Q 8: Nanophotonics and Integrated Photonics II

Time: Monday 17:00–19:00 Location: P 3

Invited Talk Q 8.1 Mon 17:00 P 3

Heterogeneous Quantum Photonics: A Platform for Quantum Sensing, Networking, and Transduction — •Samuel Gyger — Saarland University, Saarbrücken, Germany — Stanford University, Stanford, United States

Realizing quantum photonic technologies requires architectures beyond commercial foundry processes. While they provide reliability and favorable cost reduction for high-volume production, their rigid processes often conflict with the high-mix environment of quantum research, and they typically lack integrated quantum hardware, such as single photon detectors (SNSPDs) or quantum light sources. We propose a "chiplet-based" approach using heterogeneous integration of optimized submodules and robotic automation to bring industrial-grade consistency to the research lab.

We show that robotic resist development reduces the inter-chip resistance spread in superconducting devices from $\approx 7\%$ to $\approx 2\%$. We also demonstrate deterministic SNSPD integration onto arbitrary photonic substrates via transfer printing. Finally, co-integrated lithium niobate and silicon optomechanical crystals enable a platform for quantum transduction. We improve thermal anchoring to achieve ground-state operation with pulsed sideband asymmetry at repetition rates up to 3 MHz.

This automated, heterogeneous framework provides a scalable path for next-generation quantum technology laboratories.

Q 8.2 Mon 17:30 P 3

On-chip wavefront shaping via transverse mode control in integrated Si_3N_4 multimode waveguides — •Stefan Rothe, Ekin B. Boşdurmaz, Leonie M. van der Heide, Redlef B. G. Braamhaar, Jeroen P. Korterik, and Pepijn W. H. Pinkse — MESA+ Institute, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands

We demonstrate spatial mode control in integrated Si_3N_4 multimode waveguides (MWGs), establishing a compact and robust platform for wavefront shaping. We fabricate the Si_3N_4 MWGs on silicon wafers using standard low-loss nanophotonic processes in the MESA+ Nanolab Cleanroom. By adjusting the relative phases of guided transverse modes, we can generate arbitrary output fields like diffraction-limited foci, or any other modal superposition, directly at the chip output facet. One spatial light modulator placed in the conjugate plane of the MWG input enables to coherently excite and control up to five transverse modes. We apply a step-sequential optimization algorithm, and concentrate 76% of the output intensity into a diffraction-limited focus, approaching the $\pi/4$-limit for phase-only wavefront shaping. This demonstrates, for the first time, reconfigurable multimode phase control within an integrated Si_3N_4 platform. Our approach outlines the way for fully integrated spatial light control. Future integration of thermo-optic phase shifters will eliminate bulky free-space optics and enable in-waveguide modulation for scalable multimode quantum networks and photonic computing architectures.

Q 8.3 Mon 17:45 P 3

Micro-structuring of electrically switchable PEDOT:PSS using one-photon polymerization — •Julian Bolsinger, Dominik Ludescher, Leander Siegle, Monika Ubl, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

PEDOT:PSS is a conductive polymer with excellent electrical, optical, and mechanical properties used for transparent electrodes, biocompatible electronics, and sensor technology. Fabrication often requires precise structuring of a thin polymer film, typically achieved through inkjet printing, electron-beam lithography, or femtosecond direct laser writing. However, these methods are costly or offer limited resolution. We present two methods for structuring PEDOT:PSS based on one-photon polymerization using incoherent ultraviolet or coherent near-infrared light. In the first, a spin-coated PEDOT:PSS sample is exposed to ultraviolet light through a photomask, inducing cross-linking of polymer chains in the illuminated regions. Our method provides an inexpensive way for patterning large areas. For the second technique, a continuous-wave near-infrared laser beam is focused onto the polymer layer while the sample is translated, offering great flexibility and cost efficiency. We realize electrically switchable patterns with micrometer spatial resolution while keeping the polymer stable and conductive. In combination with 3D-printed micro-optics, PEDOT:PSS enables dynamic functionality. We are working towards integrating micro-optics with electrically switchable structures such as apertures and diffraction gratings.

Q 8.4 Mon 18:00 P 3

Macroscopic monolayer WS2 for robust room-temperature exciton-polaritons in open cavities — •Sander Scheel[1], Shiyu Huang[1], Jiang Qu[2], Johannes Düreth[1], Dominik Horneber[1], Simon Widmann[1], Monika Emmerling[1], Martin Kamp[1], Simon Betzold[1], Sven Höfling[1], and Sebastian Klembt[1] — [1]Technische Physik, Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, and Würzburg-Dresden Cluster of Excellence ct.qmat, University of Würzburg, Germany — [2]Leibniz-Institute for Solid State and Materials Research Dresden

Combining two-dimensional materials with photonic lattices offers a powerful route toward tunable exciton-polariton devices using engineered band structures, yet progress has been limited by the poor reproducibility of conventional exfoliation methods. Here, we demonstrate large-area monolayer WS_2 with high optical uniformity using Au-assisted exfoliation and 1-dodecanol encapsulation, providing a scalable platform for exciton-polariton studies. Room-temperature strong coupling with a Rabi splitting of 31 meV is achieved in open microcavities, yielding polaritonic spectra consistent with literature while eliminating sample-to-sample variability. Implementing a kagome photonic lattice enables the realization of polariton band structures, including Dirac cones and flat bands. These results establish large-area monolayer semiconductors as a robust basis for controllable polaritonic lattices at room-temperature.

Q 8.5 Mon 18:15 P 3

Feibelman parameters from jellium models for a metal surface — •Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

In nano-photonics, we currently witness a revived interest in quantum models for the surface of a metal, going beyond a sharp, macroscopic interface between two media with local conductivities [1]. Multiple physical features coexist: the atomic lattice structure (crystalline, reconstructed or amorphous) [1], the smooth onset of the electron density [2], the creation of electron-hole pairs [4] and of collective longitudinal excitations like (surface) plasmons [5]. We revisit 100 years of jellium models starting from hydrodynamics with simple exchange-correlation potentials. The aim is to capture the optical response of the surface in terms of few additional Feibelman parameters related to the oscillating near-surface charge [6].

[1] C. Ciracì and F. Della Sala, Phys. Rev. B 93 (2016) 205405; N. Asger Mortensen & al, Nanophotonics 10 (2021) 3647
[2] R. Smoluchowski, Phys. Rev. 60 (1941) 661
[3] J. Frenkel, Z. Physik 51 (1928) 232
[4] I. Tamm and S. Schubin, Z. Phys. 68 (1931) 97
[5] D. Wagner, Z. Naturforsch. A 21 (1966) 634; G. Mukhopadhyay and S. Lundqvist, Physica Scr. 17 (1978) 69
[6] J. Harris and A. Griffin Phys. Lett. A 34 (1971) 51; K. Kempa and W. L. Schaich, Phys. Rev. B 34 (1986) 547; Peter J. Feibelman, Phys. Rev. B 40 (1989) 2752

Q 8.6 Mon 18:30 P 3

Deep Learning Based Inverse Design of Nanophotonic Devices — •David Lemli[1,2,3], Marco Butz[1,2,3], Marlon Becker[4], Benjamin Risse[4], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Heisenbergstr. 11, 48149 Münster, Germany — [2]Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany — [3]Center for Nanotechnology, Heisenbergstr. 11, 48149 Münster, Germany — [4]Department for Geoinformatics, University of Münster, Heisenbergstr. 2, 48149 Münster, Germany

Photonic integrated circuits constitute a key platform for all areas of quantum technology, driving the need for nanophotonic components that achieve high optical performance while adhering to fabrication constraints such as minimum feature sizes.

Topology optimization provides a powerful framework for designing highly efficient, compact, and multifunctional photonic devices. Here, we present Memory Metropolis (MeMe), a deep-learning enhanced discrete topology optimization algorithm that employs deep template networks, a novel neural network architecture for generating proposal distributions in simulated annealing. By promoting the clustering of individual pixels, MeMe produces device geometries compatible with state-of-the-art lithographic processes. We experimentally validate the performance of optimized devices on the emerging tantala-on-insulator platform. Fabrication compatibility naturally emerges from MeMe's optimization process, representing a key algorithmic innovation in discrete inverse design.

Q 8.7 Mon 18:45 P 3

Imaging of Nanoholes with Digital Holography — •Lukas Limmer[1], Abhishek Anand[2], Wladimir Schoch[2], Ulrich Rädel[3], Johannes Hecker Denschlag[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]Institute for Quantum Matter, University of Ulm, Germany — [3]Frauenhofer IOF, Jena, Germany

We experimentally investigate a recently proposed low photon number method for photographing nanohole grid patterns on a two-dimensional opaque phase mask with digital holography. The experimental setup back-illuminates the phase mask with a weak coherent light source and imprints the phase information of the nanoholes diffraction pattern on a strong coherent reference beam on a CCD-camera chip. First measurements suggest that a reconstruction of the original hole pattern is possible for less than 100 scattered photons per hole. This shows potential for imaging ultra-cold atoms in optical lattices.