Experimental observation of collective resonances of a chain of resonators in a full-band gap phononic crystal slab

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Background, Motivation and Objective

Coupled-resonator elastic waveguides (CREW) are composed of lines of isolated defects in a full band gap phononic crystal. The existence of the full band gap ensures that there are no propagating waves in the crystal, only evanescent waves. Evanescent waves can tunnel elastic wave energy between adjacent identical defects, resulting in a coupling strength between resonators decreasing fast with their separation distance. The spatially localized resonances of the defects are then evanescently coupled, leading to guided waves with a smooth dispersion relation inside the band gap and low group velocity. Such a waveguide solution is particularly attractive in phononic crystal slabs, where the surfaces of the slab further guarantee vertical confinement of the waves.

Statement of Contribution/Methods

We have manufactured coupled-resonator elastic waveguides in a glass plate. A periodic pattern of cross holes arranged according to a square lattice was etched in the 500 micron-thick plate by using femtosecond laser machining followed by HF etching (FEMTOPrint model f100 aHead Enhanced). The samples have a lattice constant of 715 microns and a full band gap extending from 1.7 to 4 MHz. We created a chain of resonators by 'forgetting' to etch selected holes. We purposely chose the sequence of defects to follow a rather arbitrary path in the plane of the surface, with the intent of showing that the coupling of resonators allows to funnel elastic waves without creating straight channels. Lamb waves were excited in the sample by attaching a PZT patch. We then measured the out-of-plane displacements for monochromatic excitation using a laser vibrometer, with amplitude and phase information (Polytec MSA-500 Micro-System Analyzer).

Results/Discussion

The measurements show that collective vibrations of the evanescently coupled resonators are efficiently excited. We imaged modal vibrations over the surface and observed that the resonators oscillate coherently at the same frequency. We observed collective vibrations of a sequence of up to 18 resonators, without apparent spatial attenuation, only limited by the size of the array of 18 by 20 holes for the phononic crystal slab. Significantly, collective oscillations survive the many sharp bends along the chain. Our results support the conclusion that resonator coupling is evanescent and is dominated by near-neighbor effects.