

Q 54: Nano-Optics (Single Quantum Emitters and Plasmonics)

Time: Thursday 10:30–12:45

Location: K 0.023

Q 54.1 Thu 10:30 K 0.023

An optical nanofiber-based interface for single molecules — ●HARDY SCHAUFFERT, SARAH SKOFF, DAVID PAPENCORDT, and ARNO RAUSCHENBEUTEL — Technische Universität Wien

Integrated optical interfaces for quantum emitters are a prerequisite for implementing quantum networks. In this context, tapered optical fibers with a nanofiber waist recently received significant attention as an efficient means of light-matter interaction. Due to the sub-wavelength diameter of the waist, a large fraction of the light propagates outside of the fiber as an evanescent wave. An emitter brought close to the surface of the nanofiber strongly interacts with the guided light field. Here, we couple single organic dye molecules to the guided modes of an optical nanofiber. The molecules are embedded in a nanocrystal host that provides photostability and due to the resulting inhomogeneous broadening, a means to spectrally address single molecules. The molecules are optically excited and their fluorescence is detected solely via the nanofiber interface without the requirement of additional optical access. I will discuss our results, where we observed the emission of bandwidth limited single photons by individually addressable molecules into the nanofiber. Furthermore we show our first results of the effect of single molecules on the fiber guided light. These results show, that our approach is a possible candidate for a versatile, fiber integrated constituent for quantum hybrid systems.

Q 54.2 Thu 10:45 K 0.023

On-Chip Quantum Optics in 1D: Single Molecules Coupled via a Dielectric Nanoguide — ●DOMINIK RATTENBACHER¹, ALEXEY SHKARIN¹, PIERRE TÜRSCHMANN¹, JAN RENGER¹, TOBIAS UTIKAL¹, STEPHAN GÖTZINGER^{2,1}, and VAHID SANDOGHDAR^{1,2} — ¹Max Planck Institute for the Science of Light (MPL), Erlangen, Germany — ²Friedrich-Alexander University (FAU) Erlangen-Nürnberg, Erlangen, Germany

One-dimensional subwavelength waveguides (nanoguides) promise efficient light-matter interactions between photons in the waveguide mode and individual emitters separated on length scales much longer than their transition wavelength [1,2]. We report on the coupling of organic dye molecules at low temperatures to the confined mode of a TiO₂-waveguide via the evanescent field and demonstrate external control on the resonance frequencies of the molecules via the DC Stark effect. This allows one to match the resonance frequencies of two emitters, thus controlling their coherent coupling via the nanoguide. In future, we want to boost our emitter-nanoguide coupling by the use of on-chip resonators [3]. This will enable us to build up a network of strongly coupled quantum emitters and study the emergence of polaritonic states [4].

- [1] S. Faez et al., *Phys. Rev. Lett.* **113**, 213601 (2014)
- [2] P. Türschmann et al., *Nano Lett.* **17**, 4941 (2017)
- [3] N. Rotenberg et al., *Optics Express* **25**, 5397, (2017).
- [4] H. R. Haakh et al., *Phys. Rev. A* **94**, 053840 (2016).

Q 54.3 Thu 11:00 K 0.023

Coherent coupling of a single molecule to a scanning Fabry-Pérot microcavity — ●DAQING WANG¹, HRISHIKESH KELKAR¹, DIEGO MARTIN-CANO¹, TOBIAS UTIKAL¹, STEPHAN GÖTZINGER^{2,1}, and VAHID SANDOGHDAR^{1,2} — ¹Max Planck Institute for the Science of Light, D-91058 Erlangen, Germany — ²Friedrich Alexander University Erlangen-Nuremberg, D-91058 Erlangen, Germany

We report on the coherent coupling of a single organic molecule to a scannable, tunable and broadband microcavity. The cavity consists of a planar distributed Bragg reflector and a micromirror with a small radius of curvature of 5 μm fabricated with focused ion-beam milling and coated with silver or dielectric multilayers. By integrating a thin organic crystal in the microcavity at liquid helium temperature, we are able to coherently couple individual molecules to a single mode of the cavity. Our experimental and theoretical results show that a single molecule can block the cavity transmission nearly perfectly. We present a strong modification of the phase and photon statistics of a laser beam and demonstrate improvement of single-molecule stimulated emission compared to free-space coupling in a tight focus.

Q 54.4 Thu 11:15 K 0.023

Coherent interaction of light with a single molecule near

a plasmonic nano-antenna — ●JOHANNES ZIRKELBACH, TOBIAS UTIKAL, STEPHAN GÖTZINGER, and VAHID SANDOGHDAR — Max Planck Institut für die Physik des Lichts, 91058 Erlangen, Deutschland

At cryogenic temperatures, single molecules in organic matrices are efficient quantum emitters. Using dedicated nanofabrication and combination of high-resolution spectroscopy with localization microscopy, we observed the radiative enhancement of the fluorescence of a single molecule in the vicinity of a plasmonic nanostructure. We demonstrate the modification of the molecule's excited state lifetime through Hanbury-Brown and Twiss measurements. Direct extinction measurements in reflection and transmission allow us to explore the change of linewidth in the zero-phonon-line and the coherent interaction among the incident laser beam, the molecular emission and the scattering from the gold nanostructure. We discuss the effect of spectral diffusion and dephasing for future experiments.

Q 54.5 Thu 11:30 K 0.023

Plasmonic enhancement at a liquid-solid interface — ●YAZGAN TUNA and VAHID SANDOGHDAR — Max-Planck-Institute for the Science of Light

Trapping and manipulation of small objects have been of great interest for a range of applications. Here we report on electrostatic trapping of charged nanoparticles between the aperture of a nanopipette and a glass substrate without the need for external potentials [1]. We employ our technique to the manipulation of a plasmonic nanoantenna in an aqueous solution in order to scan a trapped gold nanosphere in the near field of a single colloidal quantum dot embedded under the substrate surface. We demonstrate about 8-fold fluorescence enhancement over a lateral full width at half-maximum of about 45 nm [2]. We analyze our results with the outcome of numerical electromagnetic simulations under consideration of the electrostatic free energy in the trap. Our approach could find applications in a number of experiments, where plasmonic effects are employed at liquid-solid interfaces.

- [1] Kim, J. T. et al. *Nat. Commun.* **5**, 3380 (2014). [2] Y. Tuna et al. *ACS Nano*. **11**, 7674 (2017).

Q 54.6 Thu 11:45 K 0.023

Coupling of quantum emitters to plasmonic nanostructures in functional devices built from DNA — ●STEFFEN BOTH¹, MAXIMILIAN J. URBAN^{2,3}, KLAS LINDFORS⁴, NA LIU^{2,3}, and THOMAS WEISS¹ — ¹4th Physics Institute and Research Center SCoPE, University of Stuttgart — ²Kirchhoff Institute for Physics, University of Heidelberg — ³Max Planck Institute for Intelligent Systems, Stuttgart — ⁴Department of Chemistry, University of Cologne

In recent years, DNA nanotechnology has emerged to a powerful platform that allows the realization of functional artificial devices on the nanoscale. Recently, we demonstrated a DNA based nanomachine that uses two gold nanocrystals as a gear and can perform a reversible sliding movement. The sliding displacement can be in situ monitored by tracking the fluorescence of two attached fluorophores, which exchange energy via Förster resonance energy transfer (FRET). Electromagnetic interaction with the plasmonic resonances of the gold nanocrystals strongly affects the fluorophores, resulting in a complex response of the system. We present a theoretical investigation of this interaction and discuss the underlying energy transfer mechanisms.

Q 54.7 Thu 12:00 K 0.023

Ultranarrow Nonlinear Resonances in Hybrid Fiber-Plasmon Cavities — ●QI AI¹, LILI GUI¹, DOMENICO PAONE¹, BERND METZGER¹, MARTIN MAYER², and HARALD GIESSEN¹ — ¹4th Physics Institute and Research Center SCOPE, University of Stuttgart, Germany — ²Leibniz Institute of Polymer Research Dresden, Department of Physical Chemistry and Polymer Physics, Germany

We demonstrate substantial reduction of the LSPR linewidth of an Au nanorod by depositing it onto the surface of a tapered fiber. When the tapered diameter is reduced to about 1-3 μm , we observe signatures of strong coupling between the LSPR modes and the whispering gallery modes of the tapered fiber. This results in a very narrow hybrid plasmon-fiber resonance of the single Au nanorod, with a much higher quality factor Q (up to 300) when compared with that of an Au nanorod or an uncoated fiber with the same diameter. The strong cou-

pling leads to a significant enhancement of the peak scattering intensity at the plasmon resonance. Second-harmonic generation is boosted to typically three orders of magnitude higher conversion efficiency in comparison to that from a single uncoupled Au nanorod. Moreover, the nonlinear resonance is ultranarrow (below 10 nm), benefitting from its fundamental mode with a high quality factor. An analytical anharmonic oscillator model gives good agreement with the experimentally observed wavelength-dependent nonlinear emission. In addition, giant multi-photon photo-luminescence up to 5th order has been observed.

Q 54.8 Thu 12:15 K 0.023

Nonlinear 3D chiral plasmonics — •LILI GUI, MARIO HENTSCHEL, and HARALD GIESSEN — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, 70569 Stuttgart, Germany

Optical activity is a general phenomenon in nature, as many biomolecules are chiral. Chiral plasmonics is highly interesting for biosensing applications since natural chiral substances can be mimicked and a gigantic chiroptical response can be obtained due to the superchiral near-field. Exploration of nonlinear chiroptical effects in chiral plasmonic nanostructures is even more desired since the nonlinear chiroptical effects might be orders of magnitude higher than their linear counterparts. Although diverse chiral plasmonic systems have been investigated, the underlying physical mechanism for nonlinear plasmonic chirality is far from being understood and further quantitative modelling is particularly missing.

Here we study the third-order chiroptical response of 3D chiral structures consisting of identical corner-stacked gold nanorods, the so-called plasmonic Born-Kuhn analog. We experimentally investigate the third-harmonic spectroscopy with both left- and right-handed fundamental light. Utilizing a coupled anharmonic oscillator model that includes phase retardation of the incoming fundamental and outgo-

ing generated wave, we are able to retrieve the third-order chiroptical effects. This model is quite instructive for the efficient design of plasmonic chiral structures for giant nonlinear circular dichroism and might pave the way towards ultrasensitive nonlinear chiral sensing.

Q 54.9 Thu 12:30 K 0.023

Measuring Quantum Yield of Organic Dyes by Lifetime Modifications Using a Metal Ball — •ERSAN ÖZELCI^{1,3}, UTE RESCH-GENGER^{2,3}, and OLIVER BENSON^{1,3} — ¹Humboldt-Universität zu Berlin — ²Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin — ³School of Analytical Sciences Adlershof (SALSA), Berlin

A key parameter for all fluorescence applications presents the photoluminescence quantum yield which can be determined by optical methods either relatively compared to a fluorescence quantum yield standard with known QY or absolutely with e.g., integrating sphere spectroscopy [1]. An interesting alternative, that can be even extended to single emitters, presents the so-called silver ball method which utilizes the modification of the spontaneous emission of dyes in the neighborhood of metallic surface [2,3].

In our experiment, the silver coated spherical ball is placed on PMMA coated glass substrate. Then, confocal fluorescence lifetime imaging (FLIM) microscope is performed using scanning piezo stage. FLIM maps with concentric rings centered with respect to the contact point of the sphere are obtained. The variation of the fluorescence lifetime as a function of the molecule to sphere distance are extracted from the FLIM map. We fitted the data to theoretical curves and derived the QY. We will discuss planned experiments towards an integration of our approach with microfluidics setups.

[1] C. Würth et al., Nat Protocols 2013.

[2] K. Drexhage et al, J.Lumin, 1-2, 693 (1970).

[3] Lunnemann et al, ACS Nano 2013, 5984-5992.