A membrane-based phononic crystal waveguide

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A phononic crystal is an elastic wave analogue of a photonic crystal. It consists of a periodically-modulated elastic media that results in a bandgap for phonons emerging [1,2]. This can prevent phonons from freely propagating which can enable the development of various phononic crystal devices. However, the phononic crystals reported so far have been passive structures whose elastic properties can only be modulated by changing either the constituent materials or the periodic geometry. In order to realize an active phononic crystal, we fabricated a one dimensional (1D) membrane-based active phononic crystal.

Figure 1 shows an optical microscope image of the 1D phononic crystal and the measurement set-up. It was fabricated by suspending one hundred 30 μm-wide electrically-active membranes ($Al_{0.27}Ga_{0.73}As$ (95 nm)/Si-doped GaAs (100 nm)) [3] by selectively etching the $Al_{0.65}Ga_{0.35}As$ sacrificial layer (3 μm) through 100 equally-spaced holes. This resulted in a 1-mm long waveguide. Application of an alternating voltage to the right-edge membrane induces mechanical oscillations due to the piezoelectric effect. The excited mechanical oscillations can travel in the waveguide and are measured at the left-edge membrane with a He-Ne laser Doppler interferometer. As a preliminary step for the demonstration of its dynamic control, we investigated the frequency response of this 1D phononic crystal in a vector signal analyzer, at room temperature and in a high vacuum when actuated between 0.1-10 MHz as shown in Fig. 2. Both a phononic bandgap (4.5-5.0 MHz) and continuous bands (2.0-4.5 MHz and 5.0-10.0 MHz) are observed. Furthermore, the group velocity of the phonon propagation can be estimated from time domain measurements. These results indicate that this membrane-based 1D phononic crystal can be used as a phononic waveguide which can transfer mechanical energy to any desired direction. The demonstration of a phonon bandgap in a piezoelectric membrane-based phononic waveguide opens up the possibility of on-chip active phononic crystal devices.

[1] R. Martinez-Sala *et al.*, Nature **378**, 241 (1995).
[2] Z. Liu *et al.*, Science **289**, 1734 (2000).
[3] D. Hatanaka *et al.*, Appl. Phys. Lett. **101**, 063102 (2012).

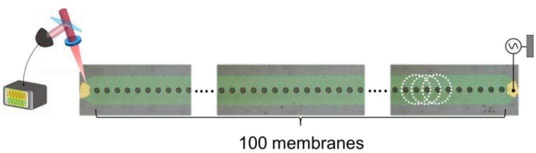

Fig. 1 An optical image of the membrane-based phononic crystal waveguide (green) and the measurement set-up. This waveguide is suspended by removing the sacrificial layer. The dotted circles show a constituent membrane.

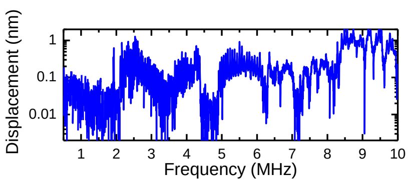

Fig. 2 Frequency response of the membrane-based phononic crystal waveguide when actuating with an amplitude of 0.4 V_{rms}.