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Imaging surface acoustic wave propagation in a triangular-lattice phononic crystal

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1. Introduction

Control of surface acoustic waves (SAW) is an important aspect in many device applications. Phononic cystals[1]—materials that have periodic variations in their acoustic properties—are becoming increasingly significant for controlling wave propagation in different situations. The periodic variations produce useful modifications to the acoustic band structure such as band gaps. While theoretical band structures and transmission spectra have been studied in some detail[2], imaging of SAW propagation provides unique insights that haven't been fully explored. In particular, the role of the source in determining propagation properties hasn't been studied in detail. Direct imaging of phononic crystals has proved to be an effective method for investigating their physics[3,4]. Such methods can reveal the details of the acoustic scattering in real-space and of the acoustic dispersion in **k**-space. Here we present spatiotemporal Fourier analysis of 2D real-time imaging experiments and of the results of finite element method (FEM) simulations of SAWs at frequencies up to ~1 GHz in a phononic crystal. The sample consisted of a triangular array of holes of spacing 10 μm in a photoresist film on a silicon substrate of thickness 30 μm (illustrated in the inset of **Fig. 1**). The holes were hexagonal and of depth 7 μm. We studied the 2D pattern of acoustic amplitude derived in **k**-space by spatiotemporal Fourier transforms, as well as the dependence on the location of the acoustic source in the phononic lattice.

2. Simulation

Simulations were performed using a finite difference time domain (FDTD) FEM method. An example of a simulation image obtained in **k**-space at 240 MHz is shown in Fig. 1. The excitation point was located at a 2-fold symmetry point between two holes. Although the underlying structure has a 3-fold symmetry, both real- and **k**-space images show a 2-fold symmetry pattern, reflecting the choice of the excitation source. The simulations also allow mapping of any arbitrary

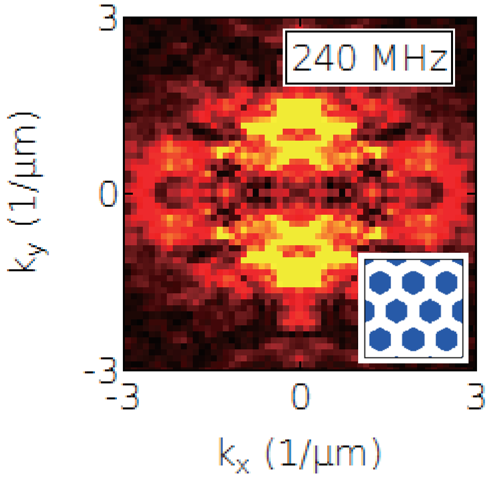

Fig. 1 Simulation of a constant frequency image in **k**-space in a triangular-lattice phononic crystal. The sample was excited at a 2-fold symmetry point between 2 holes. Inset: illustration of a 30 μm × 30 μm area of the phononic crystal structure.

plane below the surface. For example, we investigated the effect of the phononic crystal on acoustic propagation in a sub-surface region clear of the finite-depth holes. We show that there is a strong dependence of the pattern obtained in **k**-space on the plane used for the Fourier analysis.

3. Experimental

For the experiments, phononic crystals were made in the same geometry as the simulation. A 415 nm pump beam of ultrashort light pulses excited the acoustic modes with a repetition rate of 80 MHz. A similar 830 nm probe beam with variable delay relative to the pump was used for interferometric detection. The optical pulse duration was ~200 fs, and the beams were focused to a 1 μm diameter spot. The probe spot was scanned across the sample to generate images of regions of about 100×100 μm^2 in area. By taking images at successive delay times, we generated animations of the surface waves propagating through the structure. We then calculated frequency and **k**-space images by Fourier analysis. The experimental results are shown to be in good agreement with the numerical simulations.

The simulation and experimental results in real space and **k**-space reveal the effect of the symmetry of the chosen point of excitation on the acoustic propagation. This study allows a better understanding of the wave propagation and dispersion characteristics of phononic crystals through Fourier analysis of real-time imaging data.

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4. References

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