# Q 46: Nano-Optics (Single Quantum Emitters) II

Time: Thursday 14:00–16:00 Location: a310

Q 46.1 Thu 14:00 a310

**Optical studies of silicon-vacancy color centers in phosphorus-doped diamond** — •Florian Sledz[1], Assegid M. Flatae[1], Stefano Lagomarsino[1], Navid Soltani[1], Shannon S. Nicley[2], Ken Haenen[2], Robert Rechenberg[3], Michael F. Becker[3], and Mario Agio[1] — [1]Laboratory of Nano-Optics and C$\mu$, University of Siegen, Siegen, Germany — [2]Institute for Materials Research (IMO) & IMOMEC, Hasselt University & IMEC vzw, Diepenbeek, Belgium — [3]Fraunhofer USA Center for Coatings and Diamond Technologies, East Lansing, USA

A robust single-photon source operating upon electrical injection at ambient condition is desirable for quantum technologies. Silicon-vacancy (SiV) color centers in diamond are promising candidates as their emission is concentrated in a narrow zero-phonon line with a short excited-state lifetime of ~1 ns [1]. Creating the color centers in n-type diamond (phosphorus-doped) allows the implementation of a Schottky-diode configuration. This provides a simpler approach than the traditional complex diamond semiconductor junctions (e.g., p-i-n). We optically characterize SiV color centers in different phosphorus-doped diamond and show that the background due to doping, nitrogen impurities, and defects induced by Si-ion implantation can be significantly suppressed for single-photon emission [2]. This paves a way for the realization of the predicted bright electroluminescence of SiV color centers [3]. References: [1]. Lagomarsino et al, Diam. Relat. Mater. 84, 196 (2018). [2]. Flatae et al, manuscript in preparation (2019). [3]. Fedyanin and Agio, New J. Phys. 18, 073012 (2016).

Q 46.2 Thu 14:15 a310

**Molecule-photon interactions in phononic environments** — •Michael Reitz, Christian Sommer, Burak Gurlek, Diego Martin-Cano, Vahid Sandoghdar, and Claudiu Genes — Max Planck Institute for the Science of Light, Staudtstraße 2, D-91058 Erlangen, Germany

Molecular spectroscopy in the solid-state crucially depends on the interaction of electronic degrees of freedom with the surrounding environment. Processes involving absorption and emission of free space or spatially confined photons are strongly influenced by the coupling of electrons to intramolecular vibrations (vibrons) and to crystal vibrations (phonons). We describe light-matter interactions of guest molecules placed inside a host crystal environment including finite thermal occupancies of vibrons and phonons and provide analytical expressions for absorption and emission spectra derived within the formalism of quantum Langevin equations. We find that vibron-phonon couplings lead to a generally non-Markovian vibrational relaxation dynamics and that the common coupling to a continuum of bulk phonons can mediate collective vibron-vibron interactions similar to the processes of sub- and superradiance characterizing radiative transitions. On platforms showing confined optical modes we analytically derive quantities for molecular polaritonics such as the imprint of vibronic and electron-phonon coupling onto the output field and derive effective polariton cross-talk rates for finite baths occupancies.

Q 46.3 Thu 14:30 a310

**A narrow-band fiber-coupled single photon source with a single organic molecule.** — •Vladislav Bushmakin[1,2], Guilherme Stein[1], Yijun Wang[1], Jörg Wrachtrup[1,2], Andreas Schell[3], and Ilja Gerhardt[1,2] — [1]Universität Stuttgart, 3. Physikalisches Institut, Pfaffenwaldring, 57, 70569, Stuttgart, Germany — [2]Max-Plank-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [3]Leibniz Universität Hannover, Institut für Festkörperphysik, Appelstraße, 2, 30167, Hannover, Germany

A single-photon source is an essential tool for the emerging field of quantum technologies. Ideally, it should be spectrally compatible with other photonic devices while providing a high flux of narrow-band photons. A single organic dye molecule dibenzanthanthrene (DBATT, $C_{30}H_{16}$) embedded into a $n$-tetradecane Spol'skiĭ matrix under cryogenic conditions possesses the given characteristics, hence constitutes a prominent single-photon source. Nevertheless, the implementation of such a single-photon source requires a complex experimental setup involving a cryostat with a confocal microscope for the effective collection of the molecular emission. Another approach is to use a single emitter coupled directly to the end facet of an optical fiber. This approach has the potential to transfer a single-photon source based on a quantum emitter from a proof-of-principle type of setup to a scalable "plug-and-play" device. Here we present a successful coupling of a single organic molecule to an optical fiber [1].

[1] G.Stein *et al.*, A narrow-band sodium-resonant fiber-coupled single photon source, https://arxiv.org/abs/1909.08353 (2019)

Q 46.4 Thu 14:45 a310

**Creating long lived quantum coherence in organic molecules** — Burak Gurlek, Vahid Sandoghdar, and •Diego Martín-Cano — Nano-Optics Division, Max Planck Institute for the Science of Light, Erlangen, Germany.

Polycyclic aromatic hydrocarbons stand out within the select group of solid-state emitters with remarkable coherent properties for quantum processing at optical frequencies [1]. These molecules behave as effective two-level emitters embedded in organic crystals, a property that has been exploited to show fundamental devices and nonclassical states at the level of few photons [1-3]. So far, such demonstrations have mainly focused on the coherent electronic transitions of the molecules because their vibrational levels dissipate at faster time scales and thus behave as incoherent decay channels. In this work, we investigate the vibrations of organic crystals theoretically. Importantly, we show that engineering the phononic environment enables an increase in the coherence of the vibrational levels of embedded molecules by orders of magnitude. This finding holds promise for long quantum storage and unexplored quantum functionalities in these systems. **References:** [1] B. Kozankiewicz and Michel Orrit, Chem. Soc. Rev. 43, 1029 (2014). [2] D. Wang, H. Kelkar, D. Martin-Cano, T. Utikal, S. Götzinger, V. Sandoghdar, Phys. Rev. X 7, 021014 (2017). [3] D. Wang, et al., Nature Phys. 15, 483 (2019).

Q 46.5 Thu 15:00 a310

**Cavity coupled nano scale quantum emitter for integrated photonic circuits** — •Philip P.J. Schrinner[1], Jan Olthaus[2], Doris Reiter[2], and Carsten Schuck[1] — [1]Physikalisches Institut and Center for Nanotechnology, WWU Münster, Germany — [2]Institut für Festkörpertheorie, Universität Münster, 48149 Münster, Germany

Integrated quantum photonics with single photons in nano-photonic waveguides is a promising approach for quantum sensing, computing and communication. Despite current nano-technological advances, efficient and scalable coupling of single-photon sources to photonic integrated circuits remains a major hurdle. Here, we employ 1D photonic crystal cavities for efficiently interfacing NV centers in nano-diamonds with nano-photonic waveguides [1]. We fabricate nano-photonic devices from Ta2O5 thin films, use a lithographic technique for precise emitter-positioning and characterize the coupling via lifetime measurements. We find Q-factors of several thousands and lifetime reductions for single NV centers by a factor of three due to the Purcell effect. Our work paves the way for integrating large numbers of single emitters into nano-photonic networks for complex quantum optics experiments. [1] Olthaus et al., Adv. Quantum Technol. 2019, 1900084

Q 46.6 Thu 15:15 a310

**Optimal Photonic Crystal Cavities for Coupling Nanoemitters to Photonic Integrated Circuits** — •Jan Olthaus[1], Philip P. J. Schrinner[2], Carsten Schuck[2], and Doris E. Reiter[1] — [1]Institute of Solid State Theory, University of Muenster — [2]Physics Institute, University of Muenster

Photonic integrated circuits hold great promise for realizing scalable quantum technologies. On-chip implementation of those circuits requires an efficient interface between quantum emitters and nanophotonic devices. Such an interface can be provided using photonic crystal nanobeam cavities, which combine wavelength-scale mode volumes with high quality factors.

We show that the design and fabrication of photonic crystal nanobeam cavities in the visible wavelength regime is possible directly on-substrate. Our cavities are designed to host NV-centers in nanodiamonds. We stress that the on-substrate design allows compatibility with modern fabrication processes. Three different cavity geometries based on a mode-matching and a deterministic design approach are optimised using 3D-FDTD simulations. Here, we present the optimization strategies and the resulting parameters. Using the optimized parameters, we verify the theoretical predictions experimentally, finding a reasonable agreement. In our case the mode-matching approach is found advantageous for on-substrate realizations.

Our results pave the way for integrating quantum emitters with nanophotonic circuits for applications in quantum technologies.

[1] Adv. Quantum Technol. 1900084 (2019).

Q 46.7 Thu 15:30 a310

**Nitrogen Vacancy Center Coupled to a Hybrid Bullseye Grating, a Highly Directional Single Photon Source** — •Niko Nikolay[1], Boaz Lubotzky[2], Hamza Abudayyeh[2], Florian Böhm[1], Ronen Rapaport[2], and Oliver Benson[1] — [1]AG Nanooptik & IRIS Adlershof, Humboldt-Universität zu Berlin, Germany — [2]The Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 9190401, Israel

In recent years the Nitrogen Vacancy center (NV) in diamond has proven to be a particularly effective tool to sense magnetic fields [1]. In laboratory environments, e.g. solid immersion lenses or high NA oil immersion lenses are often used to capture as many photons as possible because the sensing sensitivity scales with the count rate. However, these collection techniques are not always optimal as they usually require to excite and detect through the substrate. We discuss a single photon source prototype giving high collection efficiencies and potentially high fiber coupling efficiencies using air objective lenses. This source consists of a NV coupled to a slab waveguide which is supported by a bullseye grating. In addition to the working principle of the antenna [2], we discuss the NV positioning technique [3] and show an experimental characterization of single photon source.

[1] Pham, Linh My, et al., NJP 13.4 (2011): 045021.
[2] Abudayyeh, et al., QST 2.3 (2017): 034004.
[3] Nikolay, Niko, et al., APL 113.11 (2018): 113107.

Q 46.8 Thu 15:45 a310

**Next-generation single-photon sources for satellite-based quantum communication** — •Tobias Vogl[1,2], Ruvi Lecamwasam[3], Ben Buchler[3], Yuerui Lu[3], Ping Koy Lam[3], and Falk Eilenberger[1] — [1]Friedrich-Schiller-Universität — [2]University of Cambridge — [3]Australian National University

Color centers in solid state crystals have become a frequently used system for single-photon generation, advancing the development of integrated photonic devices for quantum optics and quantum communication applications. Recently, defects hosted by two-dimensional (2D) hexagonal boron nitride (hBN) attracted the attention of many researchers, due to its chemical and thermal robustness as well as high single-photon luminosity at room temperature. Here, we present recentadvances in engineering this new type of emitter. The quantum emitter is coupled with a nanophotonic cavity, improving its performance so that the single-photon source is feasible for practical quantum information processing protocols. The cavity-coupled device is characterized by an increased collection efficiency and quantum yield, combined with off-resonant noise suppression and improvement of photophysics. Moreover, the complete source, including all control units and driving electronics is implemented on a 1U CubeSat platform. An application of particular interest is satellite-based single-photon quantum key distribution. Simulations predict the performance of the source is sufficient to outperform conventional decoy state protocols. We will also show results on the first ever quantum information experiment involving single-photons from hBN.