Q 47: Nano-Optics II

Time: Thursday 11:00–12:45 Location: C/HSO

Group Report Q 47.1 Thu 11:00 C/HSO

Quantum Nano-Optics with Single Molecules and Ions in the Solid State — •Tobias Utikal[1,2], Pierre Türschmann[1,2], Emanuel Eichhammer[1,2], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlange, Germany — [2]Department of Physics, Friedrich Alexander University Erlangen-Nürnberg (FAU), 91058 Erlangen

The coupling of single photons and single atoms establishes the most fundamental building block of quantum optics. In the solid state some organic dye molecules and rare earth ions have been shown to possess a remarkable photostability and Fourier-limited transitions at cryogenic temperatures. In this talk, we present an overview of our activities in solid state quantum optics. In the first part, we discuss the coupling of single molecules to photons confined in a subwavelength waveguide. Extinction, fluorescence excitation, and resonance fluorescence spectroscopy provide us with high spatial and spectral information on a large number of molecules in the waveguide. Our platform is ideally suited to study the coherent coupling of two or more emitters within a single optical mode. In the second part, we report on the spectroscopy and microscopy of single rare earth ions in a crystalline host. These quantum objects offer an atomic energy level scheme with a plethora of narrow optical transitions and quantum states with extremely long coherence times. Furthermore, the crystalline nature of the host material lends itself to on-chip integration. We discuss our efforts for increasing the emission of single ions via coupling to microcavities and our plans for the realization of quantum photonic circuits using waveguides.

Group Report Q 47.2 Thu 11:30 C/HSO

Optical isolation based on chiral interaction of light and matter in a nanophotonic waveguide — Clément Sayrin, Christian Junge, Rudolf Mitsch, Bernhard Albrecht, Danny O'Shea, Philipp Schneeweiss, •Jürgen Volz, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien

Nanophotonic components confine light at the wavelength scale and enable the control of the flow of light in an integrated optical environment. Such strong confinement leads to an inherent link between the local polarization of the light and its propagation direction [1-3]. We employ this effect to demonstrate low-loss nonreciprocal transmission of light at the single-photon level through a silica nanofiber in two different experimental schemes. We either use an ensemble of spin-polarized atoms weakly coupled to the nanofiber-guided mode [2] or a single spin-polarized atom strongly coupled to the nanofiber via a whispering-gallery-mode resonator [1]. We observe a strong imbalance between the transmissions in forward and reverse direction of 8 dB and 13 dB for the atomic ensemble and the resonator-enhanced scheme, respectively. At the same time, the forward transmissions still exceeds 70%. The resulting optical isolators exemplify a new class of nanophotonic devices based on chiral interaction of light and matter, where the state of individual quantum emitters defines the directional behavior.

[1] C. Junge et al., Phys. Rev. Lett. 110, 213604 (2013).
[2] R. Mitsch et al., arXiv:1406.0896 (2014).
[3] J. Petersen et al., Science 346, 67 (2014).

Group Report Q 47.3 Thu 12:00 C/HSO

Cooperative coupling of ultracold atoms and surface plasmons — •Sebastian Slama — Auf der Morgenstelle 14, Physikalisches Instiut, Universität Tübingen

High cooperativity between optical emitters and light modes is an important condition for many applications ranging from the generation of single photon sources to the reliable read-out of quantum information. We have recently demonstrated that high cooperativity can be reached by positioning ultracold atoms close to metallic surfaces and coupling the atomic emission to surface plasmons [1]. A maximum Purcell enhancement of $\eta_P = 4.9$ is reached at a distance of $z = 250$ nm from the surface. Furthermore, the coupling leads to the observation of a Fano resonance in the spectrum.

[1] Nature Phys., DOI:10.1038/NPHYS3129, Advance Online Publication, 26.10.2014

Q 47.4 Thu 12:30 C/HSO

A Scanning Cavity Microscope — •Matthias Mader[1,2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching — [3]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, F-75005 Paris

We present a versatile tool for ultra-sensitive and spatially resolved optical characterization of single nanoparticles.

Using signal enhancement in a scanning optical microcavity made of a micromachined optical fiber and a plane mirror [1] we measure the polarization dependent extinction of a single nanoparticle as well as its birefringence. Harnessing multiple interactions of probe light with a sample within the optical resonator, we achieve a 1700-fold signal enhancement compared to diffraction-limited microscopy. We demonstrate quantitative imaging of the extinction cross section of gold nanoparticles with a sensitivity below $1\,\mathrm{nm}^2$, we show a method to improve spatial resolution potentially below the diffraction limit by using higher order cavity modes, and we present measurements of the birefringence and extinction contrast of gold nanorods [2].

[1] D. Hunger, T. Steinmetz, Y. Colombe, C. Deutsch, T. W. Hänsch and J. Reichel, New J. Phys. 12, pp. 065038 (2010)
[2] M. Mader, J. Reichel, T. W. Hänsch and D. Hunger, arXiv preprint arXiv:1411.7180 (2014)