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CHT-15: Optical phonon production by phonon upconversion in heterostructure

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Abstract

High-energy optical phonons are preferred in phonon-absorbing transitions (phonon-assisted photon absorption or direct phonon absorption). In this research, based on the interaction kinetics of the low-energy phonon upconversion, we study the efficient supply of the optical phonons which have higher energy and lower entropy. The interaction kinetics is dependent on the phonon distribution, and here we consider nonequilibrium native phonon distribution (generated by phonon flux in homogeneous system) and one by heterojunction transmitted phonons. For heterojunction, steady phonon flux from low cut-off layer (e.g., Ge) is transmitted to high cut-off layer (e.g., Si), creating nonequilibrium population of low-energy phonons for upconversion, and its phonon distribution is calculated using the quantum spectral phonon transmission. Using the first-principles calculations of the phonon interaction kinetics, we identify the high conversion efficiency channels, i.e., mode and Brillouin zone (BZ) location. Junction-transmitted phonons despite suffering from reflection and spreading interactions with the equilibrium native phonons can be targeted for their high upconversion rate to BZ boundary optical phonons. The nonequilibrium native phonons are efficiently upconverted over most of the zone, with high rates in BZ locations not covered by the transmitted-phonon upconversion. So, depending on the harvested optical phonon, one of these nonequilibrium phonons can be selected for efficient upconversion rate. The approaches to phonon kinetics and distribution suggested in this work can be applied to various phonon engineering applications and interface thermal transport analyses.

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