Q 61: Quantum Effects (Cavity QED)

Time: Friday 10:30–12:30 Location: S Gr. HS Maschb.

Q 61.1 Fri 10:30 S Gr. HS Maschb.

Developing fiber cavities for quantum communication — •Steffen Gohlke, Jonas Schmitz, Pascal Kobel, Moritz Scharfstädt, Vidhya Sasidharan Nair, Moritz Breyer, Vidhya Sasidharan Nair, Pia Fürtjes, and Michael Köhl — Physikalisches Institut, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany

We are working towards new ways of employing fiber cavities in quantum communication. Due to their small mode volume, fiber cavities offer strong coupling between light and matter while providing a high collection efficiency of photons at the same time. According to cavity-QED this allows for building high bandwidth quantum networks.

We realized high quality structures machined on fiber tips by using various shooting techniques at a recently built CO2 laser setup. This allows us to construct new types of fiber cavities with tailored properties.

Q 61.2 Fri 10:45 S Gr. HS Maschb.

Production of Mode-Matched Fiber Fabry-Pérot Cavities — •David Röser, Hannes Pfeifer, Deepak Pandey, Wolfgang Alt, and Dieter Meschede — Institute for Applied Physics, University of Bonn

Fiber Fabry-Pérot cavities are formed by mirrors directly manufactured onto fiber end facets. Efficient coupling into these high finesse cavities benefits from spatial mode matching from the injecting single mode fiber (SM) to the cavity mode [1, 2].

We show how the mode matching condition can be met by splicing the injection fiber to a graded-index (GRIN) fiber lens. An attached large-core multimode (MM) fiber section acts as a mirror substrate [3]. For this purpose we cleave GRIN and MM fiber to well defined lengths with precision below 5 micrometer.

The mirror surface is afterwards micro-machined on the fiber end tip by CO2 laser pulse ablation at 9.3 micrometer wavelength [4]. Intensity stabilized laser pulses are applied in single and multi-shot technique for shaping the fiber end facets with vanishing ellipticity. Subsequently, high reflective coatings are applied to produce high quality fiber mirrors for applications including quantum information processing, spectroscopy or sensing, which profit from enhanced light-matter interaction at the single photon level.

[1] J. Gallego et al., Appl. Phys. B 122:47 (2016)
[2] B. Brandstätter et al., Rev. Sci. Instrum. 84, 123104 (2013);
[3] G. Gulati et al., Scien. Rep. 7, 5556 (2017)
[4] D. Hunger et al., NJP. 12, 065038 (2010)

Q 61.3 Fri 11:00 S Gr. HS Maschb.

Continous and coherent field generation on the single-photon level by a single atom — •Nicolas Tolazzi, Bo Wang, Jonas Neumeier, Tatjana Wilk, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Straße 1, 85748 Garching

We report on the observation of continuous and coherent frequency generation using a single atom inside of an optical high finesse resonator via a four wave mixing process. This effect uses a closed cycle in the system's energy level structure to produce a new and continuous output field on the level of single photons when driven with appropriate input fields. Along the path of bringing the input driving fields to the level of individual photons we present three different experimental configurations in this system each with a successively lower number of classical driving beams while maintaining an output on the level of single photons. We investigate the newly generated field in the spectral domain by heterodyne detection as well as its photon statistics by means of the $g^{(2)}$ correlation function which shows substantially different features for different driving configurations. We show that the output field exhibits non-classical photon correlations with very long coherence times when we exploit the energy level structure available in the strong coupling regime of cavity quantum electrodynamics. In this situation the photon statistic of the output field can be tuned all optically from sub- to super-Poissonian by just changing the power of one of the input fields.

Q 61.4 Fri 11:15 S Gr. HS Maschb.

Storage and retrieval of short light pulses via fiber-based atom-cavity systems — •Tobias Macha, Wolfgang Alt, Elvira Keiler, Hannes Pfeifer, Eduardo Urunuela, and Dieter Meschede — Institut für Angewandte Physik, Bonn, Deutschland

We demonstrate the storage and retrieval of short pulses by employing a single rubidium atom coupled to a fiber-based, high-bandwidth optical resonator and an assisting control laser. In the adiabatic limit, we use optimized control pulses for single-photon generation by adapting the impedance-matching based storage scheme of Dilley et al.[1] and the concept of time-reversal symmetry. We achieve probabilities of 66 % for generating a single, arbitrarily-shaped photon into the cavity mode upon a trigger signal. Beyond the adiabatic regime, where pulse lengths approach the cavity field decay time, we determine the optimal control pulse by numerical simulations of the system via a Lindblad master equation approach. We investigate the dependence of the storage efficiency on various control pulse parameters, such as the peak amplitude or the delay with respect to the arrival of the light pulse. The successful storage of an incoming, coherent wavepacket with a temporal extent below 10 ns encourages *hybrid experiments* with semiconductor quantum dots as light sources. Our system offers a way to solve the bandwidth-mismatch dilemma, as previously demonstrated by Purcell broadening of the atomic emission [2].

[1] PRA 85, 023834 (2012)
[2] PRL 121, 173603 (2018)

Q 61.5 Fri 11:30 S Gr. HS Maschb.

Fiber resonator photonics platform for quantum optics applications — •Stefan Häussler, Richard Waltrich, Gregor Bayer, and Alexander Kubanek — Institut für Quantenoptik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm

Solid-state quantum emitters offer one promising platform for various quantum technology applications like quantum repeaters. Especially color centers in diamond, like the negatively charged nitrogen vacancy (NV^-) and silicon vacancy (SiV^-) center have been extensively studied due to its outstanding spin and optical properties.
We present a light matter interface based on a high quality fiber Fabry Perot microcavity and color centers in different host materials to overcome the remaining challenges for a scalable use namely low rate of coherent photons, poor extraction efficiency out of the host material and low quantum yield. We show coupling of an SiV^- ensemble located in a thin ($\sim 200\,\mathrm{nm}$) diamond membrane and observe cavity funneling for different single photon emitters. We further investigate the different systems towards scattering losses to estimate possible Purcell enhancement in high Q resonators.

Q 61.6 Fri 11:45 S Gr. HS Maschb.

Observation of Multimode strong coupling of laser-cooled atoms to fiber-guided photons — •Martin Blaha[1], Aisling Johnson[1], Alexander Ulanov[2], Jürgen Volz[1], Philipp Schneeweiss[1], and Arno Rauschenbeutel[3] — [1]TU Wien, 1020 Wien, Austria — [2]Russian Quantum Center, 143025 Moscow, Russia — [3]Humboldt-Universität zu Berlin, 10099 Berlin, Germany

We report on the observation of multimode strong coupling between a cloud of cold atoms and a nanofiber-based fiber ring resonator. This novel regime of light-matter coupling is reached when the collective coupling strength between a cloud of laser-cooled Cesium atoms and the light field exceeds the free spectral range (FSR) of the resonator, leading to strong coherent coupling of the atoms with more than one longitudinal resonator mode simultaneously [1]. The mode cross-section of our resonator containing an optical nanofiber is independent of its length, such that using a 30 m long fiber ring resonator yields an exceptionally small free spectral range of 7.1 MHz, while at the same time having large collective coupling strengths [2]. The measured transmission spectra provide clear experimental evidence for multimode strong coupling of the loaded cavity, yielding coupling strengths as large as twice the FSR. In this regime of cavity QED atoms can mediate interactions between photons in different resonator modes, through which we envision to employ for the generation of novel nonclassical photonic states.

[1] D. Meiser et al., Phys. Rev. A 74, (2006).
[2] P. Schneeweiss et al., Opt. Lett. 42, (2017).

Q 61.7 Fri 12:00 S Gr. HS Maschb.

Transient analysis of continuous-wave lasing from cold Ytterbium atoms — •Anna Breunig, Dmitriy Sholokhov, Hannes Gothe, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

We analyse lasing from cold Ytterbium-174 atoms that are magneto-optically trapped inside a 5 cm long high-finesse cavity. Trapping and cooling happens on the $^1S_0-^1P_1$ transition. The atoms are laterally pumped on the $^1S_0-^3P_1$ transition and emit frequency-shifted light into the cavity. This lasing relies on a two photon process including the trap light and was previously characterized for its power, frequency and polarization properties [1]. Here, we focus on the transient dynamics when the trap or pump light is switched on or off.

[1] H. Gothe et al., to appear in PRA, arxiv:1711.08707 (2018).

Q 61.8 Fri 12:15 S Gr. HS Maschb.

Chiral light-matter interaction in the ultra strong coupling limit — •Sahand Mahmoodian and Klemens Hammerer — Institute for Theoretical Physics, Leibniz University, Hannover

Chiral light-matter interaction occurs when a circularly polarized optical transition is coupled to a nanophotonic waveguide whose counter-propagating modes are engineered to be counter circulating. This leads to exciting new physics including directional emission, non-reciprocal optical dynamics, and spin-photon coupling. These phenomena can all be described within the standard rotating-wave approximation and occur because the circularly polarized transition only interacts with one of the directional modes of the waveguide; e.g. it couples to the forward mode but is orthogonal to the backward mode which is then completely absent from the interaction Hamiltonian. In this talk I will show that when including counter-rotating wave terms, the previously non-interacting mode now enters in the interaction Hamiltonian. The Hamiltonian features rotating wave interactions with, for example, the forward propagating mode and counter-rotating interactions with the backward mode. I show that this novel Hamiltonian features a symmetry which allows writing a compact ansatz for its eigenstates. The ground states of the Hamiltonian feature strong spin-photon entanglement. Additionally, the counter-rotating wave terms also lead to modified quench dynamics such as the damping of typically observed Rabi oscillations.