In-Plane Anisotropic and Ultra-Low Loss Polaritons in a Natural van der Waals Crystal

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Polaritons – hybrid light-matter excitations – play a crucial role in fundamental and applied sciences, as they enable nanoscale control of light. Particularly large polariton confinements and long lifetimes can be found in graphene and van der Waals (vdW) materials. Intriguingly, these polaritons can be tuned by electric fields or by the material thickness, establishing a unique basis for manifold applications including nanolasers, tunable infrared and terahertz detectors, and molecular sensors.
Recently, polaritons with anisotropic propagation along the surface of vdW materials have been predicted, owing to in-plane anisotropic structural and electronic properties. Elliptic and hyperbolic in-plane polariton dispersion can be expected (e.g., plasmon polaritons in black phosphorus), the latter leading to an enhanced density of optical states and ray-like directional propagation along the surface. However, their observation in natural materials has so far remained elusive.

Here, we show the first images of anisotropic polariton propagation along the surface of a natural vdW material [1]. By infrared nano-imaging and nano-spectroscopy of semiconducting a-MoO3 flakes and disks we verify phonon polaritons with elliptic and hyperbolic in-plane dispersion, and with wavelengths (up to 60 times smaller than the corresponding photon wavelengths) being comparable to that of graphene plasmon and boron nitride phonon polaritons. From the signal oscillations in the real-space images we measured record-high polariton amplitude lifetimes of 8 ps, which are more than one order of magnitude larger than that of graphene plasmons at room temperature and a factor of about four larger than the best values reported for phonon polaritons in isotopically engineered boron nitride and graphene plasmons at low temperature.

In-plane anisotropic and ultra-low loss polaritons in vdW materials could be applied for directional strong light-matter interactions, nanoscale directional energy transfer and integrated flat optics for applications ranging from bio-sensing to quantum nanophotonics.

References

[1] W. Ma, P. Alonso-González, S. Li, A.Y Nikitin, J. Yuan, J. Martín-Sánchez, J. Taboada-Gutiérrez, I. Amenabar, P. Li, S. Vélez, C. Tollan, Z. Dai, Y. Zhang, S. Sriram, K. Kalantar-Zadeh, S-T Lee, R. Hillenbrand, and Q. Bao Nature, 562 (2018) 557-562.