O 40: Poster Session III: Poster to Mini-Symposium: Infrared nano-optics I

Time: Tuesday 10:30–12:30 Location: P

O 40.1 Tue 10:30 P

Broad spectral tuning of ultra-low-loss polaritons in a van der Waals crystal by intercalation — •Pablo Alonso-González — University of Oviedo

Phonon polaritons (PhPs) -light coupled to lattice vibrations- hold great promises for an unprecedented control of the flow of energy at the nanoscale because of their strong field confinement and long propagation. Moreover, recent experiments in polar van der Waals (vdW) crystals such as h-BN and *-MoO31*3, have demonstrated PhPs with anisotropic propagation, and ultra-long lifetime in the picosecond range. However, a main drawback of these PhPs is the lack of tunability of the narrow and material-specific spectral range where they exist * the so-called Reststrahlen Band (RB) *, which severely limits their implementation in nanophotonics technologies. Here, we demonstrate that intercalation allows for a broad spectral shift of RBs in a vdW crystal, and that the PhPs excited within them show ultralow losses (lifetime of 5 ps) similar to PhPs in the non-intercalated crystal (lifetime of 8 ps). As a difference to previous attempts, which fail in keeping the polaritonic activity of the intercalated compound, our results are possible by employing an intercalation method based on single crystal growth, that we carried out in the vdW semiconductor *-V2O5, thereby also adding a new member to the library of vdW materials supporting PhPs. We expect this intercalation method to be applied in other vdW materials, opening the door for the use of PhPs in broad spectral bands that eventually cover the whole mid-IR range, which seems to be elusive with currently known polaritonic materials.

O 40.2 Tue 10:30 P

In_3SbTe_2 as a Programmable Nanophotonics Material Platform for the Infrared — •Andreas Hessler[1], Sophia Wahl[1], Till Leuteritz[2], Matthias Wuttig[1], Stefan Linden[2], and Thomas Taubner[1] — [1]Institute of Physics (IA), RWTH Aachen University — [2]Physikalisches Institut, University of Bonn

The high dielectric optical contrast between the amorphous and crystalline phases of non-volatile phase-change materials (PCMs) provides a promising route towards tuneable nanophotonic devices [1]. Here [2], we employ the next-generation PCM In_3SbTe_2 (IST) whose optical properties change from dielectric to metallic upon crystallization in the whole infrared spectral range. We demonstrate how resonant metallic nanostructures can be directly written, modified and erased on and below the meta-atom level in an IST thin film by a pulsed switching laser. With this technology, we demonstrate large resonance shifts of nanoantennas of more than 4 μm, a tuneable mid-infrared absorber with nearly 90% absorptance as well as screening and nanoscale "soldering" of metallic nanoantennas. Our novel concepts can empower new and improved designs of programmable nanophotonic devices for telecommunications, (bio)sensing and infrared optics, e.g. programmable infrared detectors, emitters and reconfigurable holograms.

[1] M. Wuttig, H. Bhaskaran and T. Taubner. Nature Photonics 11, 465-476 (2017)

[2] A. Heßler, S. Wahl, T. Leuteritz et al.. in submission at Nature Communications (2020)

O 40.3 Tue 10:30 P

Reconfiguring magnetic resonances with the plasmonic phase-change material In_3SbTe_2 — Andreas Hessler, •Lukas Conrads, Konstantin Wirth, Matthias Wuttig, and Thomas Taubner — Institute of Physics (IA), RWTH Aachen University

Phase-change materials (PCMs) have been established as promising materials for tunable nanophotonic devices [1]. Normally, they feature a large optical contrast between their dielectric amorphous and crystalline phases. However, the recently introduced plasmonic PCM In_3SbTe_2 (IST) changes from dielectric to metallic in the infrared upon crystallization which enables novel resonance tuning mechanisms and direct laser writing of plasmonic nanostructures [2]. Here, directly optically written metallic, crystalline IST antennas with electric dipole (ED) resonances are first reconfigured into split-ring resonators (SRRs) with ED and magnetic dipole (MD) resonances by local optical switching. By selectively decreasing the arm lengths of the SRRs with reamorphizing laser pulses, we demonstrate tuning of the MD resonances by more than 2.4 μm, while the ED resonances for the same polarization are unchanged. Our work may pave the way towards engineering ultrathin, tunable, plasmonic devices for infrared nanophotonics which rely on separate tuning and superposition of ED and MD resonances.

[1] M. Wuttig, H. Bhaskaran and T. Taubner. Nature Photonics 11, 465-476 (2017)

[2] A. Heßler, S. Wahl, T. Leuteritz et al.. in submission at Nature Communications (2020)

O 40.4 Tue 10:30 P

Infrared-to-THz near-field nanoscopy with the free-electron laser FELBE — •Lukas Wehmeier[1,3], Tobias Nörenberg[1,3], Thales V.A.G. de Oliveira[1,2], J. Michael Klopf[2], Lukas M. Eng[1,3], and Susanne C. Kehr[1] — [1]Technische Universität Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]ct.qmat, Dresden-Würzburg Cluster of Excellence - EXC 2147, Technische Universität Dresden, Germany

Panelist: Infrared nanoscopy of 2D materials, metamaterials, and optical nano-structures is often limited by the wavelength range provided by table-top laser sources. Radiation from the tunable narrow-band free-electron laser FELBE (Dresden, Germany) uniquely enables near-field nanoscopy over the broad spectral range from 5 to 250 μm (i.e. 1.2 - 60 THz), particularly covering also the *so-called* THz gap [1-7]. I will present intriguing applications of FELBE in IR-optical nanoscopy by demonstrating extreme field confinement, anisotropic dispersion tracking, and resonant phenomena of THz polaritons in van der Waals crystals [1], nano-structures [2,3] and functional perovskite oxides [4-8].

[1] T.V.A.G. de Oliveira et al., Advanced Materials 33, 2005777 (2021).
[2] D. Lang et al., Nanotechnology 30, 084003 (2018).
[3] F.H. Feres et al., submitted.
[4] J. Döring et al., Nanoscale 10, 18074 (2018).
[5] L. Wehmeier et al., Phys. Rev. B 100, 035444 (2019).
[6] L. Wehmeier et al., Appl. Phys. Lett. 116, 071103 (2020).
[7] S.C. Kehr et al., Nat. Commun. 2, 249 (2011).
[8] H. Aminpour et al., Opt. Express 28, 32316 (2020).

O 40.5 Tue 10:30 P

SNOM-examination of THz polaritons in the van der Waals crystal α-MoO_3 — •Maximilian Obst[1], Thales V. A. G. de Oliveira[1,2], Tobias Nörenberg[1,3], Susanne C. Kehr[1], and Lukas M. Eng[1,3] — [1]Institute of Applied Physics, Technische Universität Dresden, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf — [3]ct.qmat: Dresden-Würzburg Cluster of Excellence - EXC 2147, Technische Universität Dresden, Germany

The confinement of electromagnetic fields to the nanometer length scale is of great importance for advancing nanophotonic technologies, since allowing for enhanced light-matter interaction. For terahertz (THz) radiation, extreme field confinement can be achieved via the excitation of low-loss phonon-polaritons e.g. in van der Waals (vdW) crystals.

Nevertheless, experimentally proving such highly-confined phonon-polaritons at THz frequencies is very challenging. In the present work, we combine scattering-type scanning near-field optical microscopy (s-SNOM) with an IR-2-THz free-electron laser, in order to enable nanometer-scale optical resolution at narrow-band and tunable THz excitation. This poster presents measurements of low-loss polaritonic excitations at frequencies between 8 to 12 THz in the vdW semiconductor α-MoO_3[1].

[1] T.V.A.G. de Oliveira et al., Advanced Materials 2005777 (2020)

O 40.6 Tue 10:30 P

Near-field optical investigations of the switching behavior of Ta_2O_5-based ReRAMs — •Christoph M. Bauerschmidt[1], Konstantin G. Wirth[1], Thomas Heisig[2], Sophia Wahl[1], Andreas Hessler[1], Regina Dittmann[2], and Thomas Taubner[1] — [1]Institute of Physics (IA), RWTH Aachen — [2]Peter Grünberg Institute, Research Center Jülich

Tantalum oxide (Ta_2O_5) shows promising properties for applications as non-volatile Resistive Random Access Memories (ReRAMs). Local resistive switching through a valence change mechanism[1] leads to the formation of reduced Ta_2O_x-filaments of ≈10-100nm in size, accompanied by a difference in conductivity to pristine Ta_2O_5 by seven

orders of magnitude[2]. The different stoichiometry and the increase in charge carrier density of Ta_2O_x cause changes of the dielectric function. Our calculations suggest that this change in the dielectric function of the switched Ta_2O_x will lead to a strong near-field contrast in the infrared region. Therefore, scattering-type Scanning Near-field Optical Microscopy (s-SNOM) is performed during this work to investigate these local optical properties with nm-sized spatial resolution. s-SNOM allows us to characterise single switched Ta_2O_x-filaments in Ta_2O_5-films. Furthermore, s-SNOM yields promising opportunities for in-situ investigations of switched filaments through transparent graphene electrodes.

[1] Waser et al., *Adv. Mat.*, 21, 2632-2663 (2009)
[2] Dittmann et al., *Adv. Func. Mat.*, 25, 7154-7162 (2015)