BP 48: Posters - Bioimaging and Spectroscopy

Time: Wednesday 17:00–19:00 Location: Poster C

BP 48.1 Wed 17:00 Poster C

NET- the Network Extraction Tool — •Jana Lasser — MPI for Dynamics and Self-Organization, Göttingen, Germany

We present the Network Extraction Tool (NET). The tool is especially designed for high-throughput semi-automated analysis of biological datasets containing networks of very large sizes. Applied to a network, NET extracts information about its geometry (node positions and edge radii) as well as information about the topology (neighbourhood relations). The information NET collects provides a basis for quantitative research of the networks in question. The framework starts with the segmentation of the image and then proceeds to vectorization using methodologies from optical character recognition. After a series of steps to clean and improve the quality of the extracted data the framework produces a graph in which the network is represented only by its nodes and edges. The networks extracted by NET are comparable to manually extracted networks with regards to their quality but take significantly less time to generate. Additionally, the extracted networks are very easy to handle computationally. Several projects researching biological networks such as leaf veins, insect trachea and blood vessels already use NET for their data acquisition. As it is an open source tool based on a collection of python scripts feel free to find and try out the software at https://github.com/JanaLasser/network_extraction.

BP 48.2 Wed 17:00 Poster C

Aggregation of mono-stained proteins visualized ex vivo by two-dimensional polarization microscopy — •Daniela Täuber[1], Rafael Camacho[1], Christian Hansen[2], Jia-Yi Li[2], and Ivan Scheblykin[1] — [1]Chemical Physics, Lund University, Lund, Sweden — [2]Biomedical Center, Lund University, Lund, Sweden

Neurodegenerative diseases are linked to aggregation of particular proteins. The investigation of pathologic pathways and the development of suitable medication demand for methods to visualize protein aggregation ex vivo. Sophisticated microscopy often requires two color labelling, while conventional fluorescence microscopy can reveal the expression of such proteins in brain tissue, but not their aggregation. Here we apply 2-dimensional polarization imaging [1] to visualize aggregation of human α-synuclein expressed in brain tissue from transgenic mice. We employ Förster Resonance Energy Transfer (FRET) between identical (single color) green fluorescent protein (GFP) tags linked to α-synuclein. We obtain information on aggregation, which cannot be seen from fluorescence intensity [3]. Our finding of α-synuclein aggregation in olfactory bulbs of old mice correlates with results from a behavioral study on that mice [2]. The aggregation pattern was not found in young mice.

D.T. acknowledges funding from the german science foundation DFG-TA 1049/1-1.

[1] Camacho, R. et al., Chem. Phys. 406, 30, 2012. [2] Hansen, C. et al., Neurobiol. Dis. 56, 145, 2013. [3] Camacho, R. et al., in preparation

BP 48.3 Wed 17:00 Poster C

Fluorescence-Lifetime Imaging Microscopy of the Specific Uptake of Gold Nanoparticles into Cells — •Marina Mutas, Tim Hadler, Christian Strelow, Tobias Kipp, and Alf Mews — Institute of Physical Chemistry, University Hamburg, Grindelallee 117, 20146 Hamburg, Germany

Small gold nanoparticles (AuNPs) with a thiol-functionalized surface show strong emission attributed to Au-S-hybrid states on the particle surface. AuNPs with a diameter of 2 nm functionalized with Mercaptoundecanoic acid (MUA-AuNPs) exhibit fluorescence lifetimes longer than 100 ns. In comparison, the autofluorescence of biological cells exhibit lifetimes of just a few ns. We use the different fluorescence lifetimes to investigate the specific uptake of these biofunctionalized MUA-AuNPs into cells by means of fluorescence-lifetime imaging microscopy (FLIM). We show that the biofunctionalized MUA-AuNPs specifically bind to their receptors on the cells' membrane. To distinguish between bound and uptaken MUA-AuNPs we are using cross-sectional FLIM scans of individual layers at different heights through the cells. With these scans we are able to image the whole cell with the bound/uptaken MUA-AuNPs based on their different lifetimes.

BP 48.4 Wed 17:00 Poster C

Probing the heterogeneity of cellular fluids — Olivia Stiehl, •Claudia Donth, and Matthias Weiss — Universität Bayreuth, Experimentalphysik 1

Cellular fluids, e.g. the cytoplasm, are crowded with macromolecules at concentrations up to 400g/l. Such crowded fluids may feature not only a considerable environmental heterogeneity on the scale of proteins but also diffusive transport on the mesoscale can be expected to exhibit remarkable spatiotemporal fluctuations.

To explore the heterogeneity of cellular and biomimetic fluids on the nano- and mesoscale, we have used fluoresecence lifetime imaging (FLIM), fluorescence correlation spectroscopy (FCS), and high-resolution imaging.

Imaging and FCS on mitotic cells suggests a significant heterogeneity of the contiguous nucleo-cytoplasmic fluid on length scales of some micrometers [1,2]. Our FCS results on interphase cells suggest that mesoscale heterogeneities in cytoplasm and nucleoplasm are comparable to those in highly concentrated solutions of established crowding agents such as dextran or PEG.

FLIM experiments on an environment-sensitive molecular rotor indicate a similar heterogeneity of cytoplasm and nucleoplasm on the nanoscale while artificial crowded fluids appear to be somewhat less heterogeneous.

[1] Pawar, Donth & Weiss, Curr. Biol. 24, 1905 (2014).
[2] Schweizer, Pawar, Weiss & Maiato, J. Cell Biol. 210, 695 (2015).

BP 48.5 Wed 17:00 Poster C

Optical setup and algorithms for a fast synchronized dual image acquisition — •Jonas Pfeil[1], Tobias Neckernuss[1], Christoph Koch[2], and Othmar Marti[1] — [1]Institute of Experimental Physics, Ulm University, Germany — [2]Department of Physics, Humboldt University Berlin, Germany

For thickness measurements and 3D reconstruction of microscope images, the most-common approach is using a z-stack of pictures. As this requires a sequential image acquisition of the sample with different focal heights, it is not feasible in time resolved experiments. Therefore we use two synchronized cameras to get a minimal z-stack at well defined time points. To image at two different focal heights, we split the light path with a beam splitter and mount the cameras at different distances from the objective. For adjustment and recording of the images it is necessary to develop a software which is able to capture two cameras at the same time.

The software for the camera control is written in Matlab and C++ for easy maintenance and high flexibility and extensibility. Only documented features of Matlab and only standard C++ methods are used to retain highest possible compatibility across different computation systems and versions. We demonstrate a live asynchronous picture display with two different cameras at the same time for alignment purposes and a blocking synchronous method for a short burst capturing of as many frames as possible.

BP 48.6 Wed 17:00 Poster C

Functionalization of Nanodiamond for the Use in Biophysics — •Frederike Erb[1], Patrick Paul[1], Fedor Jelezko[2], and Kay-E. Gottschalk[1] — [1]Institute of Experimental Physics, Ulm University, Germany — [2]Intstiute of Quantum Optics, Ulm University, Germany

Synthetic nanoparticles offer various new imaging and metrology approaches [3]. Of particular interest is the use of fluorescent nanodiamonds (FND) as markers for cell labeling. They contain negatively charged nitrogen-vacancy centers as fluorophores, whose emission lies in the near-infrared window of bioimaging and is dependent on the environment. Those nanodiamond markers are biocompatible and in contrast to dyes do neither blink nor bleach.

In order to prevent agglomeration and to offer specific binding the FNDs need to be functionalized [1], [2]. Here, we present preliminary results for our functionalization.

References: [1] Martin, R., Alvaro, M., Herance, J. R., Garcia, H. (2010). Fenton-treated functionalized diamond nanoparticles as gene delivery system. ACS Nano, 4(1), 65-74.

[2] Liang, Y., Ozawa, M., Krueger, A. (2009). A general procedure to functionalize agglomerating nanoparticles demonstrated on nanodiamond. ACS Nano, 3(8), 2288-2296.

[3] Chang, B. M., Lin, H. H., Su, L. J., Lin, W. D., Lin, R. J., Tzeng, Y. K., Lee, R. T., Yu, A. L., Chang, H. C. (2013). Highly fluorescent nanodiamonds protein-functionalized for cell labeling and targeting. Advanced Functional Materials, 23(46), 5737-5745.

BP 48.7 Wed 17:00 Poster C

Measurement of the height of living cells via an optimized phase-shifting interferometer. — •Shuaishuai Li[1], Xia Wang[2], and Othmar Marti[1] — [1]Institute for Experimental Physics, University of Ulm, 89069 Ulm, Germany — [2]School of Optoelectronics, Beijing Institute of Technology, 100081, China

Phase-Shifting Interference Microscopy is a real-time observation technique. It is widely used for observing the growth process of monolayer cells and has many advantages, such as high precision, non-contact measurement etc. According to the principle of phase-shifting interferometry measuring method, a dual-angle incident interferometer is designed in our lab. Using a CCD digital imaging device to record the vision field, we can get a serial of cell interference patterns with certain phase changes. Phase unwrapping is the step that we extract the phase of an interference pattern. Afterward, we could reductive the Wavefront Pattern which can reflect the microscopic appearance and calculate the height value of living cells. We synthesize the advantages of the branch-cut method and the quality guide method. Experimental results show that this fusion phase unwrapping method is effective and practical in the processing of cell interferograms.Finally, through the experiment setup we designed, we measured the height value of one Styrene particles, which had been accurately measured by ZYGO measure instrument. The relative error is 0.023.

BP 48.8 Wed 17:00 Poster C

Application of Rotational Dark-Field Microscopy in Biology — •Daniela Beck, Daniel Geiger, Tobias Neckernuss, and Othmar Marti — Institute of Experimental Physics, Ulm University

It has been published recently, that rayleigh's criterion can be beaten by total internal reflection dark-field imaging [1]. This is based on the incoherent summation of images that are obtained by coherent scattering at different angles of incidence. The original setup is altered in order to increase the maximum possible frame rate.

Our new measurement technique sets the path for high temporal and increased spatial resolution. This makes the observation of biological processes on the millisecond timescale with increased resolution compared to Abbe's limit feasible. Preliminary measurements on biological samples show the prospects of this measurement setup that is also capable of simultaneous fluorescence and bright-field imaging.

[1] P. von Olshausen and A. Rohrbach, Opt. Lett. 38, 4066-4069 (2013)

BP 48.9 Wed 17:00 Poster C

Experimental Setup for THz-Time-Domain-Spectroscopy on Complex Biological Samples — •Lisa Schneiderwind, Andreas Garz, Heiko Lokstein, and Maria Krikunova — Institut for Optik und Atomare Physik, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin

The goal of this project is a free space setup for THz time-domain spectroscopy (THz-TDS) on samples containing water and biomolecules, for example molecules involved in the processes of photosynthesis. The generation and detection of the THz radiation to investigate such molecules is based on a photo-conductive antennae equipped with a focusing aspheric silicon lens. In this setup a femtosecond fiber laser is used to pump the antennae. With this configuration, it is possible to perform THz-TDS experiments by either measuring the amplitude of the THz-field at a fixed time-delay or fully characterizing the THz-field at all time delays. The setup can be further extended by replacing the detection antenna by electro-optical sampling. To produce THz radiation with higher field strength the generation antenna can also be replaced by non-linear crystals. The setup allows to perform time-resolved experiments to investigate the behavior of complex molecules after excitation.

BP 48.10 Wed 17:00 Poster C

Confocal Light-Sheet Microscopy: Separation of ballistic and diffusive fluorescence photons — •Tobias Meinert and Alexander Rohrbach — Laboratory for Bio-and Nano-Photonics, University of Freiburg, Germany

In the last ten years light-sheet microscopy has got more and more attention in biological research and is on its way to become the standard technology for long time observation of thick samples. However, the observation of strongly scattering objects suffers from strong imaging artefacts. In particular, the scattering of coherent illumination light generates strong image artifacts. Microscopy with Self-Reconstructing Beams (MISERB), such as Bessel beams, has proven to be a powerful tool to reduce scattering artifacts. By imaging 150 μm thick Arabidopsis root tips, these effects become well visible.

Reduced contrast due to strong side loops in the Bessel beam profile can be compensated effectively by confocal line detection. Independently of the illumination beam, a general source of reduced contrast is the scattering of fluorescent photons emitted from layers deep inside the object. This effect usually becomes very dominant at an imaging depth of a few 10 μm. In this presentation a so-called object point spread function (PSFobj) is introduced, which describes the blurring of images due to the object itself. By estimating this function, it is possible to separate the influence of ballistic (unscattered) and diffusive (multiply scattered) photons on the imaging process. Removing the influences of the diffusive photons, a so far unreached image quality in strongly scattering media is obtained.

BP 48.11 Wed 17:00 Poster C

Single Shot Quantitative Phase Microscopy Technique — •Tobias Neckernuss[1], Xiaoming Jiang[1,2], Jonas Pfeil[1], Christoph Koch[2], and Othmar Marti[1] — [1]Institute of Experimental Physics, Ulm University, Germany — [2]Department of Physics, Humboldt University Berlin, Germany

The thickness of adherent cells is an important parameter in various biological and biophysical applications. However it is a difficult task to measure cell thickness with a microscope when using conventional microscopy techniques. There are several commercial systems around, measuring the optical path length through the cell with an interferometric approach. However, most of these systems use a compact Mach-Zehnder interferometer which is difficult to customize for special needs and additional instrumentation. To overcome this, we designed a setup that allows us to measure the optical path length through a transparent phase object with an inline holographic approach. We use a two camera system with two slightly different focus points. The sample is illuminated by a LED light source with sufficient spatial coherence. For reconstruction of the phase image the "Transport of Intensity Equation" is used for a first guess and an iterative algorithm for phase retrieval refines the reconstruction by forward and backward propagation of the reconstructed images and comparison to the captured ones. With this method we are able to determine the phase shift during transmission through a phase object. The main advantage of this compared to conventional z-stack techniques is the potential for high acquisition speeds.

BP 48.12 Wed 17:00 Poster C

Rotational Dark-Field Microscope for Fast Image Acquisition — •Daniel Geiger, Tobias Neckernuss, and Othmar Marti — Institute of Experimental Physics, Ulm University

The technique to obtain label-free optical images beyond the diffraction limit has been published recently [1]. Incoherent addition of coherent scattering images illuminated from different directions leads to an increase in contrast between two adjacent objects. However, this original setup is, due to the implementation with a spatial light modulator, only able to take images at rates around 1 Hz.

We replaced the spatial light modulator with a rotating double prism setup that can rotate with much higher frequencies. Our setup is designed to operate at 100 Hz that is the maximum image capturing rate of the used camera. Furthermore the illumination angle can be dynamically adjusted between zero and maximum angle given by the used objective's NA by variation of the prism separation. In principle, this setup can be enhanced to rotation rates in the kHz regime by using a hollow shaft electromotor that contains the prisms. This allows the label-free observation of fast biological processes on a length scale that was so far not accessible by conventional light microscopy.

[1] P. von Olshausen and A. Rohrbach, Opt. Lett. 38, 4066-4069 (2013)

BP 48.13 Wed 17:00 Poster C

Light sheet microscopy using Bessel beams and the STED principle — •Luis Köbele, Cristian Gohn-Kreuz, and Alexander Rohrbach — University of Freiburg, Laboratory for Bio- and Nano-Photonics, 79110 Freiburg, Germany

Light sheet microscopy is an imaging technique which features enhanced optical sectioning by using a thin, sheet-like illumination of

only that part of the object, which is in the plane of focus. By the use of computer-generated holograms, we generate self-reconstructing Bessel beams, which showed enhanced propagation stability and penetration depth in scattering media and are thus superior, particularly for imaging in dense biological specimen. However, the pronounced ring system, which facilitates the self-reconstructing property of the scanned Bessel beams, produces a significant image background by exciting out-of-focus fluorophores. By superposing a concentrically aligned, doughnut shaped Bessel beam, stimulated emission depletion (STED) is used to improve the light sheet quality, generating effectively thinner light sheets with reduced background. We present first results of such an imaging setup and discuss advantages and challenges.

BP 48.14 Wed 17:00 Poster C

Photothermal detection of single gold nanoparticles in living fibroblasts — •Alice Abend, Romy Schachoff, and Frank Cichos — Universität Leipzig, Linnéstr. 5, 04103 Leipzig, Germany

Live cell bioimaging allows for the observation of cellular processes and their dynamics and provides insight into functions of cells such as metabolism, replication and movement. Modern nanotechnology enables manufacturing of nanometer sized objects with tailored optical properties and specific functionalization which turns them into ideal optical probes for several imaging techniques. Our method to transfer nanoscopic objects into the cytoplasm of live mammalian cells is called mechanodelivery [1]. This approach is based on mechanical damage of the cell membrane to deliver nano objects into the intracellular space. In contrast to passive delivery strategies allows the mechanodelivery approach for deposition of nano objects without them being engulfed in vesicles. We deliver gold nanoparticles (AuNPs) to the cells as they are photostable and allow for long-term imaging and seem to be less toxic to living organisms in comparison to semiconductor quantum dots. Our imaging method, photothermal optical microscopy, provides sensitive detection of AuNPs and is therefore suitable to prove the presence of AuNPs in the fibroblasts' interior. As photothermal microscopy is based on heating of the contrast agent, AuNPs can double as heat sources for inducing local intracellular temperature fields which could be useful to manipulate cellular functions such as protein synthesis and metabolism processes.

[1] Nanoscale, 2014, 6, 4538

BP 48.15 Wed 17:00 Poster C

Combined AFM/SPR ellipsometry study of protein adsorption at liquid/solid interface — •Peter Basa[1], Peter Petrik[2], and Nils Anspach[1] — [1]Semilab Semiconductor Physics Laboratory Co. Ltd., Budapest, Hungary — [2]Institute for Technical Physics and Materials Science, Budapest, Hungary

The deeper understanding of interaction of biomaterials with solid surfaces is crucial in case of microfluidic devices applied to biosensorics. In this study, surfactant molecules mixed with protein species were adsorbed on gold nanofilm coated solid surfaces. Surface plasmon resonance (SPR) enhanced spectroscopic ellipsometry (SE) utilizing special adapted liquid cell, and atomic force microscopy (AFM) were used to study the adsorption dynamics, the resulting composition ratio of adsorbed species, and the biomolecule surface coverage depending on initial gold thin film surface structure/morphology.

In the poster, the performance of Semilab's combined SE and AFM measurement platform will be described using real experiment examples, with correlations pointed out in between different metrology results on the measured samples.

BP 48.16 Wed 17:00 Poster C

Time Modulated Stimulated Emission Depletion (STED) Based Fluorescence Correlation Spectroscopy (FCS) — •Benedikt Prunsche[1], Peng Gao[1,2], Karin Nienhaus[1], and Gerd Ulrich Nienhaus[1,3] — [1]Institute of Applied Physics, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe, Germany — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [3]Department of Physics, University of Illinois at Urbana-Champaign, 1110 West Green Street, Urbana, Illinois 61801, USA

Fluorescence correlation spectroscopy (FCS) is a powerful tool to study bio-molecular dynamics, such as protein diffusion or receptor-ligand interactions inside living cells. It is based on the correlation analysis of fluorescence intensity fluctuations in a small observation volume. These fluctuations arise due to Brownian motion of fluorescent particles in and out of the volume. Because of the diffraction-limited size of the focus volume, conventional FCS is only sensitive to fluorescence fluctuations induced by fluorophores at nanomolar concentrations, which is typically not realized in biological samples. To overcome this limitation, we have reduced the focal volume in all three dimensions by stimulated emission depletion. Background noise, which is inherent in conventional STED based FCS, has been reduced by time-gated detection, and further compensated by using an auxiliary Gaussian depletion beam. As a result, the dynamics of biomolecules at ~10-fold higher concentrations can be quantified with 3D STED based FCS.

BP 48.17 Wed 17:00 Poster C

Acto-myosin in cardiac muscle cells by scanning x-ray nanodiffraction — •Jan-David Nicolas, Marten Bernhard, and Tim Salditt — Institut für Röntgenphysik, Göttingen, Deutschland

Owing to the highly oriented molecular structure of the actin-myosin cortex in muscle cells, diffraction techniques are well-suited to study the geometry of this filament assembly down to nanometer resolution. In particular, classical x-ray diffraction studies on muscular tissue were the first to unravel the detailled structure of the sarcomere. In these experiments, however, structural information is averaged over macroscopically large volumes of the tissue, with diffraction volumes containing a vast ensemble of muscle cells. Contrarily, recent progress in x-ray optics has enabled diffraction experiments with spot sizes in the sub-micron range, well-suited to illuminate only selected organelles of a single cell.

We report on recent experiments analyzing the micro-structure of acto-myosin complexes in individual cardiomyocytes which make up the striated muscular tissue of the heart. We performed experiments on (initially) alive, chemically fixed as well as freeze-dried cell preparations. Scanning the sample through the nano-focused beam, SAXS data were recorded and analysed to generate mappings of different structural parameters. Scanning SAXS mappings are complemented by holographic reconstructions, extending the covered frequency range by two orders of magnitude. By means of x-ray holography, samples could also be immediately checked for radiation damage.

BP 48.18 Wed 17:00 Poster C

Photothermal Excitation for Reliable and Quantitative High-resolution AFM imaging and force spectroscopy — •Florian Johann, Aleksander Labuda, Deron Walters, Maarten Rudgers, Jason Cleveland, and Roger Proksch — Asylum Research, an Oxford Instruments Company, Wiesbaden, Germany

Photothermal excitation is an alternative method for exciting a cantilever by heating/cooling the base of the cantilever to drive the cantilever. Photothermal excitation results in repeatable, accurate and time-stable cantilever tunes. Therefore, the setpoint remains truly constant while imaging, preventing tip crashes, or unwanted tip retractions. True atomic resolution images of calcite in water were made for hours with no user intervention, testifying to the stability of photothermal excitation. Unlike other specialized drive methods, photothermal excitation is compatible with almost any cantilever and with all AFM techniques. Furthermore, because the photothermal tune represents the true cantilever transfer function, existing AFM theories can be applied to accurately recover conservative and dissipative forces between the tip and the sample. This is especially important for force spectroscopy, dissipation studies, as well as the frequency modulation AFM techniques.

BP 48.19 Wed 17:00 Poster C

Signatures of correlated noise and disorder in 2D electronic spectroscopy — •David J. Ing[1,2], James Lim[2], Jan Jeske[1], Jared H. Cole[1], Susana F. Huelga[2], and Martin B. Plenio[2] — [1]Chemical and Quantum Physics, School of Applied Sciences, RMIT University, Melbourne, Victoria 3001, Australia — [2]Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, D-89069 Ulm, Germany

Two-dimensional electronic spectroscopy has revealed the presence of long-lived quantum coherences in photosynthetic systems. To explain the microscopic origin of the long-lived coherences in these biological systems, several hypotheses have been formulated theoretically, including correlated noise and vibronic coupling. However the complexity of photosynthetic systems and their 2D spectra make the identification of the microscopic origin a challenging task. Here, we investigate a correlated noise model to study how the correlations in noise and disorder affect the features in 2D spectra. By employing the Bloch-Redfield equation, where the degree of spatial correlation can be quantified

continuously, we show that the amount of correlation affects both the lineshapes and lifetimes of oscillatory 2D signals. We also show how non-secular effects in the noise, that yield to coupling between populations and coherences, influence the 2D signals.

BP 48.20 Wed 17:00 Poster C

Nonlinear optical properties and photochemical polymerization of monomer crystals — •Oktay Aktas[1], Max Jonathan Kory[2], Carsten Becher[1], Arnulf Dieter Schlüter[2], and Manfred Fiebig[1] — [1]The Laboratory for Multifunctional Ferroic Materials, Department of Materials, ETH Zurich, Switzerland — [2]Polymer Chemistry, Department of Materials, ETH Zurich, Switzerland

Organic materials have been used in a variety of applications for a century. With the advances in their synthesis, their potential applications are also rapidly increasing. In recent years there has been a growing interest in organic crystals for applications in electronics and photonics since some of them exhibit large optical nonlinearities. To possibly find such functional optical properties, we performed second harmonic generation spectroscopy on a polar and chiral monomer crystal, which can be polymerized by a photochemical reaction and confined to two dimensions (2D polymer) [1]. Measurements performed with 10 ns pulses have revealed that the monomer is strongly nonlinear in a large spectral range. In addition, the light-induced polymerization of monomers leads to differences in SHG intensities. As the depolymerization of polymer crystals can be achieved through heating, the monomer and polymer represent two switchable states with different nonlinear optical properties, which may find applications in integrated optics. [1] Max J. Kory, Michael Wöle, Thomas Weber, Payam Payamyar, Stan W. van de Poll, Julia Dshemuchadse, Nils Trapp and A. Dieter Schlüter, Nat. Chem. 6, 779 (2014)