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Perspectives on spatial dispersion in cubic crystals provided by neutron scattering, phonon imaging, picosecond laser ultrasound and lattice dynamics models

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Spatial dispersion is the variation of acoustic wave speed with wavelength, and sets in when the wavelength approaches the natural scale of length of a medium, or lattice spacing in the case of a crystal. The first onset of dispersion can be treated within the context of continuum mechanics by the incorporation of third and fourth order spatial derivatives of the displacement field in the elastic wave equation. These additional terms yield corrections to the phase velocity which in general are quadratic in the spatial frequency k. This paper will survey the experimental techniques that give one access to the coefficients in these expansions, in particular inelastic neutron scattering, ballistic phonon imaging and picosecond laser ultrasound. The main emphasis of the paper will be on deriving the numerical values of the dispersion coefficients for four cubic crystals, Si, Ge, GaAs and InSb, from published neutron scattering data and demonstrating how modified continuum elastodynamics with these values of the coefficients is able to account well for the available dispersive phonon images of these crystals. Comparison will be made with values for the dispersion coefficients that have been obtained from laser ultrasound measurements and from lattice dynamics models.