MQC-meeting Fall 2017

Date: 13th of October, 2017

Location: Technische Universität München

Zentrum für Nanotechnologie und Nanomaterialien (ZNN)

Am Coulombwall 4a

85748 Garching

Groundfloor seminar room

Time schedule:

1:30 pm	Come-together with coffee & tea
2:00 pm	Tatjana Wilk: Quantum nonlinear optics with a single atom strongly coupled to a cavity
2:30 pm	Kai Müller: Achievements and surprises in quantum nanophotonics
3:00 pm	Coffee & tea refreshment

MUNICH **QUANTUM** CENTER

Quantum nonlinear optics with a single atom strongly coupled to a cavity

Tatjana Wilk, Christoph Hamsen, Nicolas Tolazzi, and Gerhard Rempe

Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Single atom cavity quantum electrodynamics (CQED) in the strong coupling regime provides an ideal platform for the observation of nonlinear optical effects on the level of individual photons. A prominent example is single-photon blockade, where the absorption of one photon blocks the absorption of further photons, and which has been observed using a two-level atom [1]. Recently, the concept of photon blockade has been extended to multi-photons and a two-photon blockade, where two photons block the absorption of further photons, has been demonstrated [2]. More quantum nonlinear effects can be observed if, instead of a two-level atom, one with three or four levels is used. For example, a three-level atom showing cavity electromagnetically induced transparency [3] allows for an all optical control of the photon statistics of the transmitted light field [4] and for four-wave-mixing on the single-photon level. Furthermore, a four-level atom with strong coupling to two different cavity modes gives the possibility to implement controlled coupling between the two light fields in the cavity, resulting in, e.g., mutual switching [5] or conjunct tunneling of photons. First experimental results of quantum nonlinear effects with multi-level atoms will be presented.

[1] K. M. Birnbaum et al., Nature 436, 87 (2005).

[2] C. Hamsen, K. N. Tolazzi, T. Wilk, G. Rempe, Phys. Rev. Lett. 118, 133604 (2017).

[3] M. Mücke et al., Nature 465, 755 (2010).

[4] J. A. Souza et al., Phys. Rev. Lett. 111, 113602 (2013).

[5] F. Le Kien, A. Rauschenbeutel, Phys. Rev. A 93, 013849 (2016).

Achievements and surprises in quantum nanophotonics

Kai Müller

Walter Schottky Institut, Technical University of Munich
Am Coulombwall 4, 85748 Garching, Germany

Optically active semiconductor nanostructures are promising candidates for building blocks in future photonic quantum technologies, including quantum information processing, quantum communication, quantum sensing and quantum metrology. Embedding a single quantum emitter or optically-active spin qubit, such as self-assembled InAs quantum dots (QDs) or color centers, into a tailored nanophotonic environment allows to control its interaction with the outside world or to efficiently couple it to integrated nanophotonic circuits.

First, I will review the potential of resonantly excited two-level systems for the on-demand generation of single photons. I will discuss fundamental limitations and demonstrate that resonantly driven two-level systems are surprisingly also capable of generating two-photon pulses [1]. By making use of nanophotonic resonators which strongly localize the optical field, it is possible to achieve a very strong light–matter interaction. Embedding self-assembled QDs into photonic crystal cavities with ultra-small mode volume allows to reach the strong coupling regime where the formation of hybridized light-matter states results in effective photon-photon interactions and enables the on-chip generation of nonclassical light [2-3]. Exploiting interference effects which are intrinsic to the photonic crystal platform [4] allows to significantly improve the signal to noise ratio and enables the on-chip generation of indistinguishable photons with state-of-the-art metrics [5].

[1] K. A. Fischer, L. Hanschke, J. Wierzbowski, T. Simmet, J. J. Finley, J. Vuckovic and K. Müller, *"Signatures of two-photon pulses from a quantum two-level system"*, Nature Physics 13, 649–654 (2017)

[2] K. Müller, A. Rundquist, K. A. Fischer, T. Sarmiento, K. G. Lagoudakis, Y. A. Kelaita, C. Sanchez Munoz, E. del Valle, F. P. Laussy, and J. Vuckovic, *"Coherent generation of nonclassical light on chip via detuned photon blockade"*, Physical Review Letters 114, 233601 (2015)

[3] K. Müller, K. A. Fischer, A. Rundquist, C. Dory, K. G. Lagoudakis, T. Sarmiento, Y. A. Kelaita, V. Borish and J. Vuckovic, *"Ultrafast Polariton-Phonon Dynamics of Strongly Coupled Quantum Dot-Nanocavity Systems"*, Physical Review X 5, 031006 (2015)

[4] K. A. Fischer, K. Müller, A. Rundquist, T. Sarmiento, A. Y. Piggott, Y. Kelaita, C. Dory, K. G. Lagoudakis, and J. Vuckovic, *"Self-homodyne measurement of a pulsed Mollow triplet in the solid state"*, Nature Photonics 10, 163-166 (2016)

[5] K. Müller, K. A. Fischer, C. Dory, T. Sarmiento, K. G. Lagoudakis, A. Rundquist, Y. A. Kelaita and J. Vuckovic, *"Self-homodyne enabled generation of indistinguishable photons"*, Optica 3, 931-936 (2016)