HL 71: Focus Session: Tailored Nonlinear Photonics II

The research field of nonlinear photonics is driven by the tailoring and control of nonlinear light-matter interactions and by the application of nonlinear concepts for advanced light management. Current research activities are driven by concepts from quantum optics, coherent optics, and solid-state physics. The progress in the field strongly benefits from advanced solid-state materials, nanostructures, and photonic structures, as well as from extremely intense and efficient ps and fs laser sources. The application of new concepts paves technically viable routes towards advanced nonlinear photonic devices, which are indispensable for the implementation of efficient frequency conversion, conditional photonic functionalities, and photonic quantum technologies.

Organizers: Artur Zrenner (Universität Paderborn), Thomas Zentgraf (Universität Paderborn) and Manfred Bayer (TU Dortmund)

Time: Thursday 15:00–17:15 Location: POT 51

Invited Talk HL 71.1 Thu 15:00 POT 51

Quadratic nanomaterials for nonlinear integrated photonic devices — •Rachel Grange — ETH Zurich, Department of Physics, Institute for Quantum Electronics, Zurich, Switzerland

Nonlinear optics is present in our daily life with many applications, e.g. light sources for microsurgery or green laser pointer. All of them use bulk materials such as glass fibres or crystals. Generating nonlinear effects from materials at the nanoscale can expand the applications to integrated devices. However, nonlinear signals scale with the volume of a material. Therefore, finding nanostructured materials with high nonlinearities to avoid using high power and large interaction length is challenging. Here I will show several strategies to maximize nonlinear optical signals in nano-oxides with noncentrosymmetric crystalline structure and semiconductors. I will demonstrate how we enhance second-harmonic generation by using the scattering properties of individual barium titanate nanoparticles, and III-V standing nanodisks. Our results suggest that a strong increase of the nonlinear signal can be obtained without using plasmonics or hybrid nanostructures.

Then, I will present innovative fabrication approaches of metal-oxides materials that are very different from standard semiconductors or metals. First, solution-processing of nano-oxides may solve, at the same time, the low nonlinear signal and the low throughput of photonic crystal cavity fabrication to obtain cost-effective disposable devices. Second, we also developed lithography processes to obtain lithium niobate nanowaveguides or metasurfaces.

Invited Talk HL 71.2 Thu 15:30 POT 51

Resonant nanostructured surfaces for parametric frequency conversion — •Frank Setzpfandt — Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena

Metasurfaces composed of high-refractive-index nanoparticles supporting electric and magnetic Mie-type resonances offer unique opportunities for controlling the properties of transmitted or reflected light. Recent technological advances furthermore enabled the fabrication of Mie-resonant nanoparticles from materials with strong second-order nonlinearity, like gallium arsenide and lithium niobate. Metasurfaces based on these materials are a versatile platform for efficient nonlinear frequency conversion using parametric three-wave mixing, e.g. by second-harmonic or sum-frequency generation. They enable control of emission direction and polarization of the nonlinearly generated light through the geometry of the nanoparticles. I will discuss our recent advances in understanding and controlling nonlinear frequency conversion in dielectric metasurfaces made from gallium arsenide and lithium niobate, which feature very different nonlinear properties. Alternatively, efficient frequency conversion is also possible using strong material resonances e.g. in 2D transition metal dichalcogenides, where the nonlinear susceptibility can be notably increased in the vicinity of the resonance. I will demonstrate that nanostructuring transition metal dichalcogenides also enables spatial control of second-harmonic light generated in the 2D material, without using Mie resonances.

HL 71.3 Thu 16:00 POT 51

Optimizing the single-photon emission from a quantum-dot biexciton based on a direct two-photon transition — Tom Praschan[1], •Dirk Heinze[1], Artur Zrenner[1], Andrea Walther[2], and Stefan Schumacher[1,3] — [1]Department of Physics and Center for Optoelectronics and Photonics Paderborn (CeOPP), Paderborn University, Warburger Strasse 100, 33098 Paderborn, Germany — [2]Department of Mathematics, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany — [3]College of Optical Sciences, University of Arizona, Tucson, Arizona 85721, USA

Semiconductor quantum dots are excellent candidates for on-demand single photon sources. A partly stimulated party spontaneous two-photon process from the biexciton state to the ground state of the quantum dot makes it possible to tailor the properties of the emitted single photon all-optically with a laser pulse [1,2]. An optimized and complex control pulse can steer the emission process into the desired emission path [3]. Here, we optimize the pulse parameters numerically to trigger the direct two-photon process with its maximum emission probability. We include phonon assisted processes [4] near the quantum dot resonances into our theoretical analysis and calculate single photon properties. Considering an emission into a high-Q cavity we find that on-demand single photon emission is possible for realistic parameters. [1] D. Heinze et al. Nat. Commun. 6, 8473 (2015). [2] D. Breddermann et al. Phys. Rev. B 94, 165310 (2016). [3] D. Breddermann et al. Phys. Rev. B, 97,125303 (2018). [4] D. Heinze et al. Phys. Rev. B, 95, 245306 (2017).

HL 71.4 Thu 16:15 POT 51

ZnO-based dielectric nanoantennas for nonlinear applications — •Christian Golla, Nils Weber, Sophia Thies, Thomas Zentgraf, and Cedrik Meier — Department Physik, Universität Paderborn, 33098 Paderborn, Germany

Boosting nonlinear optical effects like second and third harmonic generation on the nanoscale is a subject of many theoretical and experimental studies. Here, plasmonic nanoantennas play an important role due to their capability of enhancing local electric fields and thus increasing the efficiency of nonlinear processes. However, intrinsic losses caused by metals limit the efficiency of such devices especially in the visible regime. In this context, nanostructures made of dielectric materials emerged as complementary candidates to plasmonic systems in recent years. These structures allow the confinement and magnification of electric and magnetic fields to subwavelength volumes based on Mie resonances. Due to the low absorption compared to metals they are considered as an alternative to overcome the limitations of plasmonic structures. In our work, zinc oxide based nanoantennas on sapphire substrates are investigated. Not only enhancement of the generation of second and third harmonic light but also the realization of a metasurface in the linear regime are demonstrated. Furthermore, preliminary results for combining the nonlinear character and the metasurface are shown.

HL 71.5 Thu 16:30 POT 51

Indirect optical transitions induced by a refractive index front — Mahmoud Gaafar[1,2], Hagen Renner[1], Manfred Eich[1,3], and •Alexander Petrov[1,4] — [1]Institute of Optical and Electronic Materials, Hamburg University of Technology, Hamburg, Germany — [2]Department of Physics, Menoufia University, Menoufia, Egypt — [3]Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany — [4]ITMO University, St. Petersburg, Russia

Refractive index fronts in dispersive waveguides can lead to indirect transition of light where frequency and wavenumber is changed. At the new position on the dispersion relation light might have strong change of the group velocity. Adjusting the front velocity and dispersion relation, reflection, transmission and trapping by the front are possible. We experimentally implement the free carrier front in silicon waveguides by the two photon absorption of the pump pulse and show all three effects. In case of trapping, also known as optical push broom effect, the light is trapped in the front and strongly compressed in time and space. Also transitions to zero group velocity are possible to stop and store optical pulses. We will make an overview of the possible front induced transitions and provide the outlook for the further research.

HL 71.6 Thu 16:45 POT 51

Acoustically induced bistability switching and memory effect in confined exciton-polariton condensates — •Alexander Kuznetsov, Klaus Biermann, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Bistability is a remarkable and useful property of nonlinear exciton-polariton (EP) quasiparticles. In this work, we demonstrate the switching of trapped EPs between bistable states by 0.4 GHz acoustic strain pulses. A microsecond-long strain pulse, piezoelectrically generated on-demand, triggers the bosonic stimulation (Bose-Einstein-like condensation) from an initial state below the condensation threshold to the final state above the threshold, i.e., the bistability switching. The system remains in this final state for as long as the optical pump is supplied (recorded time up to 15 minutes). Thus, the reported effect is a novel concept for an on-chip optical memory with electro-acoustic triggering based on confined EP condensates.

HL 71.7 Thu 17:00 POT 51

Second Harmonic Generation on excitons and magnon-sideband in the antiferromagnet Cr_2O_3 — •Johannes Mund[1], Victor V. Pavlov[2], Roman V. Pisarev[2], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, Technische Universität Dortmund, Germany — [2]Ioffe Institute, Russian Academy of Sciences, St. Petersburg, Russia

We present results of optical second harmonic generation (SHG) in Cr_2O_3 on Frenkel excitons formed by $^4A_1$-^2E states of Cr^{3+} ions in the near infrared range $1.7 - 1.78$ eV. As was shown in previous work [1], the electric-dipole SHG is allowed in Cr_2O_3 due to its particular antiferromagnetic ordering below $T_N = 307.5$ K. In addition, it was possible to image the antiferromagnetic domains in a Cr_2O_3 sample by SHG [2]. We investigated detailed SHG polarization dependencies for linearly and circularly polarized light of the exciton states using femtosecond laser pulses. In magnetic field B, applied parallel and perpendicular to the sample optical c-axis, further information on exciton symmetries and optical selection rules were obtained. Moreover, in our spectra, we succeed for the first time to observe SHG signals on the exciton-magnon-sideband.

[1] M. Fiebig et al. PRL 73, 2127 (1994)
[2] M. Fiebig et al. Appl. Phys. Lett 66, 2906 (1995)