Q 38: Quantum information: Photons and nonclassical light I

Time: Thursday 10:30–12:30 Location: UDL HS3038

Q 38.1 Thu 10:30 UDL HS3038

Cooperative coupling of ultracold atoms and surface plasmons — •Matthias Mildner and Sebastian Slama — Physikalisches Institut, Universität Tübingen

Cooperative coupling between specific light modes and individual optical emitters is one of the outstanding goals in quantum technology. The extraordinary radiation properties of the participating emitters are fundamentally interesting. While this goal has been achieved using high-finesse optical cavities, cavity-free approaches that are easy to build and broadband have attracted much attention recently. In this experiment we demonstrate cooperative coupling of ultracold atoms with surface plasmons that propagate on a plane gold surface. The atoms are excited by an external laser pulse, while surface plasmons are detected via leakage radiation into the substrate of the gold layer. With a maximum Purcell enhancement of $\eta_{\mathrm{P,max}} = 3.1$ we deduce that a number of $N \approx 100$ atoms are coupled with high cooperativity to surface plasmons.

Q 38.2 Thu 10:45 UDL HS3038

Narrow band photon pairs linked to a solid state quantum memory suited for quantum repeaters. — •Daniel Rieländer[1], Kutlu Kutluer[1], Patrick Ledingham[1], Mustafa Gündoğan[1], Julia Fekete[1], Margherita Mazzera[1], and Hugues de Riedmatten[1,2] — [1]ICFO - The Istitute of Photonic Science, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]ICREA - Institució Catalana de Recerca i Estudis Avançats, 08015 Barcelona, Spain

We create photon pairs where one photon is stored in a praseodymium (Pr^{3+}) doped crystal for up to 4.5 μs and its associate photon is at telecom wavelength. This combination is ideally suited for quantum repeaters to overcome limitations in long distance quantum communication. The photon pair source is based on cavity enhanced spontaneous parametric down conversion (SPDC). Widely non degenerate photon pairs at 606 nm and 1436 nm wavelength are created inside a bow-tie cavity. The output rate is enhanced inside the cavity modes and double resonance leads to a strong reduction of redundant modes due to the clustering effect. This brings a high spectral brightness with few spectral modes of 2 MHz line width. Quantum storage of heralded photons at 606 nm has been demonstrated using the atomic frequency comb protocol in a Pr:YSO crystal at cryostatic temperature. A storage time up to 4.5 μs has been achieved, the longest storage time in solid state devices. We will discuss further experiments on the quantum light source, e.g. the variation of the emitted number of modes by setting dispersive elements inside the cavity.

Q 38.3 Thu 11:00 UDL HS3038

High purity single photons at 532 nm by means of upconversion — •Axel Schönbeck[1], Christoph Baune[1], Aiko Samblowski[1], Jaromír Fiurášek[2], and Roman Schnabel[1] — [1]Albert-Einstein-Institut, Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstraße 38, D-30167 Hannover — [2]Department of Optics, Palacký University, 17. listupadu 12, 77146 Olomouc, Czech Republic

Single photon states are of fundamental interest in quantum physics. Furthermore, the link between telecommunication and quantum memory wavelengths is useful in future quantum communication tasks. We connect these two wavelengths by up-conversion of single photons from 1550 nm to 532 nm while an ancilla photon at 810 nm triggers the detection. Frequency filtering of the signal mode leads to slightly smoothed out correlation functions. Finally, in a Hanbury Brown and Twiss setup we verified the single photon characteristics of the up-converted state.

Q 38.4 Thu 11:15 UDL HS3038

A Mode-filter-free Source of Narrow-band Photon-pairs — •Amir Moqanaki and Philip Walther — University of Vienna, Vienna, Austria

Narrow-band (few MHz band-width) single photons are an essential tool for a variety of quantum information studies, atomic quantum memories, quantum networks, and studying atom-light interactions.

Spontaneous Parametric Down-Conversion (SPDC) has proven to be a robust, relatively easy, bright, probabilistic source of photon-pairs. But the typical phase-matching band-width is broad (about 100 GHz or more) and filtering such leads to very poor brightness.

On the other hand, SPDC inside a high finesse cavity can enhance the narrow-band emission by a factor of finesse squared and drastically improve the brightness. But for single longitudinal mode operation of the enhancing cavity, additional external filters (either atomic line, or etalons) are necessary. This mode filtering comes at the cost of losing photon counts and adding complexity to the setup.

In this talk, a novel mode-filter-free, frequency degenerate, type-II phase-matched, SPDC based source of narrow-band photon-pairs at 780nm is introduced. An intra-cavity Pockels cell tunes the signal and idler photons free spectral ranges such that they satisfy the doubly resonant condition and render the cavity single mode. This technique improves the brightness and packs a compact, robust setup.

Q 38.5 Thu 11:30 UDL HS3038

Narrow-band single photons efficiently filtered by atoms — •Wilhelm Kiefer[1], Petr Siyushev[1], Robert Löw[2], Jörg Wrachtrup[1,3], and Ilja Gerhardt[1,3] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]5. Physikalisches Institut, Universität Stuttgart — [3]Max Planck Institute for Solid State Research, Stuttgart

Single organic dye molecules allow for the generation of high flux single photons. Under cryogenic conditions, these can be as narrow-band as a few tens of MHz. It has been shown recently, that the fluorescence spectrum of certain molecules corresponds well to the absorption spectrum of atoms. Therefore, it is possible to join single molecule studies and atomic spectroscopy. One crucial measure is the purity of single photons. Therefore, the generated photons are filtered utilizing an atomic line filter. This so-called Faraday anomalous dispersion optical filter (FADOF) consists of two crossed polarizers, an atomic vapor cell, and a magnetic field. It allows for a few GHz wide band-pass filter, with exceptional high transmission (>95%). We present theoretical calculations to optimize the operating parameters for this filter, which consists of atomic sodium. Based on these calculations, the filter was implemented. The experimental configuration allows for a wide temperature range and a tunable magnetic field up to 0.4T. The theoretical results are confirmed by atomic spectroscopy, using a dye laser. The single photon source, based on single dibenzanthanthrene (DBATT) molecules, allows for an unsurpassed spectral brightness and can be spectrally detuned by the DC-Stark effect. We are able to perform atomic spectroscopy on the filter using a single molecule light source.

Q 38.6 Thu 11:45 UDL HS3038

Heralded Photon-Pairs by Monolithically Integrated Cascaded Parametric Down-Conversion — •Stephan Krapick, Vahid Ansari, Benjamin Brecht, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

We report on a novel integrated approach for heralded pairs of photons, the generation of which is realized by cascading two parametric down-conversion processes on-chip. For the nonlinear optical conversion device, we implemented Ti-indiffused waveguide structures in lithium niobate, which are periodically poled with two different grating periods. From our measurements we extract the raw and dark-count corrected photon-triplet generation rate, and we analyze the heralding efficiency. Our results show the generation of photon-triplet states applicable for fundamental tests of quantum mechanics.

[1] Hübel et al., Nature **466**, 601-603 (2010)
[2] Shalm et al., Nature Physics **9**, 19-22 (2012)
[3] Krapick et al., New Journal of Physics **15**, 033010 (2013)
[4] Krapick et al., submitted

Q 38.7 Thu 12:00 UDL HS3038

Mode spectrum and emission pattern of whispering gallery mode disk resonators — •Gerhard Schunk, Michael Förtsch, Josef Fürst, Dmitry Strekalov, Florian Sedlmeir, Harald Schwefel, Gerd Leuchs, and Christoph Marquardt — Max Planck Institute for the Science of Light, Institute for Optics, Information and Photonics, University Erlangen-Nuremberg, Erlangen, Germany

The concept of circulating waves in convex-shaped materials enables whispering gallery mode resonators to be both outstanding systems for fundamental research and a promising photonic technology. Here we report on a technique to identify eigenmodes of large whispering gallery disk resonators by extending initial studies of [1,2]. This is equivalent to exactly assigning radial, polar, and azimuthal mode numbers q,l, and m to whispering gallery modes by combining spatial and spectral measurements of the outcoupled modes. The fit also reproduces the experimental changes of the frequency differences of WGMs under a change of the resonator temperature by 25°C, which demonstrates one way for tailoring the eigenspectrum of whispering gallery mode resonators.

[1] M. L. Gorodetsky et al., Opt. Commun. Vol. 113, Issue 1-3, pp. 133-143 (1994)

[2] S. Schiller et al., Opt. Lett. Vol. 16, Issue 15, pp. 1138-1140 (1991)

Q 38.8 Thu 12:15 UDL HS3038

Nanodiamond nitrogen vacancy centers coupled with tapered optical fibers as hybrid quantum nanophotonic devices
— •Masazumi Fujiwara[1,2,3], Mohamed Almokhtar[1,2,4], Hideaki Takashima[1,2], and Shigeki Takeuchi[1,2] — [1]Research Institute for Electronic Science, Hokkaido University, Sapporo, Hokkaido, 001-0021, Japan — [2]The Institute of Scientific and Industrial Research, Osaka University, Ibaraki, Osaka, 567-0047, Japan — [3]Present address: Institut für Physik, Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin, Germany — [4]Physics Department, Assiut University, Assiut, Egypt

Tapered optical fibers are promising one-dimensional nanophotonic waveguides that can provide efficient coupling of their fundamental mode and quantum nanoemitters placed inside them. Here we present numerical studies on the coupling of single nitrogen-vacancy (NV) centers in nanodiamonds with the tapered fibers. The results show that (1) the maximum of 53.4 % of coupling efficiency can be realized when the NV bare dipole is located at the center of the tapered fiber and that (2) NV centers even in 100-nm-sized nanodiamonds, where bulk-like optical properties were reported, show the coupling efficiency of 22 % at the taper surface. These results are an important guide to build hybrid quantum devices for applications in quantum information and quantum sensing.