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2D materials

Nanoscale probing of interfaces

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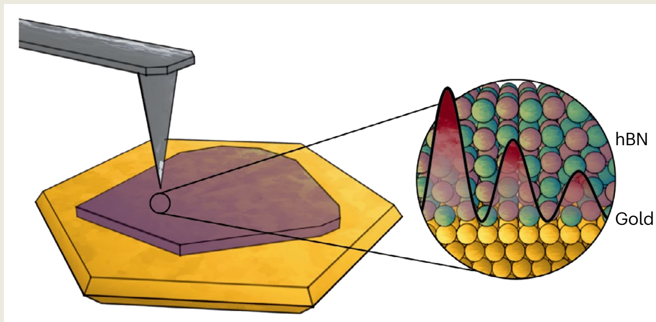
Researchers are constantly searching for capable instrumentation that can accurately probe the morphology and optical properties of 2D materials, with particular interest in capturing nanoscale surface features of interfaces and devices. One approach is to make use of quasiparticles known as phonon-polariton modes, formed from the interaction between the atomic lattice vibrations and light. To achieve a sufficient probing resolution of 10s of nanometres, the quasiparticles are slowed down to confine them within a tighter region. This trick reduces the phonon-polariton effective wavelength and increases the light–matter interaction time. However, the reduction in velocity is constrained by intrinsic material limits. When phonon-polariton modes fall below the characteristic velocities of the interfacing materials, nonlocal interactions arise, reducing probing accuracy.

Now, Jacob T. Heiden and colleagues in their recent paper in *ACS Nano* report the extreme confinement of light without the complications introduced by nonlocal phenomena, opening the way for more accurate probing of 2D material interfaces (*ACS Nano* 19, 42719–42728; 2025).



The research team from the Korea Advanced Institute of Science and Technology and Ulsan National Institute of Science and Technology in Korea, and the University of Southern Denmark, successfully reduced the phase velocity of the phonon-polariton modes in the interface between the flakes of the popular 2D material hexagonal boron nitride (hBN) and gold (pictured). Using the mirroring effect, the quasiparticle from the metal surface forms a confined image state concentrated in the hBN layer. As a result, the dynamics of the image phonon-polariton state are not affected by the non-local material responses from the gold.

In the team's experiment, the interface between a high-quality layered hBN flake and a monocrystalline Au flake is examined with scattering-type near-field optical microscopy (s-SNOM). Asger Mortensen, who leads the Danish group involved in the study, explained to *Nature Photonics* why they use this method: "s-SNOM provides real-space, nanometre-scale maps of the near-field [electric field] amplitude and phase, which lets us directly image launched phonon-polaritons, measure fringe wavelengths, and extract both real and imaginary parts of the propagation constant."

Key to the team's success was eliminating losses in the layered hBN and gold structure by selecting the lowest-loss vibration mode and engineering a large-area atomically thin gold substrate layer for minimal scattering. With these enhancements to the scanning setup, the team detects the image phonon-polariton modes of a wavelength as small as 70 nm. The experiment shows consistent agreement between classical theory and experimental measurements of the quasiparticle's oscillations. This performance holds across varying thicknesses of the hBN layer, and even at low phase velocities below the Fermi velocity of gold, where non-local effects are anticipated.

Mortensen further clarified: "The primary benefit is reliable access to extreme nanophotonic regimes using classical electromagnetism, i.e. if nonclassical effects can be mitigated, the macroscopic Maxwell's equations can continue to serve as the fundamental tool for understanding electromagnetism even on microscopic length-scales."

Aside from the improvement in the characterization of the interface's thickness and optical properties, the effective control over the strength of the non-local material response allows validation of future models for them. Mortensen also noted: "Research in that direction [...] opens the door to the exploration of other velocity-dependent phenomena, such as Shockley–Tamm surface states."

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