HL 15: Focus Session: Tailored Nonlinear Photonics

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 10:00–12:45 Location: H4

Invited Talk HL 15.1 Thu 10:00 H4

Quasi-instantaneous switch-off of deep-strong light-matter coupling — •Christoph Lange[1], Joshua Mornhinweg[2], Maike Halbhuber[2], Viola Zeller[2], Cristiano Ciuti[3], Dominique Bougeard[2], and Rupert Huber[2] — [1]Department of Physics, TU Dortmund University, 44227 Dortmund, Germany — [2]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [3]Université de Paris, laboratoire Matériaux et Phénomènes Quantiques, CNRS, F-75013 Paris, France

Optical microresonators facilitate custom-tailored quantum states of matter by dressing electronic excitations with virtual cavity photons. Once the rate of energy exchange between light and matter modes exceeds the carrier frequency of light, "deep-strong coupling" emerges, which profoundly modifies the vacuum ground state and gives rise to novel phenomena including cavity-mediated superconductivity and other phase transitions. While the exploration of the equilibrium properties of deep-strong coupling has just started, yet more unusual effects are expected on subcycle scales. Here, we explore the dynamics that arises when deep-strong coupling is switched off abruptly. The experiments employ cyclotron resonances of two-dimensional electron gases coupled to light modes of custom-cut THz nanoresonators, which can be switched off by femtosecond photoexcitation. The polariton states are extinguished more than an order of magnitude faster than the polariton cycle duration, leading to sub-polariton-cycle oscillations as confirmed by a quantum model. Our experiments introduce time as a new control parameter for deep-strong light-matter coupling.

Invited Talk HL 15.2 Thu 10:30 H4

Lithium niobate nonlinear nanophotonics — •Frank Setzpfandt — Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena

Lithium niobate is one of the most interesting optical materials, owing to its high transparency in a wide spectral range, high second-order nonlinearity, and the ability for quasi-phase matching. These enticing properties have been utilized many times in nonlinear optics, in particular for nonlinear parametric frequency conversion. However, lithium niobate is also a material that is challenging to structure on the nanoscale, which is only done regularly since a short time.

In this talk, I will discuss our recent progress in the implementation of nanoscale structures in lithium niobate and their application for the generation of classical and quantum light by parametric frequency conversion. In particular, I will focus on our realization of lithium niobate metasurfaces and their use in experimental demonstrations of second-harmonic and photon-pair generation .

Invited Talk HL 15.3 Thu 11:00 H4

Quadratic nanomaterials for integrated photonic devices — •Rachel Grange — ETH Zurich, Switzerland

Nonlinear and electro-optic devices are present in our daily life with many applications: light sources for microsurgery, green laser pointers, or modulators for telecommunication. Most of them use bulk materials such as glass fibres or high-quality crystals, hardly integrable or scalable due to low signal and difficult fabrication. Generating nonlinear or electro-optic effects from materials at the nanoscale can expand the applications to biology and optoelectronics. However, the efficiency of nanostructures is low due to their small volumes. Here I will show several strategies to enhance optical signals by engineering metal-oxides at the nanoscale with the goal of developing nonlinear and electro-optic photonics devices for a broad spectral range. We use metal-oxides such as barium titanate (BTO) and lithium niobate (LNO) as an alternative platform for nanoscale nonlinear photonics. BTO and LNO are non-centrosymmetric materials with high refractive index and high energy band gaps. We already demonstrated linear Mie resonances in BTO and LNO nanostructures, such as nanospheres or nanocubes. Recently, we focused on bottom-up assemblies of BTO nanoparticles to obtain electro-optic metasurfaces and quasi phase matching effects. We measured an electro-optic response in assembled nanostructures as strong as certain other perfect crystalline structure. The field of metal-oxides at the nanoscale has a huge potential of applications in nanophotonics, integrated optics and telecommunication.

15 min. break.

Invited Talk HL 15.4 Thu 11:45 H4

Topological plasmonics: Ultrafast vector movies of plasmonic skyrmions on the nanoscale — •Harald Giessen[1], Pascal Dreher[2], David Janoschka[2], Frank Meyer zu Heringdorf[2], Tim Davis[1,3], and Bettina Frank[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]CENIDE, University of Duisburg-Essen, Duisburg, Germany — [3]University of Melbourne, Melbourne, Australia

Plasmonic skyrmions are topological defects in the electromagnetic near-field on thin metal films, recently observed using scanning near-field optical microscopy. However, only one spatial component of the electric field was measured and one of the most intriguing features of skyrmions, namely their dynamics, was not assessed.

Two-photon photoemission electron microscopy was previously able to image the local plasmon fields with femtosecond time resolution. Still, the vector information about the local electric fields was missing. Here we introduce a new technique, time-resolved vector microscopy, that enables us to compose entire movies on a sub-femtosecond time scale and a 10 nm spatial scale of the electric field vectors of surface plasmon polaritons [1]. Specifically, we image complete time sequences of propagating surface plasmons that demonstrates their spin-momentum-locking as well as plasmonic skyrmions on atomically flat single crystalline gold films that have been patterned using gold ion beam lithography.

[1] T. Davis et al., Science 367, eaba6415 (2020).

Invited Talk HL 15.5 Thu 12:15 H4

Supercontinuum second-harmonic generation spectroscopy of 2D semiconductors — •Steffen Michaelis de Vasconcellos — Institute of Physics and Center for Nanotechnology, University of Münster, Germany

The emergence of 2D materials has opened up a wealth of new research topics for a wide variety of applications. The intensive research efforts on 2D materials were initially ignited by the groundbreaking work on graphene. Since then, the family of 2D crystals and their heterostructures has been expanding rapidly. The research has been focusing not only on their unique electrical properties, but also on their fascinating optical, mechanical, thermal, and chemical properties. Several of the materials are particularly suited for establishing nonlinear light-matter interactions. The strong optical nonlinearity, broadband and tunable optical absorption, and ultrafast response of these materials have been successfully employed in all-optical modulators, saturable absorbers used in passive mode locking and Q-switching, wavelength converters, and optical limiters.

A powerful tool to gain insight into nanoscale materials is the prototypical nonlinear process second-harmonic generation (SHG) due to its dependence on crystal symmetry and electronic structures. We developed a new method to perform ultra-broadband SHG spectroscopy, which provides access to the frequency-dependent nonlinear susceptibility $\chi^{(2)}$ of atomically thin materials and allows for the identification of the prominent excitonic resonances.