Q 2: Nano-Optics and Optomechanics

Time: Monday 16:30–18:30 Location: P

Q 2.1 Mon 16:30 P

Fiber-pigtailing quantum-dot cavity-enhanced light emitting diodes — Lucas Rickert[1], •Frederik Schröder[1], Timm Gao[1], Christian Schneider[2,3], Sven Höfling[2], and Tobias Heindel[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, Berlin, Germany — [2]Technische Physik, Physikalisches Institut, Wilhelm Conrad Röntgen Research Center for Complex Material Systems, Universität Würzburg, Würzburg, Germany — [3]Institut für Physik, Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany

Semiconductor quantum dots embedded in engineered microcavities are considered key building blocks for photonic quantum technologies [1]. The direct fiber-coupling of respective devices would thereby offer many advantages for practical applications [2]. Here, we present a method for the direct and permanent coupling of electrically operated quantum-dot micropillar-cavities to single-mode fibers [3]. The fiber-coupling technique is based on a robust four-step process fully carried out at room temperature, which allows for the deterministic coupling of a selected target device. Using the cavity mode electroluminescence as feedback parameter, precise fiber-to-pillar alignment is maintained during the whole process. Permanent coupling is achieved in the last process step using UV curing of optical adhesive. Our results are an important step towards the realization of plug-and-play benchtop electrically-driven single-photon sources.

[1] T. Heindel et al., Appl. Phys. Lett. 96, 11107 (2010)
[2] T. Kupko et al., arXiv.2105.03473 (2021)
[3] L. Rickert et al., arXiv.2102.12836 (2021)

Q 2.2 Mon 16:30 P

Tailoring the thermal noise of membrane-based interferometric measurement schemes — •Johannes Dickmann[1,2], Mariia Matiushechkina[2,3], Jan Meyer[1,2], Anastasiia Sorokina[1,2], Tim Käseberg[4], Stefanie Kroker[1,2], and Michèle Heurs[2,3] — [1]Laboratory for Emerging Nanometrology (LENA), Technical University of Braunschweig, Langer Kamp 6a/b, 38106 Braunschweig — [2]Cluster of Excellence QuantumFrontiers — [3]Max Planck Institute for Gravitational Physics, Leibniz University Hannover, Callinstraße 38, 30167 Hannover — [4]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The interaction of mechanical systems like membranes with the optical light field inside interferometers established access to manifold measurement schemes. The application of these measurement schemes spans the optical cooling of membranes, the investigation and manipulation of macroscopic quantum states, the detection and analysis of viruses and bacteria as well as the generation of non-classical states of light for quantum computing and gravitational wave detection. We present the analysis of thermal noise sources, which severely influence the performance of membrane-based interferometric measurement schemes. In particular, the influence of structural parameters such as geometry, temperature and loss mechanisms are studied to provide guidelines for future experimental set-ups.

Q 2.3 Mon 16:30 P

Measurement of the photoelastic constant at cryogenic temperatures for the calculation of the photoelastic noise of the Einstein Telescope — •Jan Meyer[1,2], Johannes Dickmann[1,2], Mika Gaedtke[1,2], and Stefanie Kroker[1,2] — [1]Laboratory for Emerging Nanometrology (LENA),Langer Kamp 6a/b, 38106 Braunschweig, Germany — [2]Cluster of Excellence QuantumFrontiers

Currently most precise measurement instruments are gravitational wave detectors with a relative precision of less than 10^{-23}. This accuracy is limited by various noise sources. Most of the critical noise sources are driven by thermal fluctuation in the optical components of the detector, e.g. input mirrors of the cavities in the interferometer arms or the beamsplitter. To further enhance the sensitivity and, thus, the detection range, all potentially critical noise sources must be quantified and, if possible, mitigated. In this poster we present for the first time a noise source based on the photoelastic effect in solids. The photoelastic effect describes the change of the refractive index based on the local deformation of a material. The thermal fluctuations inside the optical parts lead to local deformations and, hence, to the local change of the refractive index. We present first calculations of the photoelastic noise for the Einstein Telescopes beamsplitter at a temperature of 300 K and the input mirrors of the cavities in the interferometer arms at 10 K. Due to the insufficient literature values of the photoelastic constant at cryogenic temperature, we developed a measurement setup to close this knowledge gap.

Q 2.4 Mon 16:30 P

A cavity optomechanical locking scheme based on the optical spring effect — •Felix Klein[1], Jakob Butlewski[1], Alexander Schwarz[2], Roland Wiesendanger[1,2], Klaus Sengstock[1,3], and Christoph Becker[1,3] — [1]ZOQ (Zentrum für Optische Quantentechnologien), Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]INF (Institut für Nanostruktur- und Festkörperphysik), Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [3]ILP (Institut für Laserphysik), Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We present a new method for stabilizing the length of a cavity optomechanical device using the optical spring effect, i.e. the detuning dependent frequency shift of a nanomechanical device caused by optomechanical coupling to the intra-cavity field. The error signal is based on this frequency shift, which is derived from the continuous position measurement of the nanomechanical device. Our locking scheme does not require any additional laser- or cavity modulation and its technical implementation is straightforward. The optical spring lock specifically suits systems with large linewidth such as e.g. microcavities and can be considered as an alternative when other locking schemes appear unfavorable. We demonstrate the implementation of this lock in a fiber-based Fabry-Perot membrane-in-the-middle optomechanical device and characterize its performance in terms of bandwidth and gain profile.

Q 2.5 Mon 16:30 P

Polymer drum resonators in fiber Fabry-Perot cavities — Lukas Tenbrake[1], Alexander Fassbender[2], Sebastian Hofferberth[1], Stefan Linden[2], and •Hannes Pfeifer[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Institute of Physics, University of Bonn, Germany

Cavity optomechanical experiments have been demonstrated on a wide range of experimental platforms during the past years. Record optomechanical coupling strengths were reached in micro- and nanophotonic realizations, which require elaborate techniques for interfacing and are limited in scaling towards multimode systems, tunability and flexibility. Here, we demonstrate a cavity optomechanical experiment that uses 3D laser written polymer structures inside fiber Fabry-Perot cavities. First experiments show vacuum coupling strengths of $\gtrsim 10\,\mathrm{kHz}$ at mechanical mode frequencies of $\gtrsim 1\,\mathrm{MHz}$. The extreme flexibility of the laser writing process allows for a direct integration of the mechanical resonator into the microscopic cavity. The ease of interfacing the system through the direct fiber coupling, its scaling capabilities to larger systems with coupled resonators, and the possible integration of electrodes makes it a promising platform for upcoming challenges in cavity optomechanics. Fiber-tip integrated accelerometers, directly fiber coupled systems for microwave to optics conversion or large systems of coupled mechanical resonators are in reach.

Q 2.6 Mon 16:30 P

Nanofiber-induced losses inside an optical cavity — •Sebastian Slama, Bernd Welker, and Thorsten Österle — Center for Quantum Science and Physikalisches Institut, Universität Tübingen, Germany

Optical cavities are well-known to enhance light-matter interactions, and are an established tool in the context of cold atoms. In contrast, putting single solid emitters into cavity modes remains a challenge, mainly due to the fact that the typically plane substrates, where the emitters are embedded, lead to a substantial optical loss in the cavity. We follow the idea to use nanofibers with sub-wavelength diameter as possible substrates with low loss. We have experimentally measured the nanofiber-induced loss inside an optical cavity with a finesse of F=1250 as function of nanofiber position for various nanofiber diameters. Only little reduction of the finesse is observed for a fiber diameter of 150 nm. The observations are consistent with the optical loss induced by Mie scattering theory.

Q 2.7 Mon 16:30 P

High-resolution spectroscopy and nanoscale mode mapping of photonic microresonators in a transmission electron microscope — Jan-Wilke Henke[1,2], Arslan Sajid Raja[3], Armin Feist[1,2], Guanhao Huang[3], Germaine Arend[1,2], Yujia Yang[3], •F. Jasmin Kappert[1,2], Rui Ning Wang[3], Marcel Möller[1,2], Jiahe Pan[3], Junqiu Liu[3], Ofer Kfir[1,2,4], Tobias J. Kippenberg[3], and Claus Ropers[1,2] — [1]Georg-August-Universität, Göttingen, Germany — [2]Max Planck Institute for Biophysical Chemistry, Göttingen, Germany — [3]Swiss Federal Institute of Technology Lausanne (EPFL), Lausanne, Switzerland — [4]School of Electrical Engineering, Tel-Aviv University, Tel-Aviv, Israel

Ultrafast electron microscopes are a powerful platform for investigating nano photonic devices, as they provide direct access to optical near-fields in photon-induced near-field electron microscopy (PINEM).

In this work, we demonstrate for the first time the spatial and spectral characterization of a single optical mode in a photonic-chip-based high-Q microresonator by electron microscopy. We map the evanescent cavity field with nanometer spatial and μeV energy resolution by laser-frequency-tuned electron energy-gain spectroscopy [1].

Future studies will explore the application of various nonlinear effects in integrated photonics for temporal and spectral electron-beam control, including dissipative Kerr solitons.

[1] J.-W. Henke, A. S. Raja, et al., preprint, arXiv:2105.03729 (2021)

Q 2.8 Mon 16:30 P

Precise Approaches for Determining Transition Rates and Quantum Efficiency of Single Color Centers — •Di Liu[1,2], Naoya Morioka[3], Öney Soykal[4], Izel Gediz[1,2], Charles Babin[1,2], Rainer Stöhr[1,2], Takeshi Ohshima[5], Nguyen tien Son[6], Jawad Ul-Hassan[6], Florian Kaiser[1,2], and Jörg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Institute for Quantum Science and Technology (IQST), Germany — [3]Institute for Chemical Research, Kyoto University, Uji, Japan — [4]Booz Allen Hamilton, McLean, VA, USA — [5]National Institutes for Quantum and Radiological Science and Technology, Takasaki, Japan — [6]Department of Physics, Chemistry and Biology, Linköping, Sweden

Optically-active spins in solids are appealing candidates for quantum technological applications due to the unique interplay between their spins and photons. The performance of those spin-based technologies is further boosted with highly-efficient spin-photon interfaces, such as a nanophotonic resonantor. The design of such nanostructures requires comprehensive understanding of the system's spin-optical dynamics. To overcome this, we developed a full set of measurements combining sublifetime short resonant and off-resonant pulses to infer the transition rates of a single color center i.e. V1 center in silicon carbide, with high precision. With those measured rates, we also estimated the quantum efficiency of the system. Our method paves way for a better understanding of the intrinsic properties of color centers, which in turn guides the design of nanophotonic resonators.

Q 2.9 Mon 16:30 P

Quantitative Waveform Sampling on Atomic Scales — •Lukas Kastner[1], Dominik Peller[1], Carmen Roelcke[1], Thomas Buchner[1], Alexander Neef[1], Johannes Hayes[1], Franco Bonafé[2], Dominik Sidler[2], Angel Rubio[2,3,4], Rupert Huber[1], and Jascha Repp[1] — [1]University of Regensburg, Germany — [2]MPSD, MPG, Hamburg, Germany — [3]CCQ, Flatiron Institute, New York, USA — [4]UPV/EHU, San Sebastían, Spain

Using a single molecule as a local field sensor, we precisely sample the absolute field strength and temporal evolution of tip-confined nearfield transients in a lightware-driven scanning tunnelling microscope. To develop a comprehensive understanding of the extracted atomic scale nearfield, we simulated the far-to-near-field transfer with classical electrodynamics and include time-dependent density functional theory to validate our calibration and conclusions.

Q 2.10 Mon 16:30 P

Investigating and Improving the Quantum Efficiency of Defect Centers in hBN — •Pablo Tieben[1,2], Bhagyesh Shiyani[2], Nora Bahrami[2], Hiren Dobarya[2], and Andreas W. Schell[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Institute for Solid State Physics, Leibniz University Hannover, Appelstr. 2, 30167 Hannover

Single photon emitters play a central role in the rapidly developing field of quantum technologies. Therefor new sources of single photons are highly sought after and understanding their properties is essential for their application in quantum technologies. Defect centers in hexagonal boron nitride (hBN) have become prominent candidates as single photon sources due to some of their highly favorable properties, like bright single photon emission, narrow line width, and high photo stability at room-temperature. Recently a spectral dependency on the excitation wavelength of the fluorescence of these emitters has been shown. In general, both the intensity and purity of the quantum emission, as well as the emission spectrum, vary with the excitation wavelength. By tuning the excitation over a broad range inside the visible spectrum and performing measurements regarding the quantum nature as well as the spectral decomposition of the emission light, we gain further insight to the characteristic properties and energy level schemes of these defect centers. In particular we find a strong dependency of the saturation behavior of individual emitters on the excitation wavelength and thus show, that the single photon emission of optically active defects in hBN has a tunable quantum efficiency.

Q 2.11 Mon 16:30 P

Shallow implantation of color centers in silicon carbide with high-coherence spin-optical properties — •Timo Steidl[1], Tobias Linkewitz[1], Raphael Wörnle[1], Charles Babin[1], Rainer Stöhr[1], Di Liu[1], Erik Hesselmeier[1], Naoya Morioka[1], Vadim Vorobyov[1], Andrej Denisenko[1], Mario Hentschel[1], Christian Gobert[2], Patrick Berwian[2], Georgy Astakhov[3], Wolfgang Knolle[4], Sridhar Majety[5], Pranta Saha[5], Marina Radulaski[5], Nguyen Tien Son[6], Jawad Ul-Hassan[6], Florian Kaiser[1], and Jörg Wrachtrup[1] — [1]Universität Stuttgart, Germany — [2]Fraunhofer IISB, Erlangen, Germany — [3]HZDR, Dresden, Germany — [4]IOM, Leipzig, Germany — [5]University of California, Davis, USA — [6]Linköping University, Sweden

Next-generation solid-state quantum information devices require efficient photonic interfaces, e.g., as provided by cavity QED systems. This requires precise positioning of optically active color centers in the centre of such cavities. Here, we report the creation of shallow silicon vacancy centers in silicon carbide with high spatial resolution using implantation of protons, He ions and Si ions. We observe remarkably robust spin-optical properties, e.g., nearly lifetime limited absorption lines and the highest reported Hahn echo spin-coherence times of the system. We attribute these findings to the much lower ion energy used in our experiments (few keV), which minimizes collateral crystal damage. Our findings provide a significant step forward for the SiC platform.

Q 2.12 Mon 16:30 P

Single-Molecule Quantum Optics on a Chip — •Dominik Rattenbacher[1], Alexey Shkarin[1], Jan Renger[1], Tobias Utikal[1], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich Alexander University, Erlangen, Germany

One-dimensional subwavelength waveguides (nanoguides) are very promising candidates for exploring the rich physics of quantum many body systems. However, the efficiency of coupling between an individual emitter, e.g., an organic dye molecule and a realistic nanoguide is limited by geometric and material constrains and a rich internal level structure of the emitters. To address these issues, we employed TiO_2 nanoguide racetrack resonators and demonstrated a sevenfold Purcell enhancement of the molecule's zero-phonon line emission into the nanoguide mode [1]. Additionally, we explored the use of gallium phosphide (GaP) as a high refractive index nanoguide material. Here, we could observe up to 15% extinction for linear nanoguides, twice higher than for TiO_2 [2]. We also show how studies on the spatio-temporal behavior of several molecules reveal nanoscopic charge fluctuations in GaP. Finally, we discuss our plans for improving the quality factor of our microresonators and for implementing individual control on the molecule frequencies to achieve long-distance photonic coupling of several molecules [3].

[1] D. Rattenbacher et al., New J. Phys. 21, 062002 (2019)
[2] A. Shkarin et al., Phys. Rev. Lett. 126, 133602 (2021)
[3] H. R. Haakh et al., Phys. Rev. A 94, 053840 (2016)

Q 2.13 Mon 16:30 P

Polarization sensitive correlations of single photon emitters in *h*-BN — •Niko Nikolay[1], Florian Böhm[1], Fridtjof Betz[2], Günter Kewes[1], Noah Mendelson[4], Sven Burger[2,3], Igor Aharonovich[4], and Oliver Benson[1] — [1]Institut für Physik

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Optically active color centers in hexagonal boron nitride are promising cadidates as single photon sources. Therefore, they have been extensively studied in recent years [1]. Their atomic origin is still unknown, so the experiments presented in this paper shed light on the underlying level structure. We will show that two spectra differing in their polarization contribute to the fluorescence of the observed single photon emitter. Based on these results, we then present polarization-sensitive photon correlation measurements [2] and compare them to a multilevel rate equation model. As a future perspective, we discuss the potential of this theoretical and experimental framework to further explore the electronic level structure of single photon centers in hexagonal boron nitride.

[1] Hayee, Fariah, et al., Nature materials 19.5 (2020): 534-539.

[2] Sontheimer, Bernd, et al., Physical Review B 96.12 (2017): 121202.