Q 9: Photonics II

Time: Monday 14:30–16:15 Location: f342

Q 9.1 Mon 14:30 f342

Polymer based optics for sensing applications — •Axel Günther, Maher Rezem, Maik Rahlves, and Bernhard Roth — Hannover Centre for Optical Technologies, Leibniz Universität Hannover, Nienburger Str. 17, 30167 Hannover

Integrated polymer photonics is highly relevant to various fields in optical technologies ranging from optical communication to integrated sensor networks. Key components for such devices are optical waveguides with propagation losses lower than 1dB/cm as well as highly efficient coupling structures for light coupling.

We developed a process which allows the realization of fully polymer based low-loss optical waveguides and relies on a hot embossing step to create a micro-structured substrate and cladding layer. In a subsequent doctor blading step, the core material is introduced into the structure. Using a similar process, we also realized integrated grating coupler elements. In addition, to establish rigid and low-loss connections between two optical waveguides or waveguides and laser diodes, we realize all-polymer self-written waveguides (SWW). Here, we use UV curable monomer which is applied to a gap between two optical components such as fibers, waveguides or light sources. Launching UV light through the fiber or the waveguide leads to local polymerization of the monomer at the end facet, which also increases the refractive index locally and acts as a seed point for the SWW.

In the talk we discuss various application scenarios where our process can be utilized to create highly integrated sensing structures for detection of physical quantities or chemical analytes.

Q 9.2 Mon 14:45 f342

All-polymer optical WGM sensor approach — •Ann Britt Petermann[1], Uwe Morgner[2], and Merve Meinhardt-Wollweber[1] — [1]Hannover Centre for Optical Technologies (HOT), Leibniz University Hannover, Nienburger Strasse 17, D-30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, D-30167 Hannover, Germany

Microcavities, which support whispering gallery modes (WGMs) are resonant optical sensors providing high quality factors. In recent years WGM sensors are continuously enhanced with respect to sensitivity and detection limit which is a highly promising feature in molecular analytics. One of the next steps is the implementation of WGM sensors for real-world applications, such as measurement of force and temperature or sensing of biomolecules. To this end, an all polymer WGM-sensor is being realized. For this purpose various polymer specific issues need to be addressed. Among others, the investigation of a suitable geometry of the resonator and a possible supporting structure is important. In an all-polymer device the commonly used excitation of the sensor with a tapered fiber is not possible. One aim is the design of a new coupling structure with high coupling efficiency. The performance of the polymer sensor compared to silica devices is crucial to determine the sensitivity range and the possible applications. Due to the fabrication, the Q-factor of polymer sensors will be smaller than that of silica sensors, which in turn leads to a smaller sensitivity. However, polymer based systems are attractive because of their diversity in refractive index and hydrophobicity and prospective mass fabrication.

Q 9.3 Mon 15:00 f342

Laser-induced volume phase gratings in lithium niobate for noncollinear frequency conversion — •Haissam Hanafi, Dennis Niemeier, Sebastian Kroesen, Mousa Ayoub, Jörg Imbrock, and Cornelia Denz — Westfälische Wilhelms-Universität Münster, Institute of Applied Physics, Correnssstr. 2, 48149 Münster, Germany

We demonstrate the fabrication and characterization of direct femtosecond laser written volume diffraction gratings (VDG) for efficient second-harmonic generation (SHG) in x-cut lithium niobate ($LiNbO_3$). The designed integrated nonlinear beam splitter device allows due to it's hybrid architecture to satisfy the noncollinear phase matching condition between the transmitted and diffracted fundamental wave within the crystal. To determine the grating period, grating thickness and refractive index change, we have measured the linear diffraction efficiency of 532 nm cw laser light depending on the incident angle and input-polarization. The nonlinear properties are analyzed by measuring noncollinear phase-matched SHG using femtosecond laser pulses with a wavelength between 1200 nm and 1400 nm. The linear as well as the nonlinear properties are investigated for a large variety of fabrication parameters of the grating, like writing speed, pulse energy, polarization, and writing direction in order to characterize the diffraction properties. Using a laser scanning SHG microscope, the structural modifications are visualized in three dimensions with high spatial resolution. Furthermore, these permanent femtosecond laser-induced gratings were systematically compared with optical erasable gratings, induced by cw laser light using the photorefractive effect in $LiNbO_3$:Fe.

Q 9.4 Mon 15:15 f342

Theoretical description of all-optically induced, transient long period gratings — •Tim Hellwig, Kai Sparenberg, and Carsten Fallnich — Institute of Applied Physics, University of Münster, Corrensstrasse 2, 48149 Münster, Germany

A theoretical model is developed for transverse mode conversion at all-optical long-period gratings[1] transiently induced via multimode interference of a control beam and the optical Kerr-effect. An analytic expression for the resulting directed energy exchange of two transverse probe beam modes is derived in a material representation, in analogy to coupled mode theory, as well as in a four-wave mixing representation. The developed continuous-wave model gives insight into the all-optical mode conversion process and shows excellent agreement to existing numerical simulations. Even for pulsed probe and control beams very good agreement to a corresponding numerical simulation[2] is found, when the occurring group-walk offs are negligible in comparison to the conversion length of the process.

[1] Hellwig T, et al., *Opt. Express* **22**, 24951 (2014).
[2] Hellwig T, et al., *Opt. Express* **23**, 19189 (2015).

Q 9.5 Mon 15:30 f342

Characterisation of nanostructured multifocal lenses for use in ophthalmology — •Jürgen Otten[1,2,3], Ulf Hinze[1], Boris Chichkov[1], and Ulrich Teubner[2,3] — [1]Laser Zentrum Hannover e.V., D-30419 Hannover — [2]Institut für Laser und Optik, Hochschule Emden/Leer, D-26723 Emden — [3]Institut für Physik, Universität Oldenburg, D-26129 Oldenburg

Cataract surgery is one of the most performed surgeries in industrial nations, leading to many advancements of intraocular lens (IOL) implants. Several lens designs are available. One of them uses a monofocal lens combined with a micron-sized Fresnel Zone Plate, yielding a multifocal lens. The zone plate at hand has been constructed using two-photon-polymerisation (2PP). The optical properties of this lens are characterized. Therefore, an experimental setup is built and automated. The lens is placed in a water filled cuvette and illuminated by a collimated laser beam. Using a camera mounted to a positioning system, the beam profile after passing through the lens is recorded in an image series. This series can be evaluated in regard to the beam profile and the distance of the focal points to the zone plate. Using light with a vacuum wavelength of 532nm, the focal points are expected at distances of 28.9mm, 32mm and 35.8mm. Actual measured distances are 28.8mm, 31.95mm and 35.61mm. The deviations from theoretical and measured results are minor, showing that the fabrication of a multifocal lens employing 2PP poses a reliable production process.

Q 9.6 Mon 15:45 f342

3D SLM-based STED-lithography — •Julian Hering, Erik H. Waller, and Georg von Freymann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern

3D direct laser writing (DLW) is a commonly used technology for the fabrication of almost arbitrarily polymer structures in a single processing step. As the achievable resolution in standard DLW is diffraction limited, several proposals using superresolution technology have been presented in recent years. One of the most promising is stimulated emission depletion (STED) inspired lithography. Here, using especially shaped phase masks, a second laser beam suppresses the polymerization reaction via stimulated emission. Using spatial light modulators (SLMs) for the writing as well as the depletion laser beam allows for (i) automatically aligning the setup, (ii) correcting aberrations present in the setup, and (iii) varying the phase masks used for the depletion laser to find optimal conditions. We compare doughnut- and bottlebeam-modes realized with the SLMs to theoretical expectations. In writing experiments we observe a reduction of the lateral polymerization linewidth of 50% for the doughnut- mode. The bottlebeam-mode results in a reduction of the axial feature size by 56%. Furthermore, we use a numerical algorithm to calculate corresponding phase- and amplitude-patterns for alternative mode patterns: We compare the writing performance of so called multifoci-modes with the results achieved for doughnut and bottlebeam phase masks. Experimentally, the multifoci-modes show at least comparable performance while being conceptually much simpler to realize.

Q 9.7 Mon 16:00 f342

Realization of Photonic Quantum Simulators with Direct Laser Writing — •Christina Jörg[1], Fabian Letscher[1,2], Michael Renner[1], Michael Fleischhauer[1], and Georg von Freymann[1,3] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Fraunhofer-Institute for Physical Measurement Techniques IPM, Kaiserslautern, Germany

We present a new technique of manufacturing low-loss 3D waveguide arrays on a μm-scale, based on direct laser writing in negative photoresist. As hopping between atom sites corresponds to coupling of light between waveguides, these systems act as simulators for the electronic properties of solids. A hollow waveguide array is fabricated via 3D laserlithography. The structure is then infiltrated with a higher index material, creating waveguides of about 1 μm in diameter and spacing of 1.5 μm. By choosing appropriate infiltration materials the coupling constant between waveguides can be tuned. Coupling lengths of about 50 μm at propagation lengths of up to 500 μm could be obtained so far.

For straight waveguides arranged on a honeycomb-lattice the bulk modes as well as the static edge modes are observed. Using helical waveguides as in [1], a Floquet topological insulator with chiral edge modes can be realized.

[1] Rechtsman, M. C. et al. Photonic Floquet topological insulators. Nature 496, 196-200 (2013).