Q 32: Photonics and Biophotonics II

Time: Wednesday 14:30–16:30 Location: P 3

Q 32.1 Wed 14:30 P 3

Alternative phase-reconstruction algorithms for 3D spot-based beam shapes — •Tim-Dominik Gómez[1], Daniel Flamm[2], 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 manipulating optical elements. The resulting calculation of an appropriate phase mask for a specific 3D beam-shape often use iterative Fourier transform algorithms (IFTA). For free-space propagation the number of 2D Fast Fourier transforms (FFT) involved scale with the number observed layers and is thus computationally intensive. This is the case even if the desired beam shape consists only of a number of high intensity spots in space, as is often required for material processing applications.

In this work, we present alternative algorithms for the generation of phase masks for such 3D, spot-based beam shapes for Fresnel diffraction with Gaussian spots, as well as when using the first Rayleigh-Sommerfeld solution. These do not require the use of 2D Fast Fourier Transforms and promise faster calculation speeds in cases of spots that are highly distributed in the z-direction.

Q 32.2 Wed 14:45 P 3

Si-Te Ring-Resonator Photodetector for the Telecom Band — •Guillermo Godoy[1,2], Saif Shaikh[1,2], Alessandro Puddu[1,2], Ahmad Echresh[1], Kambiz Jamshidi[2], Shengqiang Zhou[1], and Yonder Berencén[1] — [1]Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany — [2]Dresden University of Technology (TU Dresden), Dresden, Germany

Silicon is a widely used material in photonics, particularly for passive photonic elements, but its indirect bandgap (~1100 nm) limits its use as an active material in the telecom bands. Integration with materials like Ge or InGaAs is typically required for lasers and detectors at telecom wavelengths, increasing fabrication complexity and cost. Tellurium incorporation into Si has recently shown promise for extending silicon's optical response into the near-infrared, covering the telecommunication range (~1260-1625 nm). By introducing deep-level states within the Si bandgap, Si-Te enables absorption of sub-bandgap infrared photons, achieving performance comparable to state-of-the-art heterogeneous devices while maintaining CMOS compatibility and enabling monolithic integration. In this work, we implement Si-Te technology in a microring resonator (MRR) to realize a resonant-enhanced photodetector. This approach is expected to significantly enhance Si-Te sub-bandgap absorption through resonant field amplification, enabling narrowband, spectrally tunable detection in the telecom range. It demonstrates a CMOS-compatible route toward compact infrared photodetectors, paving the way for scalable silicon photonic circuits for optical communication and sensing.

Q 32.3 Wed 15:00 P 3

Vectorial SLM Holography for Flat, Low-Aberration Optical Traps — •Fiona Hellstern, Michael Wischert, Paul Uerlings, Kevin Ng, Tim Jeglortz, Stephan Welte, Ralf Klemt, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We present a self-developed framework for holographically generating high uniformity optical traps for ultracold atoms using a spatial light modulator (SLM) placed in the conjugate plane of the experiment. By correcting optical aberrations and producing homogeneous potentials, our framework establishes a reliable platform for quantum-gas experiments that require precise control and uniform trapping potentials. This is especially crucial, as spatial intensity variations shift the local chemical potential and can couple low-energy collective modes, making dynamical measurements unreliable. State-of-the-art hologram algorithms, including Gerchberg-Saxton, are often limited in applications for extended potentials. To overcome these limitations, we built a gradient-descent-based hologram optimization toolbox that directly minimizes intensity inhomogeneities. This approach yields smooth, low-aberration traps and achieves an order-of-magnitude reduction in RMS noise compared to conventional Gerchberg-Saxton holography. A central advantage of our framework is that it naturally goes beyond the assumptions of scalar Fourier optics. At numerical apertures around NA = 0.5, standard paraxial models break down, and accurate trap prediction requires non-paraxial and vectorial propagation models.

Q 32.4 Wed 15:15 P 3

Microscopic lasers as biointegrated sensors — •Marcel Schubert — Humboldt Centre for Nano and Biophotonics, University of Cologne, 50939, Cologne

Microscopic lasers combine the unique advantages of laser light with a small footprint and variable material choice, making them ideal light sources for biointegrated optical sensors. Their intense and narrow-band emission also allows optical barcoding to identify large numbers of biological cells. In addition, changes of the spectral positions of the laser modes are used for sensing various physical, chemical, and biological stimuli.

Here, we present different micro- and nanolaser devices, called laser particles, for use as intracellular and biointegrated sensors. Laser particles have a typical size of 1-15 μm and are fabricated from either organic dyes doped into a chemically inert matrix or from inorganic semiconductors. As an example, the contractile properties of heart cells are characterized in detail on the level of individual cells as well as in in vivo experiments in zebrafish embryos. We demonstrate that the high signal intensity and elastic nature of light scattering enable deep-tissue sensing at unprecedented depth and spatio-temporal resolution. By making the matrix of the microlasers mechanically flexible, biological forces can also be measured with high precision. Finally, we will present our progress in developing alternative nanolaser platforms that allow to implement various laser mode shapes, therefore making the laser particles more adaptable to specific biological sensing applications.

Q 32.5 Wed 15:30 P 3

Experimental measurement of the non-Abelian Quantum Geometric Tensor in a multiband photonic lattice — •Martin Guillot[1], Cédric Blanchard[1], Martina Morassi[1], Aristide Lemaître[1], Luc Le Gratiet[1], Abdelmounaim Harouri[1], Isabelle Sagnes[1], Robert-Jan Slager[2], F. Nur Ünal[3], Jacqueline Bloch[1], and Sylvain Ravets[1] — [1]Center for Nanoscience and Nanotechnology, CNRS, Paris-Saclay university, 91120 Palaiseau, France — [2]Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom — [3]School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

Recent discoveries in semi-metallic multi-gap systems featuring band singularities have galvanized enormous interest in particular due to the emergence of non-Abelian braiding properties of band nodes. This previously uncharted set of topological phases necessitates novel approaches to probe them in laboratories, a pursuit that intricately relates to evaluating non-Abelian generalizations of the Abelian quantum geometric tensor (QGT) that characterizes geometric responses.

In this talk, we present the first direct measurement of the non-Abelian QGT. We achieve this by implementing a novel orbital-resolved polarimetry technique to probe the full Bloch Hamiltonian of a six-band two-dimensional (2D) synthetic lattice, which grants direct experimental access to non-Abelian quaternion charges, the Euler curvature, and the non-Abelian quantum metric associated with all bands

Q 32.6 Wed 15:45 P 3

Joule-Thomson Cooling of Light in Photonic Lattices — •Marco Steffen Kirsch[1], Giorgos G. Pyrialakos[2], Tom A. W. Wolterink[1], Alexander Szameit[1], Matthias Heinrich[1], and Demetri N. Christodoulides[2] — [1]University of Rostock, Rostock, Germany — [2]University of Southern California, Los Angeles, USA

We report the experimental observation of an all-optical analogue of the Joule-Thomson expansion in nonlinear multimode photonic lattices. By injecting light through a single-site throttle into a significantly larger waveguide array, we induce a power-dependent redistribution of modal populations. Increasing input power drives a condensation of energy into the fundamental mode, resulting in a measurable reduction of the system's optical temperature. Our results demonstrate a controllable pathway for optical cooling in multimode environments, offering new tools for managing coherence and beam quality in complex nonlinear photonic systems.

Q 32.7 Wed 16:00 P 3

Efficient simulation of tapered photonic structures — •Konrad Tschernig[1,2,3], Swati Bhargava[3], Vinzenz Zimmermann[3], Daniel Cruz-Delgado[3], Janik Wolters[1,2], Sergio Leon-Saval[4], Steven Eikenberry[3], Rodrigo Amezcua-Correa[3], and Miguel A. Bandres[3] — [1]Technical University of Berlin, Berlin, Germany — [2]German Aerospace Center (DLR), Berlin, Germany — [3]University of Central Florida CREOL, Orlando, FL, USA — [4]University of Sydney, Sydney, NSW, Australia

Tapered optical structures play a crucial role in modern photonics, enabling efficient coupling, mode conversion, and multiplexing. Modeling such structures is challenging since, as the region of interest shrinks, there is a significant loss of numerical resolution. We present a novel approach to modeling tapered structures by introducing the taper reference frame, which renders the tapered refractive index profile constant. Working in this frame eliminates the need for recalculating or resizing the refractive index distribution, which reduces computational overhead. Most importantly, our approach maintains high resolution in the region of interest, critical for capturing intricate features of the taper. We validate our method by comparing our simulations with analytical solutions. We applied our model to the analysis of photonic lanterns. Our results demonstrate vastly improved accuracy and computational efficiency compared to existing approaches. The proposed tapered reference frame technique enables major advancements in the design and optimization of optical devices across various applications.

Q 32.8 Wed 16:15 P 3

The Gouy phase of singular beams — •Lyubomir Stoyanov[1,2], Gerhard G. Paulus[3,4], and Alexander Dreischuh[1,2] — [1]Sofia University, Faculty of Physics, Department of Quantum electronics, Sofia, Bulgaria — [2]National Centre of Excellence Mechatronics and Clean Technologies, Sofia, Bulgaria — [3]Institute of Optics and Quantum Electronics, Friedrich Schiller University, Jena, Germany — [4]Helmholtz Institute Jena, Jena, Germany

Ever since the first observation of the second harmonic generation (SHG) of the emission of a ruby laser, the nonlinear optics attracts continuous research interest and is a subject of intensive further development. Part of it, is the singular nonlinear optics, a field in photonics in which the objects of interest are beams/pulses with phase and/or polarization dislocations. Not that obvious, but Bessel-Gaussian beams (beams carrying a finite number of concentric rings surrounding a central peak/ring.) can also be classified as singular beams because of these radial phase jumps of π characteristic for their phase profiles. Here we demonstrate both experimentally and by numerical simulations a strong reshaping of the second harmonics of zeroth- and first-order Bessel-Gaussian beams (BGBs). Detailed interferometric measurements showing flat phase profiles of the broadened central part of the SH beam, and between it and the neighboring rings, will be presented, discussed, and compared with numerical simulations. Numerical simulations for third harmonic generation will also be presented and discussed.