Amplitude- and Phase-Resolved Infrared Imaging of 2D Materials

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Surface plasmon polaritons (SPPs) and surface phonon polaritons (SPhPs) in 2D materials, with their high spatial confinement, can open up new opportunities for enhanced light-matter interaction, super lenses, subwavelength metamaterials, and novel photonic devices. *In situ* characterization of these polaritonic excitations in different applications requires a versatile optical imaging and spectroscopy tool with nanometer spatial resolution.

Through a non-invasive near-field light-matter interaction, scattering-type scanning near-field optical microscopy (s-SNOM) provides a unique way to selectively excite and locally detect electronic and vibrational resonances in real space. By collecting scattered light from the area underneath the atomic force microscope (AFM) tip, local optical properties of the sample can be measured with spatial resolution limited by the tip radius of ~20nm. The full near-field optical response of the polaritonic resonances can be measured with phase resolved detection, providing both amplitude and phase information.

Here we demonstrate the technique by imaging both SPhPs on hexagonal boron nitride (hBN) and SPPs on graphene with tunable QCL and CO_2 laser sources. Amplitude and phase near-field optical images provide complementary information for characterizing the complete polaritonic resonances. Phase shifts >90° for SPhPs are observed on hBN, indicating strong light-matter coupling.

By integrating with broadband and ultrafast light sources, sSNOM can be further used to study nonlinear properties associated with these polaritonic resonances.