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Time and momentum-resolved phonon decay¹

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The high brightness of x-ray free-electron lasers provides us a unique opportunity to measure lattice dynamics directly in the time domain and out of equilibrium. As a first step in this direction we demonstrate how ultrafast optical excitation creates temporal coherences in the mean-square phonon displacements spanning the Brillouin zone by a second-order squeezing process. This leads to broad-bandwidth high-resolution measurements of the phonon dispersion without the need for high-resolution monochromators or analyzers. We will also show how anharmonic phonon decay can be viewed as a parametric squeezing process, and present first momentum-resolved measurements of the downconversion of a coherent optical phonon into pairs of high-wavevector acoustic modes, information that cannot be obtained by spectroscopic measurements in the frequency domain.

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