Q 16: Quantum Optics

Time: Thursday 16:30–18:30 Location: P

Q 16.1 Thu 16:30 P

Incoherent seeding of a nonlinear interferometer — •Joshua Hennig[1,2], Björn Haase[1,2], Mirco Kutas[1,2], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Center for Materials Characterization and Testing, Fraunhofer ITWM, Kaiserslautern, Germany — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern (TUK), Germany

Quantum sensing and imaging with undetected photons based on nonlinear interferometry has been demonstrated in various spectral regions in the past few years. Due to their low photon energy in the terahertz frequency range thermal photons contribute to the signal at room temperature. In order to investigate the effect of such incoherent photons on a nonlinear interferometer, we use an incoherent seed on a Mach-Zehnder approach based on [1]. Here, spontaneous parametric down conversion of two nonlinear crystals pumped by a 532 nm laser leads to correlated pairs of signal and idler photons at wavelengths of 810 nm and 1550 nm, respectively. While the idler photons interact with an object, only the signal photons, which then carry the object's information, are detected with a scientific CMOS camera. That way, the information can be transferred from one wavelength to another. By seeding the idler of this experiment incoherently at 1550 nm, we find that the detected count rate can be increased by at least an order of magnitude while the visibility of the interference reaches up to 90% compared to about 70% without seeding. This can be beneficial in applications with low count rates or where detectors are sparse.

[1] Lemos et al., Nature 512(7515), 409-412 (2014)

Q 16.2 Thu 16:30 P

Integrated free-space cavity optomechanics with AlGaAs heterostructures — •Anastasiia Ciers[1], Sushanth Kini Manjeshwar[1], Jamie M. Fitzgerald[2], Shu Min Wang[1], Philippe Tassin[2], and Witlef Wieczorek[1] — [1]Department of Microtechnology and Nanoscience, Chalmers University of Technology, 41258 Gothenburg, Sweden — [2]Department of Physics, Chalmers University of Technology, 41258 Gothenburg, Sweden

Cavity optomechanics exploit the coupling of mechanical resonators to light fields with applications in quantum-enhanced sensing, quantum networks, or for foundational studies. Multielement systems, whereby multiple mechanical resonators couple to the common light field, may allow reaching the single-photon strong coupling regime and open a path to explore collective effects such as synchronization or entanglement generation between mechanical resonators. Realization of these experiments is challenging due to the prerequisite of extremely precise positioning of highly reflective mechanical resonators within the cavity. In our work we address this challenge and fabricate and characterize suspended single- and bi-layer photonic crystal membranes in AlGaAs heterostructures, which simultaneously integrate a highly reflective distributed Bragg reflector. Our approach allows to create integrated, closely spaced membrane systems embedded in an optical microcavity. With proper design such systems can exhibit photonic bound states in the continuum, which can further increase the light-matter interaction. Our work paves the way for a versatile optomechanics platform realizing multielement mechanical resonators in high-Finesse microcavities.

Q 16.3 Thu 16:30 P

Nano-Macro Transition of NV centers' Optical Properties in Nanodiamond Agglomerates — •Jonas Gutsche, Ashkan Zand, Marek Bültel, and Artur Widera — Department of Physics, University of Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Color centers in diamond have developed to a fundamental building block of recent quantum technology as a single-photon source or optical quantum probe of magnetic fields. However, when such devices are ever further miniaturized, the host crystal of color centers decreases, leading to nanoscale effects. One of these nanoscale effects is the transition of the fluorescence lifetime towards higher timescales due to a change in the local density of states (DOS).

We present a systematic fluorescence lifetime study on different agglomeration states of nanodiamonds containing nitrogen-vacancy (NV) centers. The results reveal a heuristic transition on a length scale of approximately 1.8 μm, being in the order of three wavelengths of the NV center's emission. A simple theoretical model is employed to explain this transition due to a change of the DOS stemming from the nanodiamonds nearby and affecting the local refractive index. We find good agreement between measurement and theoretical prediction, taking the surrounding medium within 130 nm to 300 nm to calculate the local refractive index. This length scale of a quarter emission wavelength defines a transition between the nano- and macroscopic scale for optical properties.

Q 16.4 Thu 16:30 P

Collective emission of nitrogen-vacancy centers in nanodiamond agglomerates — •Ashkan Zand, Jonas Gutsche, Marek Bültel, and Artur Widera — Technische Universität Kaiserslautern und Landesforschungszentrum OPTIMAS, 67663 Kaiserslautern, Germany

Individual quantum emitters form a fundamental building block in emerging quantum technology. Collective effects, such as superradiance in ensembles of emitters, might improve the performance of such applications even further. In the transition to larger scales, however, correlations of collective systems might be covered in the environmental background.

We will present the experimental observation of Dicke-superradiance of nitrogen-vacancy (NV) centers in highly-doped nanodiamond agglomerates. Fluorescence-lifetime measurements show results consistent with increased collective effects in larger agglomerates. By contrast, the second-order correlation function fails to quantify collective effects for the case of an ensemble of collectively contributing domains to the emission. Therefore, a new figure of merit to trace and quantify collective emission based on the fluctuation statistics of the emitted light is introduced. Analyzing the quantity, we reveal increased collective effects of large diamond agglomerates.

While the experimental data originates from NV centers in diamond, the theoretical model presented here applies to a variety of other emitters such as other color centers or quantum dots, shedding light on collective effects in scalable quantum systems.

Q 16.5 Thu 16:30 P

Analyzing fluorescence lifetime of NV center in nanodiamonds using a phasor approach — •Elnaz Bazzazi, Jonas Gutsche, Ashkan Zand, and Artur Widera — Technische Universitüat Kaiserslautern und Landesforschungszentrum OPTIMAS, 67663 Kaiserslautern, Germany

The nitrogen-vacancy (NV) center in diamond has been object of intense research in quantum technology, for instance, sensing quantum information. Examining their photoluminescence in a varying environment allows engineering, controling, and detecting quantum properties of the NVs. A standard observable to sense the quantum optical properties of NVs is the fluorescence lifetime.

Here, we compare two methods used to analyze fluorescence lifetime data from highly-doped nanodiamonds. Traditionally, the data obtained by time-domain measurements from single-photon-counting modules, for example, is evaluated based on non-linear fitting. This requires choosing an appropriate model and fit function which is not always evident. Alternatively, one can consider a phasor analysis as a fit-free method employing the Fourier transform of time-domain data. We outline the principle equivalence and practical difference of both methods on data taken for lifetime measurements with pronounced non-exponential decay.

Q 16.6 Thu 16:30 P

Observation of a non-Hermitian phase transition and response dynamics in an optical quantum gas — •Aleksandr Sazhin[1], Fahri Emre Öztürk[1], Göran Hellmann[1], Jan Klaers[2], Frank Vewinger[1], Tim Lappe[1], Johann Kroha[1], Vladimir Gladilin[3], Michiel Wouters[3], Julian Schmitt[1], and Martin Weitz[1] — [1]Universität Bonn — [2]University of Twente — [3]Universiteit Antwerpen

Quantum gases of light, such as photon or polariton condensates in optical microcavities, are collective quantum systems enabling a tailoring of dissipation from, for example, cavity loss. This gives access to new system states and phases, which would not be accessible otherwise. We experimentally demonstrate a non-Hermitian phase transition of a photon Bose-Einstein condensate to a dissipative phase characterized by a biexponential decay of the condensate's second-order coherence[1]. Although Bose-Einstein condensation is usually connected to lasing by a smooth crossover, the observed phase transition separates the biexponential phase from both lasing and an intermediate, oscillatory condensate regime. In more recent experiments, we study the response dynamics of the photon Bose-Einstein condensate to an external perturbation of the condensate photon number. Depending on the perturbation strength, we identify linear and nonlinear relaxation behavior, which we compare to the (intrinsic) second-order correlations. Our approach can be used to study a wide class of dissipative quantum phases in topological or lattice systems. [1]Oeztuerk et al., Science 372 (6537), 88 (2021)

Q 16.7 Thu 16:30 P

Rydberg quantum optics in an ultracold Rubidium gas — •Nina Stiesdal[1,2], Hannes Busche[1], Alireza Aghababaie[1], Lukas Alheit[1], Cedric Wind[1], and Sebastian Hofferberth[1] — [1]Institute für Angewandte Physik, University of Bonn — [2]Institute for Physics, Chemistry and Pharmacy, University of Southern Denmark

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. This approach forms the basis of a growing Rydberg quantum optics toolbox, which already contains photonic logic building-blocks such as single-photon sources, switches, transistors, and two-photon gates.

Here we discuss how we experimentally implement a 1d chain of Ryderg superatoms, each formed by an individually trapped atomic cloud containing ca. N=10000 atoms. With this system we can study the dynamics of single two level systems strongly coupled to quantized propagating light fields. The directed emission of the superatoms back into the probe mode makes this free-space chain of superatoms identical to emitters coupled to a 1d optical waveguide, thus realizing a cascaded quantum system coupled to a single probe mode. This has recently allowed us to realize a multi-photon subtractor, which we present here.

Q 16.8 Thu 16:30 P

Composite pulses for nitrogen-vacancy colour centres — Josselin Bernardoff, •Jan Thieme, Ricky-Joe Plate, Manika Bhardwaj, Markus Debatin, and Kilian Singer — Universität Kassel, Kassel, Deutschland

We present numerical and preliminary experimental results of the application of tailored composite pulses [1] to shape the excitation profile addressing only selected quantum states in the system. By using analytical methods applied to the Rosen-Zener excitation model [2], we derive excitation profiles for a broadband excitation profile with respect to detuning and pulse duration. Towards this goal we are using an arbitrary waveform generator to supply these pulses to single nitrogen-vacancy colour centres. As an outlook we will show how the derived pulse sequences can be extended to qubit manipulation in trapped ions.

[1] B. T. Torosov and N. V. Vitanov, Phys. Rev. A 83, 053420 (2011). [2] N. Rosen and C. Zener, Phys. Rev. 40, 502 (1932).

Q 16.9 Thu 16:30 P

Microwave Driving of Dipole-Forbidden Transitions in the Electronic Ground State of the NV Center — •Florian Böhm[1], Niko Nikolay[1], Sascha Neinert[1], Christoph Nebel[2], and Oliver Benson[1] — [1]Institut für Physik & IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [2]Nanomaterials Research Institute, Kanazawa University, Japan

The nitrogen-vacancy (NV) center in diamond is one of the most widely studied solid-state spin systems, as it can be used in a wide variety of quantum applications [1]. It features an electronic qutrit ground state with long coherence times, which can be coherently controlled at room temperature by microwave pulses. The broad range of possible applications the NV center offers stimulates a great interest in developing new control schemes or adapting control schemes to the NV center.

For this reason, we investigate the application of two-photon microwave pulses to a single NV center, in order to directly drive the spin-forbidden transition between the $m_S = -1 \leftrightarrow m_S = +1$ sublevels. More precisely, we show the experimental implementation of two different two-photon schemes, stimulated Raman transitions (SRT) and stimulated Raman adiabatic passage (STIRAP) [2]. We show, that both schemes can successfully drive the dipole-forbidden transition and compare the experimental results to numerical simulations. Furthermore, we compare both schemes on their robustness and success of the spin-swap, as well as their experimental challenges.

[1] Doherty, Marcus W., et al., Physics Reports 528.1 (2013): 1-45
[2] Böhm, Florian, et al., Phys. Rev. B, 104.3 (2021): 035201

Q 16.10 Thu 16:30 P

Rydberg quantum optics in ultracold Ytterbium gases — •Thilina Muthu-arachchige, Rafael R. Paiva, Jiachen Zhao, Mohammad Noaman, and Sebastian Hofferberth — Institut for Applied Physics, University of Bonn, Wegelerstraße 8, 53115, Bonn

Rydberg systems offer exciting prospects for future all optical quantum computing due to the large scaling and also for investigation of exotic many-body quantum states of light. Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons paves the way to realize and control high optical nonlinearities at the level of single photons. In our group, we explore this novel approach in multiple experimental setups.

Here we present the progress with our new Rydberg quantum optics experiment utilizing ultracold Ytterbium as optical medium. The specific goal of this new setup is to study the interactions between a large number of Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Towards this goal, Yb offers several advantages compared to alkali atoms; such as long coherence times, long Rayleigh length, simple energy level scheme and efficient cooling transitions. We discuss details of our experimental setup and report on the progress towards observation of few-photon nonlinearities in Yb.

Q 16.11 Thu 16:30 P

High-harmonic generation in Fibonacci quasicrystals — •Francisco Navarrete and Dieter Bauer — Institut für Physik, Universität Rostock, 18051 Rostock, Deutschland

The mechanism of high-harmonic generation (HHG) in solids has been theoretically studied over recent years, and experimentally verified a decade ago. While many conclusions have been drawn for this process in periodic crystals, it has also been predicted a strong dependence of the HHG spectrum on the topology of the sample. The latter motivated us to explore the strong-field response of quasicrystals (QCs), which are solids whose atoms are geometrically placed in ways that are symmetrically forbidden in periodic crystals (which are comparatively abundant and have been vastly studied). This might provide insight on fundamental questions of its electron dynamics and allow us to explore the suitability to use them for compact short-wavelength light sources. Even though in our study we focus on a simplified model for QCs, the Fibonacci chain, these conclusions might also be extrapolated to both synthesized and natural QCs.

Q 16.12 Thu 16:30 P

Compact, miniaturized and robust electronics for the operation of a dual species atom interferometer on a sounding rocket — •Wolfgang Bartosch, Thijs Wendrich, Alexandros Papakonstantinou, Matthias Koch, Isabell Imwalle, Baptist Piest, Maike Lachmann, Johnas Böhm, and Ernst M. Rasel — Institut für Quantenoptik, Hannover, Deutschland

Quantum sensors based on atom interferometry have become a valuable tool in numerous fields of scientific research. The sensitivity of atom interferometers depends predominantly on the possible free falling time of the coherently split atomic ensemble. Hence working towards a space born experiment, where the free falling time is only limited by the expansion rate of the atomic ensemble, is a logical step. The MAIUS-2/3 sounding rocket missions will be a step towards such a space born experiment by showing the feasibility of a dual species atom interferometer in space. Based on our experience from the predecessor mission MAIUS-1, we improved our electronics to match the needs of a mission with two species. We downsized the electronic components used for MAIUS-1 to fit hardware for dual species operation in an apparatus of the same size. With this poster we present our current progress. The QUANTUS/MAIUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431