Q 74: Photonics II

Time: Friday 14:30–16:30 Location: HS Botanik

Q 74.1 Fri 14:30 HS Botanik

CMT-Driven Dual Fitting of 3D FDTD Bragg Grating Reflectance and Transmittance Data — •Yasmin Rahimof, Igor Nechepurenko, M. R. Mahani, and Andreas Wicht — Ferdinand-Braun-Institut (FBH)

Optical Bragg gratings are widely used in research of light-matter interactions and develop photonic devices. Their ability to precisely control wavelength, reflection and transmission characteristics makes them particularly useful in diode laser applications, ensuring reliable performance. The finite-difference time-domain (FDTD) method is widely recognized as one of the most precise techniques for simulating Bragg gratings, as it numerically solves Maxwell's equations. When implemented in 3D, FDTD method can accurately capture the complex interactions between light and intricate geometries or materials, resulting in more accurate simulation outcomes. On the other hand, Coupled Mode Theory (CMT) offers an analytical approach for modeling and predicting the optical response of Bragg gratings. While CMT lacks the dimensional details of 3D FDTD and is therefore generally less accurate, it can still effectively characterize the optical response. In this research, we aim to simultaneously fit the reflection and transmission spectra derived from 3D FDTD simulations with CMT. We investigate how CMT parameters change with different grating lengths. Furthermore, CMT allows us to predict the optical response of longer structures (up to 2 mm) based on data from much shorter structures, approximately 10 times smaller.

Q 74.2 Fri 14:45 HS Botanik

Speeding up the calculations of computer-generated holograms for complex 3D beam-shaping — •Tim-Dominik Gómez[1], Daniel Flamm[2], Pavel Ruchka[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Trumpf GmbH & Co KG, Ditzingen, Germany

Beams with spatially varying, non-Gaussian profiles are essential across diverse research fields, particularly in applications like imaging and material processing. These can be shaped with the help of diffractive or holographic optical elements, such as spatial light modulators or metasurfaces, which in many cases results in the restriction to phase-only optical elements. The resulting calculation of an appropriate phase mask for a specific 3D beam-shape necessitates the use of iterative Fourier transform algorithms (IFTA). For free-space propagation the number of 2D Fast Fourier transforms involved scale with the number of layers observed and is thus computationally intensive. For valid window sizes $>$ 1024 pixel, even current-gen CPUs require more than a second for the computation of around 100 of these 2D FFTs.

In this work, we therefore simulate free-space propagation through upwards of 500 layers on a current-generation NVIDIA 4090 GPU utilizing the angular spectrum method. We then implement, as well as compare a variety of IFTAs, identifying valid approaches and parameters. Further, we optimize memory allocation and parallelization for these approaches and aim to enable real-time processing for the control of the optical traps in Rydberg quantum computers.

Q 74.3 Fri 15:00 HS Botanik

3D printed needle-beam micro-endoscope for extended depth-of-focus intravascular OCT — •Pavel Ruchka[1], Alok Kushwaha[2], Jessica A. Marathe[3,4], Lei Xiang[2], Rodney Kirk[2,3], Joanne T. M. Tan[3,4], Robert A. McLaughlin[2,3], Peter J. Psaltis[3,4], Harald Giessen[1], and Jiawen Li[2,4] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute for Photonics and Advanced Sensing, University of Adelaide, Adelaide, SA 5005, Australia — [3]Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, SA 5005, Australia — [4]Lifelong Health Theme, South Australian Health and Medical Research Institute (SAHMRI), Adelaide, SA 5000, Australia

A fundamental challenge in endoscopy is creating small astigmatism-free fiber-optic probes that match the performance of larger systems, particularly in achieving high resolution and extended depth-of-focus (DOF). We present a novel approach using two-photon polymerization 3D printing to fabricate freeform beam-shaping endoscopic probes. Our design achieves 8 um resolution with a DOF exceeding 800 um at a central wavelength of 1310 nm. The 250 um-diameter probe is printed in a single step directly on the optical fiber. We demonstrate the device in intravascular optical coherence tomography imaging of living diabetic swine and ex vivo human arteries with atherosclerotic plaques. This is the first use of 3D-printed micro-optics in coronary arteries of living swine, closely resembling human anatomy.

Q 74.4 Fri 15:15 HS Botanik

Microcombs for Hyperspectral Holographic Imaging — •Stephan Amann[1,2], Edoardo Vicentini[2,3], Bingxin Xu[1,2], Chao Xiang[4], Yang He[5], Qiang Lin[5], John Bowers[4], Theodor Hänsch[2], Kerry Vahala[6], and Nathalie Picqué[1,2] — [1]Max-Born Institute, Berlin, Germany — [2]Max-Planck Institute of Quantum Optics, Garching, Germany — [3]CIC nanoGUNE BRTA, Donostia-San Sebastian, Spain — [4]Department of Electrical and Computer Engineering, University of California, Santa Barbara, CA, USA — [5]Department of Electrical and Computer Engineering, University of Rochester, NY, USA — [6]T.J. Watson Laboratory of Applied Physics, California Institute of Technology, Pasadena, CA, USA

Microcombs are broad optical spectra consisting of phase-coherent narrow laser lines, which are conveniently generated in high-Q optical microresonators. Due to their high coherence, broad optical bandwidth, and small footprint, microcombs have become attractive for applications such as low-noise microwave generation, optical communication and optical ranging. Digital holography is an interferometric imaging technique that gives access to both the amplitude and phase information of an object. The phase describes the three-dimensional profile of the object, while the amplitude encodes the absorption properties of the sample. By using a microcomb of 1 THz line spacing we can access the broad absorption features of condensed phase samples, measured at the comb line positions. This enables three-dimensional hyperspectral imaging and allows to discriminate the spectral properties of different plastic samples.

Q 74.5 Fri 15:30 HS Botanik

Low-loss and broadband all-fiber acousto-optic circulator — •Riccardo Pennetta, Martin Blaha, and Arno Rauschenbeutel — Department of Physics, Humboldt Universität zu Berlin, 10099 Berlin, Germany

The introduction of low-loss optical fibers probably represents the single most important advance in the growth of telecommunication systems. To meet our needs for secure communications, it is likely that our classical network will soon be operating alongside what is known as a quantum network. The latter is very sensitive to loss and thus poses constraints to the performance of current fiber components. In particular, recent quantum network prototypes underline the absence of low-loss nonreciprocal fiber-based devices. Here, we present a solution to this issue by realizing low-loss (0.81 dB), broadband (at least 50-GHz bandwidth), and high-extinction (up to 27 dB) circulators, based on Mach-Zehnder interferometers including so-called fiber null-couplers. The latter are directional couplers, whose splitting ratio can be controlled by launching acoustic waves along the coupling region. Fabricated from standard single-mode fibers and actuated electrically, these circulators can be made to fit any existing optical fiber networks and could turn out to be key for the transmission and processing of optically encoded quantum information.

Q 74.6 Fri 15:45 HS Botanik

Fabrication of Mode-Matched, Low-Loss Optical Micro-Resonators — •Patrick Maier, Manuel Stetter, and Alexander Kubanek — Institute for Quantum Optics, Ulm University, Germany

Fabry Perot cavities are essential tools for applications like precision metrology, optomechanics, and quantum technologies. A major challenge is the creation of mirror structures that allow the precise mapping of a wavefront (e.g. from a Gaussian beam) onto a glass surface, while providing high surface quality. We demonstrate the fabrication of customized Gaussian mode matched micro-cavity optics with a novel fabrication method, allowing customized geometrical parameters as well as smooth surfaces allowing coating limited Finesse F.

Q 74.7 Fri 16:00 HS Botanik

Measuring deviations from a perfectly circular cross-section of an optical nanofiber at the Ångström scale — •Jihao Jia, Felix Tebbenjohanns, Jürgen Volz, Arno Rauschenbeutel, and Philipp Schneeweiss — Humboldt-Universität zu Berlin, Germany

Tapered optical fibers (TOFs) with sub–wavelength–diameter waists, known as optical nanofibers, are powerful tools for interfacing quantum emitters and nanophotonics. This demands stable polarization of the fiber–guided light field. However, the linear birefringence resulting from Ångström–scale deviations in the nanofiber's ideally circular cross–section can lead to significant polarization changes within millimeters of light propagation.

Here, we experimentally investigate such deviations using two in-situ approaches. First, we measure the resonance frequencies of hundreds of flexural modes of the nanofiber, which can be thought of as a doubly clamped beam in this context. Assuming an elliptical cross-section with a and b, the differing second moments of area for vibrations along these axes result in a splitting of the resonance frequencies. By analyzing the measured resonance pairs, we estimate $|a-b| \approx 3$ Ångström for a nanofiber with a nominal diameter of 500 nm. An analytical model links this elliptical cross–section to the linear birefringence of the nanofiber. Second, we monitor the polarization of the guided light field along the nanofiber [1]. By analyzing the scattered light as a function of the axial position, we confirm the birefringence inferred from the flexural mode frequencies.

[1] IEEE J. Quantum Electron. 18, 1763 (2012)

Q 74.8 Fri 16:15 HS Botanik

Colloidal self-assembly for 3D second-harmonic photonic crystals — •Thomas Kainz[1,2], Ullrich Steiner[1,2], and Viola Vogler-Neuling[1,2] — [1]Adolphe Merkle Institute, University of Fribourg, Fribourg, Switzerland — [2]NCCR Bio-inspired Materials, University of Fribourg, Fribourg, Switzerland

Three-dimensional nonlinear photonic crystals can simultaneously generate different nonlinear processes, like second-harmonic generation (SHG) and other sum- and difference-frequency processes. However, creating large crystals in all three dimensions presents a considerable challenge, primarily due to the chemical inertness of metal oxides. This study shows the first demonstration of colloidal-crystal-templating into a second-order optical material. Different templates made of polystyrene opals are self-assembled from monodisperse nanospheres with tunable unit sizes. These are infiltrated with barium titanate sol-gel, which results after calcination in an inverse fcc network of tetragonal barium titanate. We fabricated samples with unprecedented sizes (above 3000 unit cells in x, y directions and 100 in z). The achieved reflectivity values are above 80 % throughout the fabrication. We can tune the final photonic bandgap over the whole optical range, matching it to material and setup requirements. We successfully replicated the photonic network into a second-order material and demonstrated, for the first time, a linear photonic band gap from a fully scalable three-dimensional photonic crystal made of a nonlinear optical material. This enables the experimental investigation of SHG within a bandgap, like inhibited spontaneous emission.