Q 56: SYPC: From Atoms to Photonic Circuits 3

Time: Friday 10:30–12:30 Location: V47.02

Q 56.1 Fri 10:30 V47.02

Towards quantum dot - photon entanglement swapping — •Tim Kroh, Otto Dietz, Andreas W Schell, and Oliver Benson — AG Nano Optics, Institut für Physik, HU Berlin

The distance of fiber based quantum communication can be increased arbitrarily with the help of quantum repeaters. In realizations of quantum repeater architectures involving semiconductor quantum dots (QDs) entanglement swapping between two dissimilar entangled states, i.e. an entangled QD-photon state on one hand and a photon pair on the other hand is a crucial operation. A first experiment involving a quantum dot and a photon pair was demonstrated recently [1].

The next important step is to demonstrate two-photon interference between a single photon from a quantum dot and a photon from an entangled photon pair. To achieve indistinguishability at least one of the photon sources has to be tunable. We present first experiments in this direction where we investigate different semiconductor QDs which are tunable with respect to photon pair sources.

[1] Solomon et al., Phys. Rev. Lett. 107, 157402

Q 56.2 Fri 10:45 V47.02

Heralded Quantum Entanglement between two Crystals — •Christoph Clausen, Imam Usmani, Félix Bussières, Nicolas Sangouard, Mikael Afzelius, and Nicolas Gisin — GAP-Optique, Université de Genève, Switzerland

A crucial requirement for quantum networks is the ability to entangle quantum nodes. With the help of a quantum repeater, for example, quantum information can be transmitted at a rate that scales polynomially with distance, whereas the exponential loss in direct transmission of single photons through optical fibers inhibits quantum communication over distances larger than a few hundred kilometers. This is only possible if two remote quantum memories can be entangled in a heralded fashion.

We present the creation of heralded entanglement between two ensembles of rare-earth ions doped into separate crystals. A heralded single photon is sent through a 50/50 beamsplitter with one crystal at each output acting as quantum memories. The absorption of the photon by one of the crystals leads to a single collective excitation delocalized between the two crystals. The entanglement between the crystals is revealed by mapping it back to optical modes and performing a series of measurements that provide a lower bound on the concurrence of the retrieved light state. Our results are a step on the way towards quantum networks based on solid-state resources.

Q 56.3 Fri 11:00 V47.02

An All-Integrated PDC Source for Heralded Single Photons in Ti:LiNbO$_3$ Waveguides — •Stephan Krapick, Benjamin Brecht, Viktor Quiring, Harald Herrmann, Wolfgang Sohler, and Christine Silberhorn — IQO, Uni Paderborn

Many applications in quantum information networking rely on heralded single photons. We present a waveguide-based source for the efficient generation of heralded single photons in Ti-diffused Lithium Niobate. Pumping with pulsed light at 532 nm, photon pairs at around 810nm and 1550nm are created in a type-I PDC process and split up into signal and idler beams using an integrated WDM coupler on the very same chip. We will optimize our source and aim to achieve heralded efficiencies of up to 93% in coincidence measurements, which are theoretically limited by the waveguide-fiber-coupling.

Q 56.4 Fri 11:15 V47.02

The inhomogeneous broadening of the zero phonon line of single nitrogen-vacancy centers in nano-diamonds — •Nikola Sadzak, Janik Wolters, and Oliver Benson — Humboldt Universität zu Berlin, Nano-optics, Newtonstraße 15, D-12489 Berlin, Germany

Color centers in diamond have proven to be a promising resource for quantum technology applications. In particular, the negatively charged nitrogen-vacancy defect (NV) center in bulk diamond is attractive as a source of indistinguishable single photons, as it provides a narrow zero phonon line (ZPL) at the optical $^3A \rightarrow ^3E$ transition at 638 nm. However, for integrated solid state devices, nano-diamonds with single NV centers are preferable as they can be manipulated and integrated in different photonic structures [1, 2]. Here, a major problem is the inhomogeneous broadening of the ZPL due to spectral diffusion. Performing interferometric and photon-correlation measurements we determine the time-scale of the spectral diffusion and gain further knowledge about the underlying processes.

[1] J. Wolters et al., *Enhancement of the zero phonon line emission from a single nitrogen vacancy center in a nanodiamond via coupling to a photonic crystal cavity*, Appl. Phys. Lett. **97**, 141108 (2010)

[2] A. Schell et al., *A scanning probe-based pick-and-place procedure for assembly of integrated quantum optical hybrid devices*, Rev. Sci. Instrum. **82**, 073709 (2011)

Q 56.5 Fri 11:30 V47.02

Ultrafast all-optical switching by single photons — •Thomas Volz, Andreas Reinhard, and Atac Imamoglu — Institute of Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

While two-color spectroscopy of the Jaynes-Cummings ladder has been performed in the microwave domain, it has so far not been demonstrated for cavity QED experiments in the optical domain. Here, we report on frequency- and time-resolved two-color spectroscopy of a strongly coupled quantum dot-cavity system which consists of a single self-assembled InGaAs quantum dot positioned at the field maximum of a photonic crystal L3 cavity. The coupled system is highly non-linear as witnessed by strong photon blockade on both fundamental polariton transitions [1]. Two (near-)resonant laser pulses with variable relative time delay are used to probe the non-linear system dynamics. With the center frequency of the first laser pulse fixed to one of the fundamental polariton transitions, we record the non-linear system response as a function of the center frequency of the second laser pulse. We obtain a clear signature due to the corresponding transition from the first to the second Jaynes-Cummings manifold. By varying the time delay between the laser pulses, we demonstrate all-optical switching by single photons on picosecond timescales [2]. Besides the single-photon switching, the present device can also be used as a single-photon pulse correlator.

[1] A. Reinhard et al., accepted for publication in Nature Photonics, arXiv:1108.3053.

[2] T. Volz et al., submitted for publication, arXiv:1111.2915.

Q 56.6 Fri 11:45 V47.02

Influence of the excitation pulse width on the purity of single-photon emission from light emitting diodes — •Fabian Hargart[1], Christian Kessler[1], Matthias Reischle[1], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Michael Jetter[1], Paul Gartner[2], Matthias Florian[2], Christopher Gies[2], Frank Jahnke[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, Allmandring 3, 70569 Stuttgart — [2]Institut für Theoretische Physik, Universität Bremen, Postfach 330 440, 28334 Bremen

For many applications in quantum information single-photons on demand are desirable. Electrically driven semiconductor quantum dots (QDs) are a promising solution due to their tailorable emission energy and the integration in well-known semiconductor devices.

Pulsed lasers afford an almost instantaneous excitation of the QDs compared to their decay time. In contrast, electrical pulse generators feature pulsewidths only down to several 10 ps. Therefore we determine the influence of the excitation pulses on the purity of single-photon emission from InP/GaInP quantum dots. For rising widths we observe an increasing $g^{(2)}(0)$ - value, which we relate to an increasing probability of further excitations during one single cycle. Using autocorrelation measurements with high temporal resolution we can distinguish the background contribution from re-excitation processes on the non-vanishing $g^{(2)}(0)$-value. Theoretical investigations are in a good agreement with the experimental results.

Q 56.7 Fri 12:00 V47.02

Quantum Simulations with a two-dimensional Quantum Walk — •Andreas Schreiber[1,2], Aurél Gábris[3], Peter P. Rohde[1,4], Kaisa Laiho[1], Martin Štefaňák[3], Václav Potoček[3], Craig Hamilton[3], Igor Jex[3], and Christine Silberhorn[1,2] — [1]IQO Group, MPI for the Science of Light,91058 Erlangen, Germany. — [2]Integrated Quantum Optics, Applied Physics, University of Pader-

born, 33098 Paderborn, Germany — [3]Department of Physics, FN-SPE, Czech Technical University in Prague, Praha, Czech Republic. — [4]Centre for Engineered Quantum Systems, Department of Physics and Astronomy, Macquarie University, Sydney NSW 2113, Australia

The concept of quantum walks has become a promising candidate for quantum computation and simulations of quantum transfer. Although theoretical models already exploit the power of higher-dimensional quantum walks all experimental implementations so far were limited to a spread in a single dimension.

Here we present the first implementation of a quantum walk in a scalable and flexible two-dimensional system. We demonstrate a highly coherent evolution of photons in an optical fiber network, allowing for a spread over up to 169 positions after 12 steps. Having full control over the quantum coin enables us to simulate entanglement in bipartite systems with conditioned interactions including non-linearities or two-particle scattering.

Q 56.8 Fri 12:15 V47.02

Quantum key distribution using a single-photon emitting diode in the red spectral range — •Christian Kessler[1], Fabian Hargart[1], Markus Rau[2], Martin Fuerst[2], Wolfgang-Michael Schulz[1], Marcus Eichfelder[1], Robert Rossbach[1], Sebastian Nauerth[2], Michael Jetter[1], Harald Weinfurter[2,3], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Universität Stuttgart, 70569 Stuttgart — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching

In 1984 Bennett and Brassard presented a scheme for secure quantum key distribution (QKD), the so-called BB84 protocol. Several QKD-experiments have been arranged with strongly attenuated lasers. But due to multi-photon emission additional shrinking of the key compared to systems using single-photon sources (SPS) is necessary. Therefore, using a SPS afford higher key rates at the same total count rate.

In this report we present free-space quantum key distribution experiments using an electrically driven SPS, based on InP quantum dots. A polarizer in combination with an electro-optical modulator prepare the polarization state. After a free-space channel of about 50 cm the beam is detected and analyzed by a single-photon polarization analyzer setup. The influence of several excitation parameters, e.g. the peak-to-peak voltage, the DC voltage and the pulse width on the $g^{(2)}(0)$-value and the transfer rate are investigated. Sifted key rates up to 81.6 kBits/s at a quantum bit error-rate of 4.2 % and a $g^{(2)}(0)$-value of 0.48 were achieved.