Coupled-resonator phononic waveguides

Coupled-resonator acousto-elastic waveguides – 1

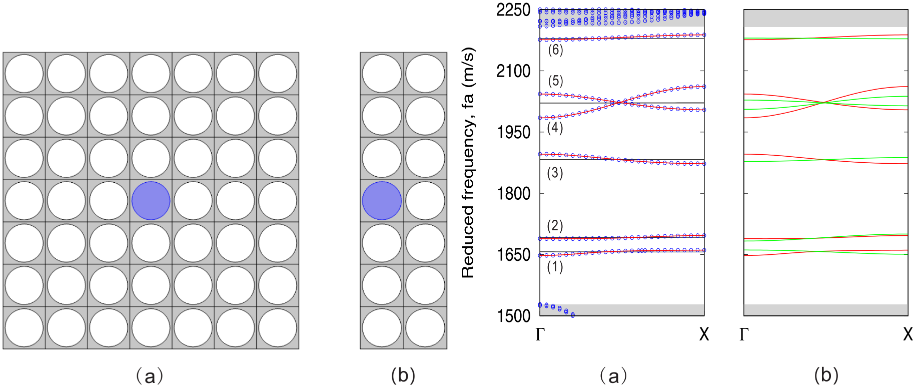


Figure: The blue, gray and white parts represent water, aluminum and vacuum, respectively [46].

Coupled-resonator acousto-elastic waveguides – 2

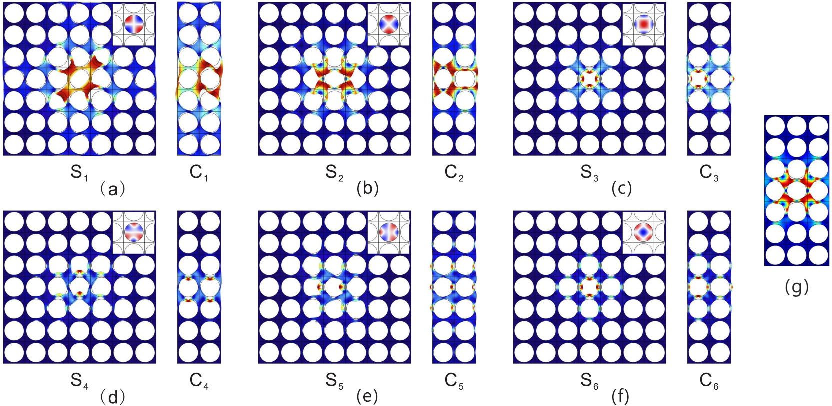


Figure: Displacement and pressure fields of the six defect modes of the acousto-elastic phononic crystal, shown at the Γ point of the first Brillouin zone.

Coupled-resonator acousto-elastic waveguides – 3

The dispersion relation of CRAEW modes is very smooth. This property can actually be associated with the rapid decrease with distance of the coupling strength between adjacent cavities [47]. The dispersion can be expressed directly as the Fourier series

$$\omega(k) = \Gamma_0 + \sum_{m=1}^{\infty} 2\Gamma_m \cos(km\Lambda) \quad (1)$$

The Fourier coefficients Γ_m can be interpreted as representing the coupling strength between defects separated by a distance $m\Lambda$.
Note that periodicity of the waveguide alone implies the Fourier series expansion: the expression is valid for all phononic crystal waveguides.

Coupled-resonator acousto-elastic waveguides – 4

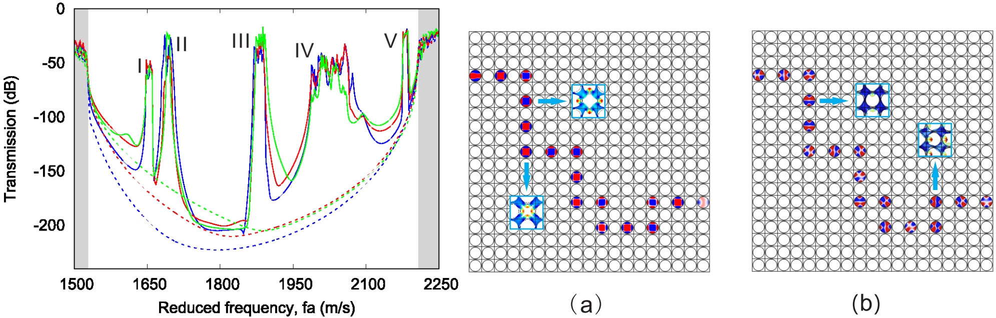


Figure: 8-bend waveguide: there are no significant losses at a waveguide bend within each passband.

Coupled-resonator acousto-elastic waveguides – 5

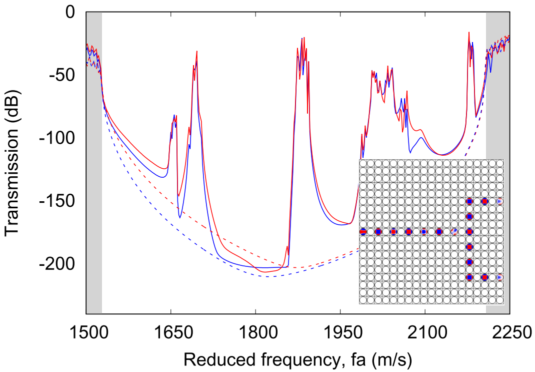


Figure: Splitter circuit: the symmetry of the Bloch wave allows for even splitting.

Channeled spectrum – 1

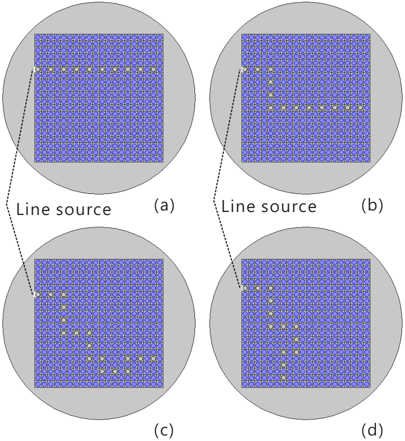


Figure: Different coupled-resonator waveguides to test the channeled spectrum idea. Square-lattice sonic crystal of mercury cylinders in water. (a) $L = 10\Lambda$, (b) $L = 13\Lambda$, (c) $L = 17\Lambda$, and (d) $L = 13\Lambda$ [48].

Channeled spectrum – 2

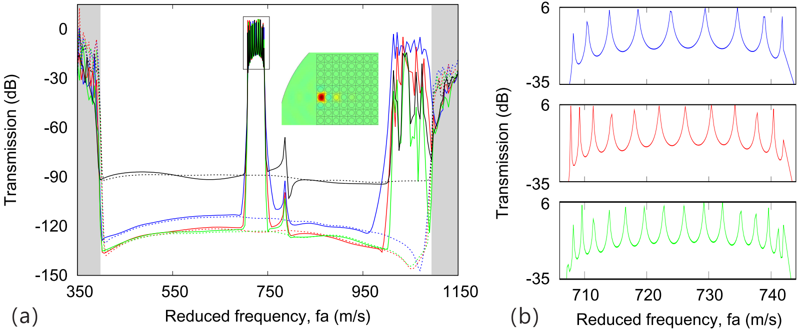


Figure: Channeled spectrum: sequence of frequency maxima and minima in the transmission spectrum. It depends mostly on the waveguide length.

Channeled spectrum – 3

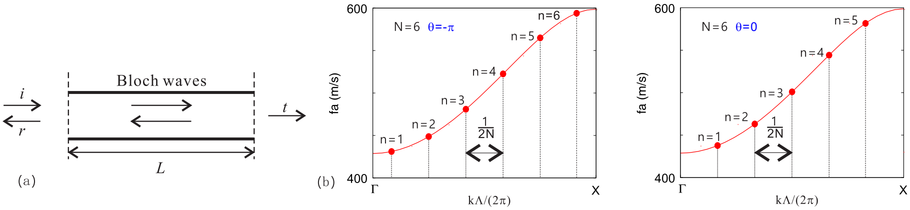


Figure: (a) Simplified model of transmission through a single-mode periodic waveguide at a single frequency. (b) Graphical construction of the channeled spectrum from the dispersion relation of the infinite waveguide.

Channeled spectrum – 4, model

Superposition of a left-traveling Bloch wave, $p_l(x, y)$, with a right-traveling Bloch wave, $p_r(x, y)$,

$$p(\omega; x, y) = \alpha p_r(x, y) e^{-\imath k(\omega) x} + \beta p_l(x, y) e^{+\imath k(\omega) x} \quad (2)$$

gives transmission:

$$t(\omega) = \alpha e^{-\imath k(\omega) L} + \beta e^{+\imath k(\omega) L}. \quad (3)$$

The transmission in intensity is then

$$|t(\omega)|^2 = |\alpha|^2 + |\beta|^2 + 2|\alpha\beta| \cos(2k(\omega)L - \theta), \quad (4)$$

with $\theta = \mathrm{Arg}(\alpha\beta^*)$ a phase angle. Transmission maxima are obtained when $2k(\omega)L = \theta$ modulo 2π, or

$$k(\omega_n)\Lambda = \frac{\theta}{2N} + \frac{n}{N}\pi. \quad (5)$$

Channeled spectrum – 5

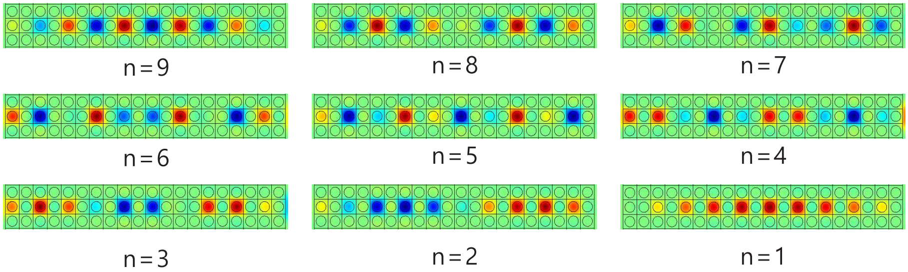
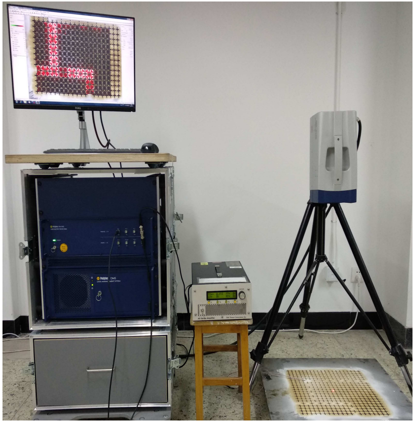


Figure: Pressure distribution of the straight CRAW (CW1, $L = 10\Lambda$) at the resonance peaks. The number of pressure oscillations is shown below the field maps.

Coupled-resonator circuits – 1, stainless steel



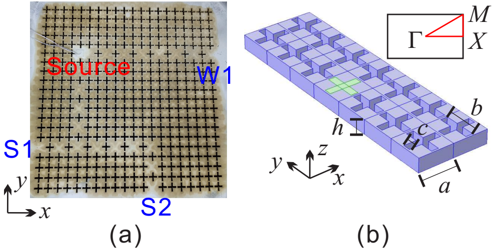
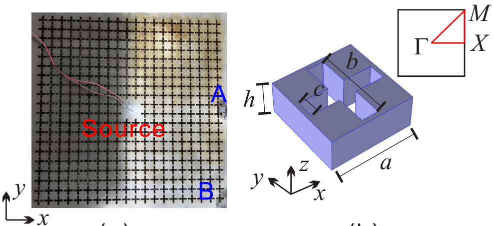
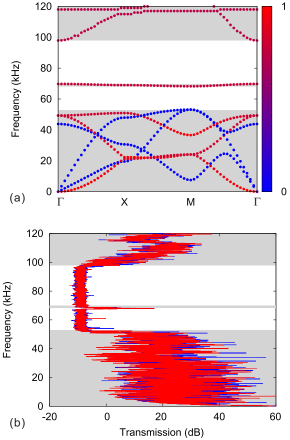


Figure: Phononic crystal slab of cross holes in stainless steel. The parameters b/a=0.9, c/a=0.2 and h/a=0.4, with the lattice constant a=20 mm optimize the band gap width [49].

Coupled-resonator circuits – 2, perfect crystal



(a) (b)



Coupled-resonator circuits – 3