Q 40: Photonics II

Time: Wednesday 14:30–16:30 Location: F442

Q 40.1 Wed 14:30 F442

Bispectral High-Reflectivity Metamirrors — •Liam Shelling Neto[1], Johannes Dickmann[1], and Stefanie Kroker[1,2] — [1]TU Braunschweig, Institut für Halbleitertechnik, Braunschweig — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

To manipulate electromagnetic waves in unique ways, metasurfaces, the two-dimensional variant of metamaterials, have opened up a whole new world of optical functionalities. From optical imaging to quantum optics, the full potential of metasurfaces depends heavily on their building blocks, i.e. metaatoms. To design metaatoms that meet tight requirements, as is the case in high-precision optical metrology, machine learning has shown promising results in the past years. Here we show preliminary results for implementing such a framework to design focusing metamirrors that provide high reflectivities for two different wavelengths. With high reflectivity and a tailored phase profile, such metamirrors could outperform conventional multilayer mirrors for high-precision optical interferometry due to their low thermal noise.

Q 40.2 Wed 14:45 F442

Light transport in designed symmetric multiple-scattering media — •Sudhir Saini[1], Kayleigh Start[1], Evangelos Marakis[2], and Pepijn Pinkse[1] — [1]MESA+ Institute for Nanotechnology, University of Twente, The Netherlands — [2]Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Crete, Greece

The latest advancement in nanofabrication technology enables the exact synthesis of designed scattering media with features on the scale of the optical wavelength. To the best of our knowledge, random scattering media with global symmetries do not naturally occur. Here we use modern nanofabrication to study the effect on light propagation of mirror-symmetric disorder in a multiple-scattering medium. A commercial direct laser writing technique based on two-photon polymerization is used to fabricate the designed three-dimensional (3D) mirror-symmetric disordered samples. Light transport experiments combined with quantitative 3D modeling are used to study the effect of mirror symmetry on the medium's scattering properties. The optical characterization results establish polarization-dependent deviations at the symmetry plane from the bulk ensemble-averaged intensity distribution when pumped in an equally mirror-symmetric way. In the weak-scattering limit, Drexhage's theory for the emission properties of an emitter above a mirror predicts the experimentally observed intensity patterns well. We model our experiments with FE numerical methods in the multiple-scattering regime. Applications are envisioned in fundamental light propagation studies and anti-counterfeiting.

Q 40.3 Wed 15:00 F442

Nonlocal optical response of finite hyperbolic metamaterials — •Olga Kochanowska[1,2] and Christin David[1] — [1]Institute of Condensed Matter Theory and Optics, Abbe Center of Photonics, Friedrich-Schiller-University Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]Faculty of Physics, University of Warsaw, Pasteura Street 5, 02-093 Warsaw, Poland

Metamaterials are artificial nano-engineered structures with properties beyond those encountered in nature. Especially interesting are hyperbolic metamaterials (HMMs), i.e. highly anisotropic media characterized by a hyperbolic dispersion relation. HMMs exhibit unusual properties, such as negative refraction of light, with applications in subdiffraction imaging, refractometric sensing and photovoltaics. In our studies, a type II HMM (consisting of alternating metal and dielectric layers) was analyzed, using Finite-Difference Time-Domain (FDTD) and Fourier Modal Method (FMM) for numerical calculations. Initially, we assumed the local-response approximation (LRA), in which nonlocal effects are neglected. However, as in an HMM metal layers are of subwavelength thickness, the quantum nature of free electrons and their interactions in metals play a significant role and spatial dispersion effects are considered. Therefore, we implement the semi-classical hydrodynamic model into the FMM to account for nonlocal effects in hyperbolic gratings. Consequently, we compare the optical response of type II HMM in different geometries in the LRA and nonlocal case. We determine optimal parameters of the hyperbolic nanostructure at which nonlocal effects are relevant.

Q 40.4 Wed 15:15 F442

Low thermal noise meta-mirrors with 99.95 % reflectivity — •Johannes Dickmann[1], Steffen Sauer[1,2], Liam Shelling Neto[1], and Stefanie Kroker[1,2] — [1]Technische Universität Braunschweig, Institut für Halbleitertechnik, Langer Kamp 6a/b, 38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Many experiments in fundamental science are limited by the thermal noise of optical components, e.g. interferometric gravitational wave detectors, optical atomic clocks or cavity experiments on dark matter and general relativity. It has been found that, in addition to quantum noise, which can be reduced by using squeezed states of light, it is primarily Brownian noise of the mirror coatings that limit the sensitivity of the measurements. One way to reduce this noise is to use mirror layers with small mechanical losses, but these are difficult to find, especially at cryogenic temperatures. We present extensive investigations on microstructured mirror surfaces, i.e. meta-mirrors, for applications in high precision metrology. In particular, noise calculations and record-breaking experimental results of the reflectivities of these mirrors are presented.

Q 40.5 Wed 15:30 F442

Modeling beam imperfection using Hermite-Gauss modes for interferometric simulations — •Kevin Weber, Gudrun Wanner, and Gerhard Heinzel — Albert Einstein Institut, Hannover, Germany

Precision laser interferometry is a widespread technique used across many disciplines due to its high measurement accuracy. Using such a technique allows us to see the changes in earth*s gravitational potential, as in the GRACE-FO mission, or enables us to detect ripples in space-time itself, known as gravitational waves, as in LIGO or VIRGO. For future missions which deploy inter-spacecraft interferometers, the prior knowledge of all noise contributions is crucial for its success. Until now, most of our simulations use only perfectly Gaussian or tophat beam geometries. However, experimental beams never possess the mathematically perfect shape the models assume. In this talk, we will discuss possible sources of noise contributions from imperfect beam geometries. Also, we show possible means to predict those using a system of Hermite-Gaussian modes as mathematical beam descriptions.

Q 40.6 Wed 15:45 F442

Creation of Gauss-Bessel quasi-nondiffracting beams using Optical Vortices — •Maya Zhekova, Nikolay Dimitrov, and Alexander Dreischuh — Sofia University "St. Kliment Ohridski", Faculty of Physics

In recent years a way of creating Gauss-Bessel quasi-nondiffracting beams (GBBs) has been investigated, using optical vortices (OVs), which have been created and later annihilated. In and behind the focus of a thin lens, the resulting beam turns out to be such GBB. Different setups using spiral vortex plates (VPs) have been investigated, but their seemingly main weakness is the wavelength usage limited to the design wavelength of the VPs.

A novel scheme for laser beam shaping has been proposed and investigated, which is applicable in a wide range of wavelengths. The setup's key OV element is a single VP designed for 532 nm, which will be proven to transform beams at 445 nm, 532 nm, 633 nm and 800 nm into GBBs. We will show that this setup can transform beams into not only zeroth-order GB beams. In the case when a residual topological charge is left, the resulting beam will be a first-order Gauss-Bessel beam, again with a lack of spectral sensitivity.

Q 40.7 Wed 16:00 F442

Optical convolutional neural network with atomic nonlinearity — •Mingwei Yang[1,2], Elizabeth Robertson[1,2], Luisa Esguerra[1,2], Kurt Busch[3,4], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institute of Optical Sensor Systems, Berlin, Germany. — [2]Technische Universität Berlin, Berlin, Germany. — [3]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Berlin, Germany. — [4]Max-Born-Institut, Berlin, Germany.

Due to their inherent parallelism, fast processing speeds and low energy consumption, free-space-optics implementations have been identified as an attractive possibility for analog computations of convolutions [1,2]. However, the efficient implementation of optical nonlinearities for such neural networks still remains challenging. In this work, we report on the realization and characterization of a three-layer optical convolutional neural network where the linear part is based on a 4f-imaging system and the optical nonlinearity is realized via the absorption profile of a cesium atomic vapor cell. This system classifies the handwritten digital dataset MNIST with 83.96% accuracy, which agrees well with corresponding simulations. [1] H. J. Caulfield and S. Dolev, *Why future supercomputing requires optics,* Nat. Photonics 4, 261*263 (2010). [2] M. Miscuglio, Z. Hu, S. Li, J. K. George, R. Capanna, H. Dalir, P. M. Bardet, P. Gupta, and V. J. Sorger, *Massively parallel amplitude-only fourier neural network,* Optica 7, 1812*1819 (2020).

Q 40.8 Wed 16:15 F442

Dispersion Interferometry for Relative Atmospheric Pressure Measurement — •Hugo Uittenbosch, Peter Mahnke, Raoul-Amadeus Lorbeer, and Oliver Kliebisch — Institute of Technical Physics, German Aerospace Center, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany

Second harmonic interferometry is a common method in fusion research to measure dispersive phase shifts, i.e. for line-average electron densities [1]. Using this technique, a contact-less, relative barometer is implemented by measuring the pressure-dependent dispersive phase shift in air. This change in phase is converted into a change in pressure via the Ciddor equation [2]. In order to minimize the footprint of the experimental setup, a single crystal dispersion interferometer (SCDI) [3] is improved upon by generating a reference beam which contains both the fundamental and second harmonic beam coaxially, thereby reducing the system complexity. The device is used to measure changes in the dispersion of air in a pressurized chamber between 10^1 to 10^5 Pa and compared against a piezoresistive pressure transceiver. The deviation between both sensors was found to be less than 150 Pa.

[1] Drachev, V. P., et al. “Dispersion interferometer for controlled fusion devices.” Rev. Sci. Instrum. **64**(4) (1993)

[2] Ciddor, Philip E. “Refractive index of air: new equations for the visible and near infrared.” Appl. Opt. **35**(9) (1996)

[3] Lee, Dong-Geun, et al. “The new single crystal dispersion interferometer installed on KSTAR and its first measurement.” Rev. Sci. Instrum. **92**(3) (2021)