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Impulsive Thermomechanics of Hypersonic Surface Phononic Crystals

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Ultrafast optical generation of pseudosurface acoustic waves [1,2] is investigated in Hypersonic Surrface Phononic Crystals. The thermomechanics is modeled from first-principles to follow the initial impulsive heat-driven displacement in the time domain. Spectral decomposition of the displacement over the surface phononic crystal eigenmodes outlines asymmetric resonances featuring the coupling between surface and bulk modes. This finding allows evaluation of impulsively excited pseudosurface acoustic wave frequencies and lifetimes, and expands the present knowledge on the scattering of surface waves in mesoscale metamaterials [3]. The theory is positively benchmarked against time-resolved optical diffraction measurements performed on surface phononic crystals. The modeling is performed exploitng COMSOL multiphysics (PDE modulus). The thermodynamics following laser exctitation up to few picoseconds is modeled via the Two Temperature Model (accounting for the electron excitation and electron-lattice thermalization in the metallic overlayer), a Kapitza thermal resistance (accounting for thermal transport across the metallic overlayer /semiconductor substrate interface) and a Fourier transport equation (accounting for the heat transport in the substrate) [4]. The thermal solution, obtained after electron-phonon thermalization in the overlayer has occurred, is exploited to calculate the initial displacement for the mechanical time-dependent problem taking place on a 10 ns time-span. The time-dependent displacement field (see Fig. 2) is calculated solving the time-dependent elastic equations with periodic boundary conditions. The initial solution is spectralized [3] on the Hypersonic phononic Crystals eigenvectors, calculated from the elastic eigenvalue equation [5]. The spectralizaton is performed in MATLAB after having exported the simulation results obtained with COMSOL Multiphysics. The frequency dependence of the spectralizations coefficient spots out two resonances showing a Fano-like line shape. These evidences allow finding the pseudosurface acoustic wave frequencies and lifetimes.

Reference

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