Radiative heat exchange driven by acoustic modes between two solids at the atomic scale

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Abstract.
In the near field (for separation distances smaller than the thermal wavelength, of the order of some microns at ambient temperature), the radiative heat flow between two solids at different temperatures can exceed the blackbody limit by several orders of magnitude. Furthermore, at the atomic scale, close to contact, the vibrational modes of the crystal lattice are expected to play an important role in the heat exchange. While the contribution of acoustic phonons tunneling due to Van der Waals forces and electrostatic interactions near the surface has been investigated [1–5], the radiative contribution of the acoustic modes has been neglected so far. Under the local assumption (wavevector \( \mathbf{k} \approx 0 \)), optical modes are independent from the acoustic modes, and are the sole responsible for the thermal radiation for distances larger than a few nanometers. However at subnanometer distances, the electromagnetic response of solids is nonlocal (\( \mathbf{k} \neq 0 \)) and both acoustic and optical modes are coupled, contributing together to the radiative heat exchange. In order to demonstrate the role of this contribution, we calculate [6] the nonlocal dielectric permittivity of magnesium oxide (MgO) using molecular dynamics. In conjunction with fluctuational electrodynamics calculations, we are able to highlight the role of radiation between two polar crystals produced by acoustic modes compared to the expected results from the local theory. We show that this additional contribution can become the dominant channel for radiative heat exchanges at atomic scale in the cryogenic regime (below 100 K). Since the acoustic vibration modes can be excited with the help of piezoelectric transducers, our work opens the possibility to the control of radiative heat exchanges at atomic scale using external mechanical actuation.

References

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