Q 13: Quantum Optics and Photonics II

Time: Monday 14:00–16:00 Location: S Gr. HS Maschb.

Invited Talk Q 13.1 Mon 14:00 S Gr. HS Maschb.

Integrated quantum photonics on silicon chips — •Carsten Schuck — Physics Institute, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — CeNTech - Center for NanoTechnology, Heisenbergstr. 11, 48149 Münster, Germany — SoN - Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany

A wide range of quantum communication, sensing and computation schemes can be implemented with single-photons. Here we envision a versatile photonic quantum information processing system on a silicon chip, which relies on nanophotonic circuits that integrate non-classical light sources and single-photon detectors in a scalable way. Single-photons are generated on-chip via spontaneous parametric down conversion or emission from nitrogen vacancy centers or single molecules. We design efficient interfaces between these sources and optical waveguides that feed into on-chip photonic networks. We realize building blocks of these networks that combine optical, electrical and mechanical functionality by leveraging modern nanofabrication technology and by exploring novel material systems as well as non-traditional design approaches. Waveguide-coupled superconducting nanowire single-photon detectors integrate seamlessly with such photonic circuitry and offer high detection efficiency, low noise and excellent timing performance. We investigate novel superconducting material systems that are favorable for high-yield production and operation at elevated temperatures. We present first steps towards integrating sources, circuits and detectors on-chip to match the demands of future large-scale implementations of quantum technologies.

Q 13.2 Mon 14:30 S Gr. HS Maschb.

Monolithically Integrated Hong-Ou-Mandel Experiment in $LiNbO_3$ — •Sebastian Brauner, Kai-Hong Luo, Christof Eigner, Polina Sharapova, Raimund Ricken, Torsten Meier, Harald Herrmann, and Christine Silberhorn — Department of Physics and CeOPP, University of Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

One crucial requirement for future quantum computation and networks is to have a single physical substrate, which is capable to host all devices for various advanced functionalities without lowering the performance of the single devices. Here we present for the first time a fully integrated Hong-Ou-Mandel (HOM) interference circuit on $LiNbO_3$, which comprises photon pair state generation, passive routing, fast active polarization manipulation, electro-optic balanced switching and a variable time delay. By showing the functionality of each device separately and their successful synergy as a HOM-interferometer with a HOM-dip visibility of 93 %, we prove the suitability of integrated circuits on $LiNbO_3$ as a powerful platform for future quantum information processing, networking and sensing. Besides, we provide a detailed explanation of the working principle of the integrated electro-optically tunable delay line.

Q 13.3 Mon 14:45 S Gr. HS Maschb.

Integrated Electrooptic Modulators in $LiNbO_3$ for Quantum Optics — •Patrick Bartkowiak, Marcello Massaro, Felix vom Bruch, Christof Eigner, Raimund Ricken, Viktor Quiring, Kai Hong Luo, Harald Herrmann, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Compact, low-loss modulators are key components for numerous quantum optic applications in the future. Such devices must be capable to manipulate the light which propagates through the device regarding polarization, phase or amplitude by an electrical control signal. Integrated electro-optic modulators in $LiNbO_3$ are attractive candidates to fulfill such requirements. Presently, such devices are well established components in particular in high bandwidth optical transmission systems. Quantum optic experiments demand fast, low loss, and compact devices. Therefore, the modulator's design and fabrication technology require a refinement.
We report on our progress in the development of low-loss electro-optic modulators relying on titanium in-diffused waveguides and directional couplers in $LiNbO_3$. The results on the development of a fiber-coupled 2x2 spatial switch based on an electro-optically switchable directional coupler will be presented. In particular, the optimized coupler design, the electrode configuration for fast switching and means for minimizing fiber-waveguide coupling losses will be discussed. Potential implementation for such 2x2 low-loss switches can be in realizing time-multiplexed heralded single photon sources.

Q 13.4 Mon 15:00 S Gr. HS Maschb.

Integrated transition edge sensors on lithium niobate waveguides — •Jan Philipp Höpker[1], Thomas Gerrits[2], Adriana Lita[2], Harald Herrmann[1], Raimund Ricken[1], Viktor Quiring[1], Richard Mirin[2], Sae Woo Nam[2], Christine Silberhorn[1], and Tim Bartley[1] — [1]Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany — [2]National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305, USA

Lithium niobate is a versatile platform for integrated quantum optics due to its low-loss waveguiding, a high second order susceptibility and its electro-optic properties. Many different tools for quantum optics applications have been realized on this platform including single-photon sources and modulators. However, the integration of single-photon detectors on these waveguides is challenging. Superconducting single photon detectors combine high detection efficiency at telecom wavelength with outstanding signal-to-noise ratio. In particular, transition edge sensors (TESs) combine these abilities with an intrinsic photon-number resolution and negligible dark counts. Combining these detectors and the lithium niobate platform enables a new variety of complex on-chip experiments. Recently, we were able to show in a first proof-of-principle-experiment the evanescent detection of single photons with on-chip TESs on a lithium niobate waveguide. We investigated the efficiency, photon-number resolution, polarization sensitivity for the evanescent coupling, and different detector geometries.

Q 13.5 Mon 15:15 S Gr. HS Maschb.

Design and Investigation of Photonic Microstructures for Atom-based Quantum Networks — •Flavie Davidson-Marquis[1], Bumjoon Jang[2], Tim Kroh[1], Chris Müller[1], Markus A. Schmidt[2], and Oliver Benson[2] — [1]AG Nanooptik, Humboldt Universität zu Berlin, Newtonstraße 15, D-12489 Berlin, Germany — [2]Leibniz Institute of Photonic Technology, Albert-Einstein-Straße 9, 07745 Jena, Germany

In the common effort to make quantum signal transmission reliable over arbitrary long distances via quantum repeaters [1], the ability to store and retrieve - or slow down - photons proves necessary. Combining one of the optical mechanisms able to produce slow light, Electromagnetically Induced Transparency (EIT) [2], with a newly developed shell-free hollow-core waveguide allows for the study of enhanced light-matter interaction due to a small mode-volume.

Here, we will focus on the experimental realization of an EIT experiment utilizing this structure. Single mode waveguiding at around the Cs D1 line (894 nm) is demonstrated and protection of the structure against degradation in Cs cell is discussed. First results on Cs spectroscopy supported by the waveguide structure are reported.

[1] L.-M. Duan et al., Long-distance quantum communication with atomic ensembles and linear optics. Nature 414, 413-418(2001)

[2] D. Höckel & O.Benson, Electromagnetically Induced Transparency in Cesium Vapor with Probe Pulses on the Single-Photon Level, Phys. Rev. Lett. 105, 153605 (2010)

Q 13.6 Mon 15:30 S Gr. HS Maschb.

Light cage: 3D Nanoprinted Hollow-core Waveguide on Silicon Chip — •Bumjoon Jang[1], Julian Gargiulo[2], Flavie Davidson-Marquis[3], Tim Kroh[3], Chris Müller[3], Torsten Wieduwilt[1], Uwe Hübner[1], Oliver Benson[3], Stefan A. Maier[2,4], and Markus A. Schmidt[1] — [1]Leibniz Institute of Photonic Technology, Albert-Einstein-Str. 9, 07745 Jena, Germany — [2]The Blackett Laboratory, Department of Physics, Imperial College London, London SW7 2AZ, United Kingdom — [3]AG Nanooptik, Humboldt-Universität zu Berlin, Newtonstraße 15, D-12489 Berlin, Germany — [4]Chair in Hybrid Nanosystems, Nanoinstitut München, Fakultät für Physik, Ludwig-Maximilians-Universität München, München 80539, Germany

Integrated photonic devices are widely used for combining microscale electronics and photonics on a compact chip. And the ability to confine light over a long distance makes on-chip waveguides an attractive

light-matter interaction platform for gas sensing and quantum information processing. However, most of the on-chip waveguides exploit the evanescent part of the light due to their solid-core nature or a small area of enhanced field in slot waveguides. To fully utilize the guided mode for interaction with matter, we present a 3D nanoprinted hollow-core waveguide. It is composed of multiple cylindrical polymer rods surrounding its air core. Waveguide characteristics will be discussed. In situ writing for coupling with other waveguides will be demonstrated.

Q 13.7 Mon 15:45 S Gr. HS Maschb.

Towards Terahertz quantum sensing: spontaneous parametric down-conversion in MgO:LiNbO$_3$ — •Björn Haase[1,2], Mirco Kutas[1,2], Felix Riexinger[1,2], Patricia Bickert[1], Andreas Keil[1], Daniel Molter[1], Michael Bortz[1], and Georg von Freymann[1,2] — [1]Fraunhofer-Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern (TUK), 67663 Kaiserslautern

We generate and measure the spontaneous parametric down conversion in periodically poled lithium niobate crystals, using a narrowband, frequency-stable (solid-state) laser and an uncooled sCMOS camera for detection. With very narrowband volume Bragg gratings and a transmission grating we separate the pump wavelength of the signal wavelengths close to the pump. It is possible to detect signals for down- as well as for up-conversion for the forward- as well as for the backward-generation (as well as for higher quasi phase-matching orders) resolvable down to the sub-THz frequency range. The measured spectra match very well both qualitatively and quantitatively to the theoretically expected spectral angular intensity distribution. Furthermore, it is possible to validate the measured quantitative temperature dependency of the conversion intensity even theoretically. Considering the temperature dependence, we estimate the part of the signal caused by the quantum mechanical interaction with vacuum fluctuations [Kitaeva, G.K. et al., Applied Physics B, **116**(6) 929-937 (2014)].