Q 54: Photonics I

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

Group Report Q 54.1 Fri 10:30 UDL HS3038

Nondestructive Detection of an Optical Photon — •Andreas Reiserer, Stephan Ritter, and Gerhard Rempe — Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We demonstrate a robust photon detector which does not rely on absorption. Instead, impinging light is reflected off an optical resonator containing a single atom in a superposition of two states. Upon reflection of a single photon, the phase of the superposition state is flipped, which allows us to nondestructively detect the photon.

This experimental achievement has two major consequences: First, it facilitates repeated measurements of one and the same photon, which boosts the photon detection efficiency. Second, nondestructive detection can serve as a herald that signals the presence of a photon without affecting its unmeasured degrees of freedom, like its temporal shape or its polarization. This is in stark contrast to absorbing detectors, where the photon and its quantum state are irreversibly lost. Both implications are of great importance for the rapidly evolving research fields of quantum measurement, quantum computation, quantum communication, and quantum networks.

Q 54.2 Fri 11:00 UDL HS3038

Tapered Fiber Coupling of Single Photons Emitted by a Deterministically Positioned Single NV-Center — •Lars Liebermeister[1], Daniel Burchardt[1], Andreas W. Schell[4], Oliver Benson[4], Ariane Stiebeiner[3], Arno Rauschenbeutel[3], Harald Weinfurter[1,2], and Markus Weber[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Technische Universität Wien - Atominstitut, Wien — [4]Humboldt-Universität zu Berlin

The development of high yield single photon sources is crucial for applications in quantum information as well as for experiments on the foundations of quantum physics. In this context the nitrogen vacancy center in diamond is a promising solid state candidate.

In our approach a diamond nano-crystal hosting a single NV-center is optically selected with a confocal scanning microscope and positioned deterministically onto the subwavelength-diameter waist of a tapered optical fiber (TOF) with the help of an atomic force microscope. Based on this nano-manipulation technique we experimentally demonstrate the evanescent coupling of single fluorescence photons emitted by a single NV-center to the guided mode of the TOF. By comparing photon count rates of the fiber-guided and the free-space modes and with the help of numerical FDTD simulations we determine a lower and upper bound for the coupling efficiency of $(9.4 \pm 0.6)\%$ and $(10.4 \pm 0.7)\%$ [1]. Our results are a promising starting point for future integration of single photon sources in photonic quantum networks and applications in quantum information science. [1] arXiv:1309.0421

Q 54.3 Fri 11:15 UDL HS3038

Ultra-small mode volume cavities for the enhancement of NV center fluorescence — •Hanno Kaupp[1,2], Andreas Weissl[1,2], Philipp Häusser[1,2], Aniket Agrawal[1,2], Helmut Fedder[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Universität Stuttgart, Stuttgart, Germany

We want to apply tunable optical microcavities as a tool to enhance the emission rate and to increase the photon collection efficiency of Nitrogen-vacancy (NV) centers in diamond. The coupling between the emitter and the cavity mode can be expressed by the Purell factor being proportional to the ratio of quality factor and mode volume. The emission rate into a particular cavity mode can be increased considerably, due to the Purcell effect.

In a new approach we use a diamond nanocrystal large enough to provide nano-scale field confinement by itself in order to build ultra-small mode volume cavities. Embedding the crystal between a pair of silver layers, a Fabry-Pérot cavity mode can be defined with mode volumes down to $0.1(\lambda/n)^3$. The resulting large Purcell enhancement ($C \sim 5$) and efficient outcoupling of the photons provide a way to build efficient solid state single photon sources as well as efficient spin-photon interfaces at ambient conditions.

Q 54.4 Fri 11:30 UDL HS3038

Fast optical modulation of the fluorescence from a single nitrogen-vacancy centre — •Michael Geiselmann[1], Renaud Marty[1], Jan Renger[1], Javier Garcia de Abajo[1,2], and Romain Quidant[1,2] — [1]ICFO - The Institute of Photonic Sciences, Barcelona (Spain) — [2]ICREA - Institució Catalana de Recerca I Estudis Avançats, Barcelona (Spain)

We demonstrate that a single nitrogen-vacancy centre at room temperature can operate as an optical switch under non-resonant continuous-wave illumination. We show an optical modulation of more than 80% and a time response faster than 100 ns in the green-laser-driven fluorescence signal, which we control through an independent near-infrared gating laser. Our study indicates that the near-infrared laser triggers a fast-decay channel of the nitrogen-vacancy mediated by promotion of the excited state to a dark band. In a second step, we use plasmon based optical tweezers to deterministically locate single nano-diamonds in the hot spot of plasmonic antennas. We demonstrate that the hybrid system formed by a single nitrogen-vacancy coupled to a gold gap antenna, resonant in the NIR, enhances the modulation effect described above with modulation intensities for the NIR of only a few mW.

Q 54.5 Fri 11:45 UDL HS3038

Detection of a single ion in a crystal via high-resolution spectroscopy — •Emanuel Eichhammer, Tobias Utikal, Stephan Götzinger, and Vahid Sandoghdar — Max-Planck-Institute for the Science of Light and Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), D-91058 Erlangen, Germany

We demonstrate the first detection of single rare earth ions in a crystal. The electronic structure of rare-earth ions offers optically addressable transitions in the 4f electronic shell, which are shielded against strong coupling to the crystal matrix by filled higher shells. The almost atom-like unperturbed properties of these ions at cryogenic temperatures together with long coherence times on the order of seconds and a ground state hyperfine substructure promise a new platform for quantum information applications. The weak fluorescence of a single ion has hampered the detection and spectroscopy of the narrow optical linewidths for more than two decades. By employing a narrow-band laser and confocal microscopy with a solid immersion lens, we have succeeded to not only detect but also resolve substructure in the single ion spectral response. We report on state preparation into specific hyperfine states, paving the way for quantum schemes such as stimulated Raman adiabatic passage with single ions. Finally we discuss methods in order to enhance the fluorescence response of a single ion.

Q 54.6 Fri 12:00 UDL HS3038

Laser-Written Parabolic Micro-Mirrors for High Single Photon Collection Efficiency — •Andreas W. Schell[1], Tanja Neumer[1], Qiang Shi[2], Johannes Kaschke[2], Joachim Fischer[2], Martin Wegener[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Nanooptik, 12489 Berlin, Germany — [2]Karlsruhe Institute of Technology (KIT), Institute of Applied Physics, DFG-Center for Functional Nanostructures, Institute of Nanotechnology, 76128 Karlsruhe, Germany

The efficient collection of single photons from solid-state single photon emitters, like quantum dots or defect centers in diamond, is a very demanding task. Typically, rather bulky high numerical aperture objectives are used to cover a solid angle as large as possible in order to maximize the number of collected photons. In this presentation we will introduce parabolic micro-mirrors fabricated by the process of two-photon direct laser-writing and silver evaporation. This technique allows for direct integration of stable single photon emitters such as the nitrogen vacancy (NV) centers in nanodiamonds [1]. The mirrors are produced in an aligned overlay process, i.e. their focus is centered around a single pre-characterized NV center. In this way we obtain an extraordinary high collection efficiency in a very small solid angle, allowing for easy collection of photons even with low numerical apertures.

[1] A. W. Schell et al., Scientic Reports 3, 1577 (2013).

Q 54.7 Fri 12:15 UDL HS3038

A Scanning Cavity Microscope — •Matthias Mader[1,2], Thomas Hümmer[1,2], Hanno Kaupp[1,2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-

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We present a novel tool for ultra sensitive and spatially resolved absorption spectroscopy on nanoscale objects. To boost sensitivity, multiple interactions of probe light with an object are realized by placing the sample inside a high finesse scanning optical microcavity. It is based on a laser machined and mirror-coated end facet of a single mode fiber and a plane mirror forming a fully tunable open access Fabry-Perot cavity [1, 2]. Scanning the sample placed on the plane mirror through the cavity mode yields a spatial map of absorptivity of the sample.

We show proof-of-principle experiments with individual gold nanospheres, demonstrating very sensitive absorption and dispersion measurements.

Our results open the perspective to use scanning cavity microscopy as a versatile tool for spectroscopy on weakly absorbing nanoparticles, for bio sensing, and single molecule detection.

[1] D. Hunger, T. Steinmetz, Y. Colombe, C.Deutsch, T. W. Hänsch and J. Reichel, New J. Phys. 12, pp. 065038(2010)

[2] D. Hunger, C. Deutsch, R. J. Barbour, R. J. Warburton and J. Reichel, AIP Advances 2, 012119 (2012)