Q 44: Quantum Effects (Cavity QED)

Time: Wednesday 14:00–16:00 Location: K 1.013

Group Report Q 44.1 Wed 14:00 K 1.013

Collective atom–photon interactions in complex environments — •Stefan Yoshi Buhmann[1,2], Roberta Palacino[3], Saeideh Esfandiarpour[1], and Robert Bennett[1] — [1]University of Freiburg, Freiburg, Germany — [2]Freiburg Institute for Advanced Studies — [3]University of Palermo

We review how macroscopic quantum electrodynamics in linear media can be used to describe the quantised electromagnetic field in arbitrary geometries and its interaction with one or several identical atoms.

For two emitters coherently sharing an excitation in free space, one recovers the well known phenomenon of a superradiant enhancement or suppression of decay, depending on the initial state. We show that this behaviour can be manipulated by a nearby metal surface in a generalised Purcell effect [1].

An even stronger impact of environments can be found in a cavity environment. We find that the strong coupling of two atoms with a single cavity mode can lead to collective Rabi oscillations which sensitively depend on the atomic positions with respect to the mode profile [2].

[1] R. Palacino, R. Passante, L. Rizzuto, P. Barcellona, S. Y. Buhmann, J. Phys. B **50**, 154001 (2017).

[2] S. Esfandiarpour, R. Bennett, H. Safari, S. Y. Buhmann, `arXiv:1708.05586` (2017).

Q 44.2 Wed 14:30 K 1.013

Strong Purcell effect on a neutral atom coupled to a fiber cavity — •Eduardo Urunuela, Wolfgang Alt, Jose Gallego, Tobias Macha, Miguel Martinez-Dorantes, Deepak Pandey, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany

We observe sixfold Purcell broadening of an atomic resonance line of a ^{87}Rb atom, that is strongly coupled to a single-sided fiber-based Fabry–Pérot cavity. In our system, a single atom is trapped in a 3D optical lattice inside the cavity and externally driven by a near-resonant laser. The enhancement of the photon emission rate into the cavity mode corresponds to a cooperativity well beyond unity, with the resonator mode collecting up to 90% of the emitted photons. These photons build up an intra-cavity field that imprints a back-action on the atom's driving conditions, leading to an enhancement of more than an order of magnitude of the total atomic emission. The photon leakage through the transmissive mirror is the dominant factor of the cavity field decay ($\kappa \approx 2\pi \times 70\,\mathrm{MHz}$), thus offering a high-bandwidth and fiber-coupled channel for single-photon interfacing. These properties are highly desirable in quantum network nodes such as fast and efficient quantum memories and single-photon sources.

Q 44.3 Wed 14:45 K 1.013

A Versatile Production Facility for Fiber-Based Mirrors — •Michael Kubista, Deepak Pandey, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

We report on a production facility for creating miniaturized fiber-based Fabry-Perot cavities, which have numerous applications in quantum information technology. A CO2 laser at 9.3 μm is used to produce mirror surfaces on fiber end facets using laser ablation [1], taking advantage of the higher absorption of silica glass at this wavelength [2]. Beam shaping and polarization control are employed to reduce mirror ellipticity. To reconstruct the profile of the mirror surfaces, a high-resolution inline Mirau interferometer has been built. Further steps will include the implementation of a multi-shot technique to create larger mirrors [3], and the use of GRIN-lenses to improve mode matching efficiency [4]. These versatile techniques will enable us to produce cavities for a wide range of applications such as quantum communication, surface analysis, and opto-mechanical devices.

[1] D. Hunger, T. Steinmetz, Y. Colombe, C. Deutsch, T. W. Hänsch, and J. Reichel, N. J. Phys. 12, 065038 (2010) [2] M. Uphoff, M. Brekenfeld, G. Rempe, S. Ritter, N. J. Phys. 17, 013053 (2015) [3] K. Ott, S. Garcia, R. Kohlhaas, K. Schüppert, P. Rosenbusch, R. Long, and J. Reichel, 9839-9853 (2016) [4] G. Gulati, H. Takahashi, N. Podoliak, P. Horak, and M. Keller, Scientific Reports 7, 5556 (2017)

Q 44.4 Wed 15:00 K 1.013

Towards electrooptically controlled cavity QED with rare-earth ion doped lithium niobate — •Thomas Kornher[1], Roman Kolesov[1], Kangwei Xia[2], Hans-Werner Becker[3], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universtät Stuttgart, Stuttgart, Germany — [2]Department of Physics, The Chinese University of Hong Kong, Hong Kong, China — [3]RUBION, Ruhr-Universitat Bochum, Bochum, Germany

Rare-earth ions doped into crystals are known for narrow optical transitions, long spin coherence times and optical access to their nuclear spins, which makes them suitable for quantum information storage applications. Boosting the emission rate of long-lived radiative transitions exhibited by rare-earth ions doped into solid hosts by means of micro-resonators can provide enhanced spin initialization for memory purposes and improved optical access down to the single ion level potentially. We present on-chip light matter interfaces composed of thin film lithium niobate disk resonators implantation-doped with Ytterbium ions. Measured devices show quality factors of over 10^5 in disk resonators with a mode volume of about $100^*(\lambda/\mathrm{n})^3$ and can be electrooptically controlled. We furthermore present experimental evidence of Purcell enhancement on the Yb $^2\mathrm{F}_{7/2}$-$^2\mathrm{F}_{5/2}$ transition at 980 nm.

Q 44.5 Wed 15:15 K 1.013

Coupling of SiV$^-$ ensemble in thin diamond membrane to fiber based microcavity — •Stefan Häussler[1], Richard Waltrich[1], Kerem Bray[2], Fedor Jelezko[1], Igor Aharonovich[2], and Alexander Kubanek[1] — [1]Institute for Quantum Optics and Center for Integrated Science and Technology, Ulm University, D-89081 Ulm, Germany — [2]School of Mathematical and Physical Sciences, University of Technology Sydney, Ultimo, New South Wales 2007, Australia

On the route to the realization of various quantum technology applications like quantum repeaters solid-state quantum emitters such as color centers in diamond appear to be promising candidates. The remaining challenges like low rate of coherent photons, poor extraction efficiency out of the host material and low quantum yield especially in the case of the silicon-vacancy center can thereby be overcome using a resonant microcavity opening the possibility for a scalable use.
We show coupling of an ensemble of negatively charged silicon-vacancy (SiV$^-$) centers located in a thin ($\sim 200\,\mathrm{nm}$) diamond membrane to a fiber-based microcavity at room temperature. The diamond membrane does not lead to significant scattering losses nor to formation of "diamond-like" cavity modes. Such hybrid systems enabling high cavity quality factors and at same time small mode volumes leading to improved optical properties and increased emission rate of the color centers. Further improvement of the cavity quality enables generation of photons with a high degree of indistinguishability from broadband emitter at room temperature.

Q 44.6 Wed 15:30 K 1.013

Polarization analysis of lasing from cold Ytterbium atoms — •Dmitriy Sholokhov, Hannes Gothe, Anna Breunig, and Jürgen Eschner — Universität des Saarlandes, Saarbrücken

We analyse the laser process from cold Ytterbium atoms that are magneto-optically trapped inside a 5 cm long high-finesse cavity. The atoms are laterally pumped to one of the three $^3\mathrm{P}_1$ Zeeman sub levels and emit frequency-shifted light into the cavity. This lasing relies on a two photon process including trap light and was previously characterized for its power and frequency properties [1]. Here, we focus on the polarization dependence between pump and cavity output and infer information about the spatial position of the lasing atoms.

[1] H. Gothe et al., arXiv:1711.08707 (2017)

Q 44.7 Wed 15:45 K 1.013

Quenches across the self-organization transition in multimode cavities — Tim Keller[1], Valentin Torggler[2], •Simon B. Jäger[1], Stefan Schütz[1,3], Helmut Ritsch[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck, Austria — [3]icFRC, IPCMS (UMR 7504) and ISIS (UMR 7006), University of Strasbourg and CNRS, 67000 Strasbourg, France

A cold dilute atomic gas in an optical resonator can be radiatively cooled by coherent scattering processes when the driving laser frequency is tuned close but below the cavity resonance. When sufficiently illuminated, moreover, the atoms' steady state undergoes a phase transition from a homogeneous distribution to a spatially organized Bragg grating. We characterize the dynamics of this self-ordering process in the semi-classical regime when distinct cavity modes with commensurate wavelengths are quasi-resonantly driven by laser fields via scattering by the atoms. The lasers are simultaneously applied and uniformly illuminate the atoms, their frequencies are chosen so that the atoms are cooled by the radiative processes, their intensity is either suddenly switched or slowly ramped across the self-ordering transition. Numerical simulations for different ramp protocols predict that the system exhibits long-lived metastable states, whose occurrence strongly depends on initial temperature, ramp speed, and number of atoms.