# HL 26: Focus Session: Integrated Quantum Photonics I

The huge impact of semiconductor-based technologies on modern society has resulted from the ability to integrate small functional units or building blocks into integrated circuits with macroscopic functionality. In a similar way, integrated nanophotonic quantum circuits are believed to enable real-world quantum technologies with applications in secure communication, information processing, metrology and sensing.

Organizers: Kai Müller (TU Munich) and Tobias Heindel (TU Berlin)

Time: Tuesday 9:30–11:45 Location: POT 51

**Invited Talk** HL 26.1 Tue 9:30 POT 51

**Nanophotonic quantum technology on silicon chips** — •Carsten Schuck — Institute of Physics, University of Münster, Germany — CeNTech - Center for NanoTechnology, Münster, Germany — SoN - Center for Soft Nanoscience, Münster, Germany

Integrated quantum photonics holds great promise for increasing the complexity and system size of quantum communication, sensing and computation schemes through leveraging modern nanofabrication processes for replicating nanoscale devices with high reproducibility. The implementation of such integrated quantum technology requires single-photon sources, linear optic circuit components and single-photon detectors connected via a network of optical waveguides. Here we show how solid-state quantum emitters, nanophotonic devices and superconducting nanowire single-photon detectors can be efficiently interfaced to realize a versatile quantum technology platform on a silicon chip. We generate single-photons from defect centers in diamond as well as single molecules, which are efficiently coupled to optical waveguides. We realize nanophotonic circuit components that combine optical, electrical and mechanical functionality in novel material systems such as tantalum pentoxide-on-insulator and employ non-traditional computational design approaches. Waveguide-coupled superconducting nanowire single-photon detectors integrate seamlessly with such nanophotonic circuitry and offer high detection efficiency, low noise and excellent timing performance. We present progress towards integrating sources, circuits and detectors on-chip to match the demands of future large-scale implementations of quantum technologies.

**Invited Talk** HL 26.2 Tue 10:00 POT 51

**Resonant excitation and coherent manipulation of quantum dots for quantum information experiments** — •Ana Predojevic — Stockholm University, Stockholm, Sweden

Single self-assembled quantum dots are established emitters of single photons and entangled photon pairs. To be used in quantum information experiments quantum dots need to be excited resonantly and coherently. The use of resonant excitation makes this system well suitable for generation of photon pairs with near-unity efficiency and high purity and also for entangling schemes such as time-bin entanglement. The entanglement of photons generated by quantum dot systems can be employed in free space-and fibre-based quantum communication. In addition to this, the versatility of entanglement can be more optimally used and explored if the photons are entangled simultaneously in more than one degree of freedom - hyperentangled, which was also recently shown to be possible using quantum dots. However, the achievable degree of entanglement and readiness of the source for use in quantum communication protocols, depend on several additional functionalities such as high collection efficiency and coherence of the emitted photon pairs. Here, we will address engineered photonic systems that promise a more efficient and better performing sources of entangled photon pairs.

**15 min. break.**

HL 26.3 Tue 10:45 POT 51

**Cavity-QED effects in dissipative resonators using coupled quasinormal modes** — •Sebastian Franke[1], Stephen Hughes[2], Juanjuan Ren[2], Andreas Knorr[1], and Marten Richter[1] — [1]Technische Universität Berlin, Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics, Engineering Physics and Astronomy, Queen's University, Kingston, Ontario, Canada K7L 3N6

Open cavity systems are of high interest in quantum optics and plasmonics and offer a variety of applications, including lasing/spasing and non-classical light generation. In many cavity-QED platforms, photons are usually described by lossless normal modes, e.g., in the Jaynes-Cummings model. However, for metallic or open cavities, the so-called quasinormal modes [1] (QNMs) with complex eigenfrequencies are more appropriate, and are the natural modes to quantize.

Using a recent developed quantization scheme [2] for three-dimensional open resonators on the basis of these QNMs, we explore the multi-photon regime in a plasmonic-photonic crystal cavity coupled to a two-level atom. On the basis of a generalized input-output theory for QNMs [3], we derive quantum correlations of the output fields using the QNM Lindblad master equation and compare the results to the phenomenological dissipative Jaynes-Cummings models.

[1] P. T. Leung *et al.*, *Phys. Rev. A* **49**, 3057, 1994
[2] S. Franke *et al.*, *Phys. Rev. Lett.* **122**, 213901, 2019
[3] S. Hughes *et al.*, *ACS Photonics* **6**, 8, 2168-2180, 2019

HL 26.4 Tue 11:00 POT 51

**Optimized designs for telecom-wavelength quantum light sources based on hybrid circular Bragg gratings** — •Lucas Rickert, Johannes Schall, Timm Kupko, Sven Rodt, Stephan Reitzenstein, and Tobias Heindel — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

We present finite-element simulations of optimized designs for hybrid circular Bragg grating devices operating at telecom O-band wavelengths [1]. The designs show Purcell factors up to 30 and photon extraction efficiencies exceeding 95%. We discuss how the optical properties are affected by the variation of structural parameters and investigate the designs' performance if possible fabrication-related structural imperfections are introduced, including imperfect side-wall etching and non-ideal positioning of the emitter inside the device. For the latter, we show that the devices are robust against emitter displacements well within reported deterministic fabrication uncertainties for structures with embedded semiconductor quantum dots. Additionally, we present simulations showing the CBG devices' compatibility to optical single mode fibers and obtain up to 80% fiber coupling efficiency with off-the-shelf fibers. We further investigate on how to improve the fiber coupling to close to unity by the use of specialty fibers and address C-band compatible CBG designs.

[1] Rickert *et al.*, Optics Express, arXiv.1908.08408, in press (2019)

**Invited Talk** HL 26.5 Tue 11:15 POT 51

**Fully on-chip single-photon Hanbury-Brown and Twiss experiment integrating semiconductors and superconductors** — •Simone Luca Portalupi[1], Mario Schwartz[1], Ekkehart Schmidt[2], Ulrich Rengstl[1], Florian Hornung[1], Stefan Hepp[1], Konstantin Ilin[2], Michael Jetter[1], Michael Siegel[2], and Peter Michler[1] — [1]IHFG-University of Stuttgart, IQST and SCoPE, Stuttgart, Germany — [2]IMS, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Stability and scalability of quantum computation and quantum simulation implementations will largely benefit from a platform capable to realize usual tabletop functionalities on a single chip. Although to fulfill this need, only few building blocks are absolutely necessary, demonstrating their successful simultaneous implementation remained elusive for long time. Here we will discuss the realization of a fully on-chip Hanbury-Brown and Twiss experiment, realizing on the same chip a non-classical light source, a basic photonic logic and two single photon detectors [1]. GaAs single-mode waveguides embedding semiconductor quantum dots are used in combination with superconducting material to realize a beamsplitter with two superconducting nanowire detectors at the output ports. To further increase the coupling of the quantum dot photons into the waveguide, the realization of waveguide-coupled Bragg grating cavities will also be discussed [2]. These results open the way to implement complex on-chip quantum photonics.

[1] M. Schwartz, et al., Nano Lett. 18, 6892 (2018).
[2] S. Hepp, et al., Opt. Express 26, 30614 (2018).