Phonon-enhanced molecular vibrational spectroscopy at the strong coupling limit

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Surface enhanced infrared absorption spectroscopy (SEIRA) is a powerful strategy to increase the weak vibrational signature of molecules in FTIR spectroscopy, by means of the confined and enhanced field on the surface of plasmonic objects [1]. Another possibility to enhance and confine infrared light into subwavelength scale is to exploit phonon-polaritons in polar crystals [2] or layered materials, such as van der Waals crystals. In particular, the van der Waals material hexagonal boron nitride (hBN) hosts low-loss hyperbolic phonon-polaritons in the reststrahlen band frequency range (1360-1610 cm^{-1}) [3]. With hBN nanocones and nanorods, extremely narrow resonances (Q up to 283) have been already demonstrated experimentally [4].

In this work we employ for the first time well-defined phononic antennas, hBN ribbons, to detect small amounts of organic molecules via infrared transmission measurements.

Strikingly, the interaction between phonon-polaritons and molecular vibrations reaches experimentally the onset of the strong coupling regime, while numerical simulations predict that vibrational strong coupling can be fully achieved [5]. Phonon-polariton nanoresonators thus could become a viable platform for sensing, active control of chemical reactivity and infrared quantum cavity optics experiments.

References

[1] Aroca, Ricardo. *Surface-enhanced vibrational spectroscopy*. John Wiley & Sons, 2006.

[2] Hillenbrand, R., Taubner, T., & Keilmann, F. (2002). Phonon-enhanced light–matter interaction at the nanometre scale. *Nature*, *418*(6894), 159-162.

[3] Caldwell, J. D., & Novoselov, K. S. (2015). Van der Waals heterostructures: Mid-infrared nanophotonics. *Nature materials*, *14*(4), 364-366.

[4] Caldwell, J. D. et al. (2014). Sub-diffractional volume-confined polaritons in the natural hyperbolic material hexagonal boron nitride. *Nature Communications*, *5*, 5221.

[5] Autore, M. et al. (2018) Boron nitride nanoresonators for phonon-enhanced molecular vibrational spectroscopy at the strong coupling limit**,** *Light: Science & Applications* 7, e17172; doi:10.1038/lsa.2017.172