O 100: Mini-Symposium: Infrared nano-optics II

Time: Thursday 13:30–15:30 Location: R2

Paper discussion O 100.1 Thu 13:30 R2

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 alfa-MoO3, 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 alfa-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.

Paper discussion with expert panel members

Prof. S. Law (U Delaware), Prof. M. Raschke (JILA, UC Boulder), Prof. Y. Abate (U Georgia) and Prof. L. Wehmeier (TU Dresden)

O 100.2 Thu 14:15 R2

Configure phonon polaritons in van der Waals materials — •Siyuan Dai — Auburn University, Auburn, United States

The manipulation of light at small scales is one of the ultimate goals for nanophotonics. For this purpose, polaritons * hybrid light-matter waves that propagate in a confined length scale * are typically involved. Recent results of polaritons in van der Waals materials reveal a series of advances, including atomic scale localization, dynamic tunability, relative low-loss and topologically protected states. These advances are attributed to the unique physical properties in reduced dimensions and the configurability through van der Waals structuring and stacking. In this talk, I will show new merits of phonon polaritons that can be obtained through van der Waals configuration. I will talk about the tunability implemented into phonon polaritons by van der Waals heterostructuring hexagonal boron nitride with graphene and vanadium dioxide, where the polaritons can be tuned dynamically and reversibly via electrostatic gating and temperature control. I will also talk about the geometry and topology configuration of phonon polariton wavefront by twisting stacked slabs of molybdenum trioxide.

O 100.3 Thu 14:30 R2

Charge-transfer plasmon polaritons at graphene/α-RuCl3 interfaces — •Daniel J. Rizzo[1], B.S. Jessen[1], Z. Sun[1], F.L. Ruta[1], J. Zhang[2], J.-Q. Yan[3,4], L. Xian[2], A.S. McLeod[1], M.E. Berkowitz[1], K. Watanabe[5], T. Tanaguchi[5], S.E. Nagler[4], D.G. Mandrus[3,4], A. Rubio[2], M.M. Fogler[6], A.J. Millis[1], J.C. Hone[1], C.R. Dean[1], and D.N. Basov[1] — [1]Columbia University, New York, NY — [2]Max Planck Institute, Hamburg, German — [3]Univ. of Tennessee, Knoxville, TN — [4]Oak Ridge National Laboratory, Oak Ridge, TN — [5]NIMS, Japan — [6]UCSD, San Diego, CA

Charge transfer at the interface of two atomically-thin layers with different work functions offers a means of tuning 2D charge densities without the inherent limitations of traditional electrostatic gates that possess thick gate insulators. Specifically, the large work function of the Mott insulator α-RuCl3 (6.1 eV) makes it an ideal 2D electron acceptor. In our study, we exploit this behavior to generate charge-transfer plasmon polaritons (CPPs) in graphene/α-RuCl3 heterostructures. Using near-field optical microscopy we measure the CPP dispersion, yielding a quantitative measure of the graphene Fermi energy (~0.6 eV) and thus the charge exchanged between α-RuCl3 and graphene (~2.7x10^13 cm-2). Concurrently, we observe dispersive edge modes and internal circular CPPs which reveal abrupt (<50 nm) changes in the graphene optical conductivity and charge density. Analysis of the CPP losses implies the presence of emergent optical conductivity in the doped interfacial layer of α-RuCl3. These results have broad implications for the study of highly-doped 2D materials.

Paper discussion O 100.4 Thu 14:45 R2

Nanocavities and polaritons in twisted and indirectly nanostructured 2D materials — •Frank Koppens — ICFO - The Institute of Photonics Sciences

Two-dimensional (2D) materials offer extraordinary potential for control of light and light-matter interactions at the atomic scale. In particular, twisted 2D materials has recently attracted a lot of interest due to the capability to induce moiré superlattices and discovery of electronic correlated phases. In this talk, we present nanoscale optical techniques such as near-field optical microscopy and photocurrent nanoscopy, and reveal with nanometer spatial resolution unique observations of the optical properties of twisted 2D materials. We report on the topological domain wall boundaries [1] of small-angle twisted graphene and interband collective modes in charge neutral twisted-bilayer graphene near the magic angle [2]. The freedom to engineer these so-called optical and electronic quantum metamaterials is expected to expose a myriad of unexpected phenomena. We will also show record-small nanoscale polaritonic cavities [3,4], where the resonances are not associated to the eigenmodes of the cavity. Rather, they are multi-modal excitations whose reflection is greatly enhanced due to the interference of constituent modes. We demonstrate mid-IR cavities with volumes more than a billion below the free-space mode volume, while maintaining quality factors above 100.

[1] Hesp et al., Arxiv 1910.07893; [2] Hesp et al., Arxiv 2011.05060; [3] Epstein et al., Science (2020); [4] Herzig Sheinfux et al., in preparation

Paper discussion with expert panel members

Prof. J.D. Caldwell (Vanderbilt U), Prof. J. Khurgin (Johns Hopkins U), Prof. S. De Liberato (U South Hampton) and Prof. M. Liu (Stony Brook U)