Theory of interactions between matter and optical phonons in two dimensions

Nicholas Rivera,[1,2,*] Thomas Christensen,[2] and Prineha Narang[1,†]

[1]*John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA*
[2]*Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA*

(Dated: November 4, 2018)

Extreme confinement of electromagnetic energy by phonon polaritons promises extremely strong and novel forms of control over the dynamics of matter. To bring such control to its ultimate limit, it is important to consider phonon polaritons in two dimensional systems. However, recent studies have pointed out that in two-dimensional systems, splitting between longitudinal and transverse (LO and TO) optical phonons, which is necessary for the existence of phonon polaritons in three dimensions, is absent. The question then arises as to whether the ability to exploit optical phonons disappears in lower dimensions. Here, we settle this question, finding that the phonon-polariton of the bulk is essentially replaced by the LO phonon. We present the confinement and propagation losses of LO phonons. We then calculate various measures of strong light-matter interaction such as single and two-photon spontaneous emission enhancement, and discuss methods such as EELS to probe these excitations.

I. ELECTRODYNAMICS OF OPTICAL PHONONS IN TWO-DIMENSIONS

In this section, we develop the theory of electromagnetic waves associated with optical phonons in two dimensions. A theory of electromagnetic waves in polar 2D materials involves first calculating the dielectric permittivity associated with the monolayer.

II. STRONG LIGHT-MATTER INTERACTIONS ENABLED BY 2D OPTICAL PHONONS

A. Spontaneous emission

B. Spontaneous and stimulated electron energy loss

III. ACKNOWLEDGEMENTS

N. R. recognizes the support of the DOE Computational Science Graduate Fellowship (CSGF) fellowship no. DE-FG02-97ER25308. P. N. acknowledges start-up funding from the Harvard John A. Paulson School of Engineering and Applied Sciences. T. C. acknowledges support from the Danish Council for Independent Research (Grant No. DFF–6108-00667). The authors thank Joshua Caldwell (Vanderbilt), Dmitri Basov (Columbia), Ido Kaminer (Technion), Siyuan Dai (UT Austin), and Samuel Moore (Columbia) for helpful discussions. This work was supported by the DOE Photonics at Thermodynamic Limits Energy Frontier Research Center under grant no. DE-SC0019140.

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* nrivera@seas.harvard.edu
† prineha@seas.harvard.edu

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