Far infrared synchrotron near-field nano-imaging and nano-spectroscopy

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Scattering scanning near-field optical microscopy (s-SNOM) has emerged as a powerful imaging and spectroscopic tool for investigating nanoscale heterogeneities in biology, quantum matter, and electronic and photonic devices. However, many materials are defined by a wide range of fundamental molecular and quantum states at far-infrared (FIR) resonant frequencies currently not accessible by s-SNOM. Here we show ultrabroadband FIR s-SNOM nano-imaging and spectroscopy by combining synchrotron infrared radiation with a novel fast and low-noise copper-doped germanium (Ge:Cu) photoconductive detector [1]. This approach of FIR synchrotron infrared nanospectroscopy (SINS) extends the wavelength range of s-SNOM to 33µm (330 cm^{-1}, 10 THz), exceeding conventional limits [2] by an octave toward lower energies. We demonstrate this new nano-spectroscopic window by measuring elementary excitations of exemplary functional materials, including surface phonon-polariton waves and optical phonons in oxides and layered ultrathin van der Waals materials, skeletal and conformational vibrations in molecular systems, and the highly tunable plasmonic response of graphene.

Continued detector development will further extend the range of FIR SINS to ultimately bridge the energy gap with available THz s-SNOM sources, yet in a single nano-spectroscopy instrument. This work highlights the continued advantage of synchrotron radiation as an ultrabroadband coherent light source for near-field nano-spectroscopy, especially in the long wavelength regime where alternative low-noise, broadband, quasi-cw laser sources are not readily available.

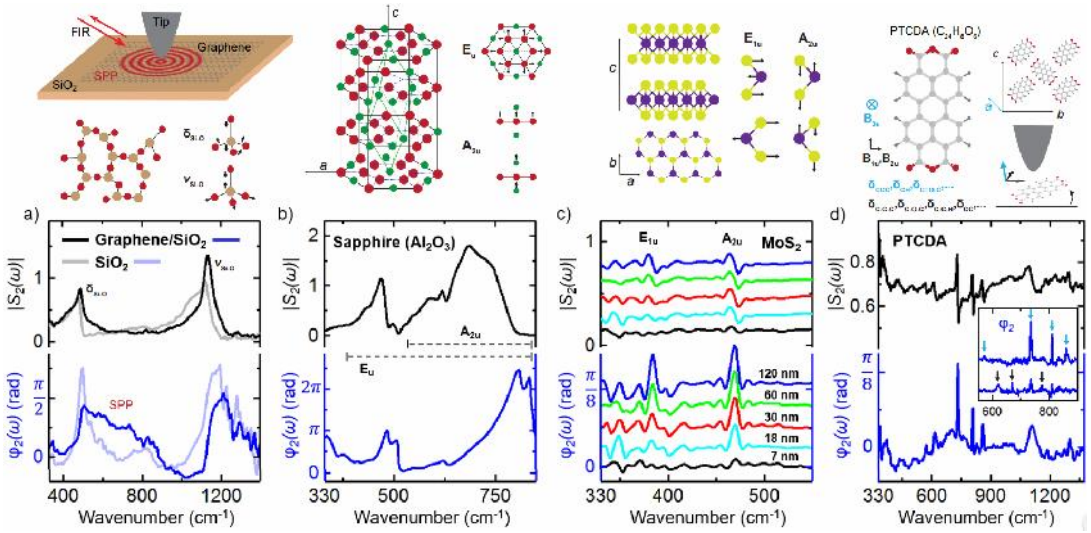

Figure. FIR SINS amplitude $|S_2(\omega)|$ (top) and phase $\Phi_2(\omega)$ (bottom curves) spectra of selected material systems.

References

[1] Khatib, Bechtel, Martin, Raschke, Carr, *Under Review* (2018).
[2] Bechtel, Muller, Olmon, Martin, Raschke, *PNAS* **111**(20), 7191–7196 (2014).