Abstract

When the phonon spectrum of a material is measured in a scattering experiment, selection rules preclude the observation of phonons that are odd under reflection by the scattering plane. Understanding these rules is crucial to correctly interpret experiments and to detect broken symmetries. Taking graphene as a case study, in this work we derive the complete set of selection rules for the honeycomb lattice, showing that some of them have been missed or misinterpreted in the literature. Focusing on the technique of high-resolution electron energy loss spectroscopy (HREELS), we calculate the scattering intensity for a simple force constant model to illustrate these rules. In addition, we present HREELS measurements of the phonon dispersion for graphene on Ru(0 0 0 1) and find excellent agreement with the theory. We also illustrate the effect of different symmetry breaking scenarios in the selection rules and discuss previous experiments in light of our results. Finally we clarify why the shear horizontal label is not equivalent to odd parity, and how this can be misleading in the identification of selection rules.