum optics. In particular, the focus lies on bridging the gap between atomic transitions (resonant idler photon) and telecom wavelengths (signal photon).

Q 54.5 Thu 15:15 E 001

Spectral and spatial correlations of PDC in waveguide arrays — •Regina Kruse, Fabian Katzschmann, Andreas Christ, Kaisa Laiho, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Integrated optical devices form a compact and easy to manipulate basis for all types of optical applications. Especially weakly coupled waveguide arrays offer the advantage of highly stable interferometric experiments, which can be used for optical simulations of solid state systems. In the non-linear regime, localization effects like solitons can be observed [1]. Here, we investigate in detail the spectral and spatial correlations of parametric down-conversion (PDC) in waveguide arrays [2], which have been studied extensively in the context of classical optics and quantum walks [3,4]. We pay special attention to the engineering of hyperentangled multimode quantum states in the spectral and spatial degree of freedom, which allow for scalable and robust quantum information applications.

[1] H. S. Eisenberg et al. PRL 81 (3383), 1998
[2] A. Solntsev et al., PRL 108 (023601), 2012
[3] A. Peruzzo et al., Science 329 (1500), 2010
[4] L. Sansoni et al. PRL 108 (010502), (2012)

Q 54.6 Thu 15:30 E 001

An Efficient Integrated Two-Color Source for Heralded Single Photons — •Stephan Krapick, Harald Herrmann, Viktor Quiring, Benjamin Brecht, Hubertus Suche, and Christine Silberhorn — Universität Paderborn, Integrated Quantum Optics Group, Warburger Straße 100, 33098 Paderborn

We report on an integrated source for heralded single photons at telecom wavelength based on a type-I parametric down-conversion (PDC) process inside Titanium-indiffused periodically poled Lithium Niobate waveguides (Ti:PPLN). The on-chip integration of a passive directional coupler allows for excellent spectral separation of the generated signal and idler photons. Measurements of the heralded single photons prove a preparation efficiency of 60 % and coincidence-to-accidentals-ratios of up to 7400. For the low pump power regime we obtain a conditioned second order auto-correlation function of $g^{(2)}(0) = 0.004$ indicating almost pure photon pair generation. The high brightness of our source was concluded from the high average photon number generated per pump pulse of $\langle n_{\mathrm{pulse}} \rangle = 0.24$ at power levels below 100 μW.

Q 54.7 Thu 15:45 E 001

Quantum noise for Faraday light-matter interfaces — •Denis Vasilyev and Klemens Hammerer — Leibniz University Hanover, 30167 Hanover, Germany

In light-matter interfaces based on the Faraday effect, quite a number of quantum information protocols have been successfully demonstrated. In order to further increase the performance and fidelities achieved in these protocols, a deeper understanding of the relevant noise and decoherence processes needs to be gained. In this paper, we provide for the first time a complete description of the decoherence from spontaneous emission. We derive from first principles the effects of photons being spontaneously emitted into unobserved modes. Our results relate the resulting decay and noise terms in effective equations of motion for collective atomic spins and the forward-propagating light modes to the full atomic level structure. We illustrate and apply our results to the case of a quantum memory protocol. Our results can be applied to any alkali atoms, and the general approach taken in this paper can be applied to light-matter interfaces and quantum memories based on different mechanisms.