Q 31: Photonics I

Time: Wednesday 10:30–12:30 Location: Q-H15

Q 31.1 Wed 10:30 Q-H15

Wavefront characterization and simulation for high precision interferometry — •Kevin Weber, Gudrun Wanner, and Gerhard Heinzel — Albert Einstein Institut, Hannover, Niedersachsen

High precision interferometry with laser light is the foundation of many modern experiments. To further improve their incredible precision, an exact knowledge of the beam geometries involved is crucial. We present a novel means to measure and quantify beam geometries and its impact on readout signals. By combining the readout of a wavefront sensor with an in-house beamfitting algorithm, we will create a precise mathematical model of an experimental beam as a superposition of transversal electromagnetic modes. The presence of Higher-order mode contaminants are likely to negatively impact measurements. Therefore, we propose a way to study their influence in the future, namely by simulating the interferometric readout using the existing in-house C++ library IfoCAD. Insight gained on the influence of beam geometries on optical readout will contribute to the success of future geodesy and gravitational wave detector missions.

Q 31.2 Wed 10:45 Q-H15

Role of order and disorder for 2D photonic structures modelled using FDTD simulations — •David Röhlig[1], Eduard Kuhn[1], Thomas Blaudeck[2], and Angela Thränhardt[1] — [1]TU Chemnitz, Institut für Physik, Reichenhainer Str. 70, 09126 Chemnitz — [2]TU Chemnitz, Forschungszentrum MAIN, Rosenbergstraße 6, 09126 Chemnitz

Investigations of real photonic systems have so far mostly neglected fabrication imperfections and aspects of disorder [1]. Nevertheless, they always play a decisive role for function [2]: deviations from ideal crystallinity occur both in nature and artificial systems. Although in nanotechnologies the accuracy of manufacturing processes has increased, irregularities still play a role for the performance of photonic components [3]. The extent to which disorder affects photonic systems depends on the type of disorder related to various geometrical and material quantities. Using FDTD, we simulated transmission spectra of 2D optical systems introducing a controlled amount of disorder of various types. We found that increasing disorder always leads to a transmission decrease and particular spectral changes. The results were compared with spectra of amorphous photonic crystals, generated by a molecular dynamics algorithm.

[1] M. Rothammer et al. Advanced Optical Materials 9, 19, 2100787 (2021). DOI 10.1002/adom.202100787. [2] E. Kuhn, D. Röhlig et al. Nano Select 2, 12, 2461-2472 (2021). DOI 10.1002/nano.202100263. [3] D. Segura et al. Sensors and Actuators A: Physical 264, 172-179 (2017). DOI 10.1016/j.sna.2017.07.011.

Q 31.3 Wed 11:00 Q-H15

Quantum-Coherent Light-Electron Interaction in an SEM — •Tomas Chlouba, Roy Shiloh, and Peter Hommelhoff — Physics Department, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 1, 91058 Erlangen, Germany

The quantum-coherent interaction of light and free electrons was shown more than a decade ago in a transmission electron microscope in the form of photon-induced near-field microscopy (PINEM). A variety of scientific demonstrations followed including attosecond quantum coherent control, free electron quantum state generation and reconstruction, attosecond pulse generation and photon statistics reconstruction. A significant drawback of the PINEM technique so far was that it required a specifically modified transmission electron microscope (TEM), mainly because high-resolution spectrometers for scanning electron microscopes (SEM) are not available. Based on a home-built, compact magnetic high resolution electron spectrometer we show the quantum coherent coupling between electrons and light in an SEM, at unprecedentedly low, sub-relativistic energies down to 10.4 keV. These microscopes not only afford the yet-unexplored energies from ~0.5 to 30 keV providing the optimum electron-light coupling efficiency, but also offer spacious and easily-configurable experimental chambers for extended, cascaded optical set-ups, potentially boasting thousands of photon-electron interaction sites. The demonstration of PINEM in an SEM opens a new avenue of electron-photon quantum interactions unfeasible in TEMs.

Q 31.4 Wed 11:15 Q-H15

Deep learning assisted design of high reflectivity metamirrors — •Liam Shelling Neto[1,2], Johannes Dickmann[1,2], and Stefanie Kroker[1,2,3] — [1]Institut für Halbleitertechnik, Braunschweig, Deutschland — [2]Laboratory for Emerging Nanometrology, Braunschweig, Deutschland — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Manipulating light in an ever so complex manner can be a complicated task. Metasurfaces, i.e. two-dimensional periodic nanostructures of sub-wavelength size, allow exotic applications in wavefront manipulation for the price of nonintuitive design of the surfaces building blocks. Since the mapping of a given design to the underlying electromagnetic response is highly non-linear, common approaches involve numerous simulations to optimize the device performance to given requirements. With increasing functionality of the metasurface, the parameter space that necessary to provide enough flexibility can be rather large and thus, difficult to control. When it comes to the application of metasurfaces as focusing mirrors in ultra-stable cavities or future gravitational wave detectors, those devices face unprecedented requirements such as high reflectivity, optimal phase agreement etc. Here, we utilize powerful deep learning algorithms to implement an inverse design framework that handles large parameters spaces with ease in order to design high-reflectivity metamirrors.

Q 31.5 Wed 11:30 Q-H15

Integrated Grating Outcoupler for Ion-based Quantum Computers — •Anastasiia Sorokina[1,2], Steffen Sauer[1,2], Johannes Dickmann[1,2], and Stefanie Kroker[1,2,3] — [1]Institute of Semiconductor Technology, Technische Universität Braunschweig, 38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology (LENA), Langer Kamp 6a/b, 38106 Braunschweig, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Trapped-ion qubits are considered a promising platform for quantum computation due to their long coherence times and high fidelity. Nevertheless, the existing requirements for the control and operation of the ions is currently accessed via conventional optics. Consequently, increasing the number of ion-trapped qubits is complex and intricate. Additionally, the sheer complexity of the optical arrangement results in vibrational noise and a decreased operational fidelity. To optically operate the multi-level transitions of the ion, we explore an integrated optical system comprising a waveguide and a grating coupler. This system delivers and focuses light to the position of the ion. In order to ensure single-mode waveguide operation, COMSOL Multiphysics FEM solver was utilized. Additionally, Lumerical FDTD solver was used to optimise the light focusing ability of the grating coupler. We present the numerical results covering the whole wavelength range of ion transitions with an optical system on a single chip.

Q 31.6 Wed 11:45 Q-H15

Aluminum nitride integration on silicon nitride photonic circuits: a new hybrid approach towards on-chip nonlinear optics — Giulio Terrasanta[1,2], •Timo Sommer[1,4], Manuel Müller[3,1], Matthias Althammer[3,1], Rudolf Gross[3,1,4], and Menno Poot[1,4,5] — [1]Department of Physics, Technical University Munich, Garching, Germany — [2]Physics Section, Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland — [3]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [5]Institute for Advanced Study, Technical University Munich, Garching, Germany

Aluminum nitride (AlN) is an emerging material for integrated quantum photonics with excellent linear and nonlinear optical properties, in particular its $\chi^{(2)}$ that allows single-photon generation. In this talk, we demonstrate the integration of AlN on silicon nitride (SiN) photonic chips. We sputtered c-axis oriented AlN on top of pre-patterned SiN microrings. We varied AlN thickness, ring radius, and waveguide width n different chips to meet the phase-matching condition for second harmonic generation or spontaneous parametric down-conversion. With XRD, optical reflectometry, SEM, and AFM, we investigated the deposited AlN films and proofed their good optical quality. This hybrid approach adds $\chi^{(2)}$ nonlinearity to the SiN platform without the challenging process of AlN etching. Therefore, the integration of single photon-pair generation depends only on reliable SiN nanofabrication.

Q 31.7 Wed 12:00 Q-H15

Tabletop setup for broadband absolute EUV reflectivity measurements from single exposures — •Johann Jakob Abel[1], Felix Wiesner[1], Florian Funke[1], Julius Reinhard[2], Martin Wünsche[2], Jan Nathanael[3], Christian Rödel[4], Silvio Fuchs[1,2], and Gerhard G. Paulus[1,2] — [1]IOQ, FSU Jena, Germany — [2]Helmholtz Institut Jena, Germany — [3]IOF, Jena, Germany — [4]TU Darmstadt, Germany

The broadband measurement of EUV reflectivity from samples is of particular interest for multilayer EUV mirror characterization [1], EUV reflection spectroscopy [2], and EUV imaging applications [3]. A tabletop setup for measurements allowing to record reference and sample spectra simultaneously with high energy resolution in a range between 40 and 100 eV is presented. The presented method provides a solution for extremely precise and robust absolute reflectivity measurements even when operating with unstable and spectrally fluctuating EUV sources. The simultaneous reference measurement improves the stability by more than one order of magnitude in comparison to a single independent reference measurement. Applications and advantages in nanoscopic three-dimensional imaging with XUV coherence tomography (XCT) [4] and reflective near-edge x-ray absorption fine structure spectroscopy (NEXAFS) are presented and discussed.

[1] J. Li, Optics Letters, 43, 16 (2018)
[2] L. Bahrenberg, Optics Express 28, 14 (2020)
[3] S. Skruszewicz, Appl. Phys. B 127, 55 (2021)
[4] S. Fuchs, Optica 4, 903-906, (2017)

Q 31.8 Wed 12:15 Q-H15

Development of a nanophotonic nonlinear unit for optical artificial neural networks — •Jan Riegelmeyer[1], Alexander Eich[1], Marlon Becker[2], Benjamin Risse[2], and Carsten Schuck[1] — [1]Institute of Physics, University of Münster, Germany — [2]Institute of Computer Science, University of Münster, Germany

Coherent nanophotonic circuit implementations of artificial neural networks (ANNs) try to mimic signal processing in biological brains and hold great potential for fast and energy efficient computing. However, the realization of nonlinear nanophotonic components, which are utilized as activation function, remains a major challenge.

In our work, we plan on employing solution-based photoresponsive molecular systems as nonlinear building blocks of optical ANNs, for which we design and fabricate nanophotonic interfaces. We perform finite difference time domain simulations of 3D waveguide-to-free-space coupling structures that create a free-space optic link on-chip, which can be filled with photoresponsive solutions realizing tunable attenuation. The corresponding structures are produced via Direct Laser Writing in photopolymer. To confine solution in-between the couplers we fabricate micrometer-sized reservoirs made from epoxy-based photoresist. Our device realizes a new platform for optically interfacing with solution-based photoresponsive systems via multiple nanophotonic channels benefitting not only ANN-implementations but integrating novel soft matter systems into nanophotonic circuits.