Quest for flexible acoustic circuitry with acousto-elastic metamaterials

Shengqiang Cai, Howon Lee, Jun Xu, and Nicholas X. Fang

[1]Department of Mechanical Engineering
Massachusetts Institute of Technology
77 Massachusetts Ave, Cambridge, MA 02139, USA
Fax: + 1–617-258-6156; email: nicfang@mit.edu

Abstract

In this invited talk, we will present our progress in bending and folding acoustic waves in a flexible acoustic circuitry. Motivated by our recent success in cloaking and beam shaping using coordinate transformation in acoustics, we will apply it to elastic and deformable systems that display strong acousto-elasticity.

1. Introduction

The remarkable success of electromagnetic metamaterials stimulated exploration of controlling and manipulation of other form of waves in materials. For example, it is theoretically predicted [1] that acoustic wave in fluids could be bent artificially by providing a desired spatial distribution of anisotropic acoustic elements. However, experimental studies of these exciting ideas based on coordinate transformation have been hindered due to the difficulty in creating suitable materials with proper anisotropic mass density or bulk modulus.

To overcome such challenges, we take the analogy between lumped acoustic elements (pipes and chambers) and electronic circuit elements to construct a new class of metamaterials. When the dimensions of the region in which the sound propagates are much smaller than the wavelength, the phase is roughly constant throughout the element, a lumped-parameter model is appropriate. This transmission line approach enabled ultrasound focusing through a metamaterial network and low-loss and broadband cloaks[2] with the use of non-resonant constituent elements.

However, in order to make these metamaterials with desired properties, complex fabrication techniques are usually required, and the properties of a metamaterial are fixed once it is fabricated. Furthermore, for most materials, the influence of deformation on their acoustic or electromagnetic properties is small and non-controllable. Inspired by recent advancement of flexible electronics, we will present our progress in bending and folding acoustic waves in a flexible acoustic circuitry[3]. Motivated by our recent success in cloaking and beam shaping using coordinate transformation in acoustics, we will apply it to elastic and deformable systems that display strong acousto-elasticity, that is, to tune the acoustic properties of a metamaterial through mechanical deformations.

Such elastic and reconfigurable metamaterials also show potential for tailoring the wavefront of the initial compressive shock and the returning tensile shocks. We will discuss our preliminary modeling work on this end through selective deflection, mode transformation, focusing, or enhanced energy dissipation in the structures to mitigate subsequent damage or to direct the blast wave to a subsequent target.

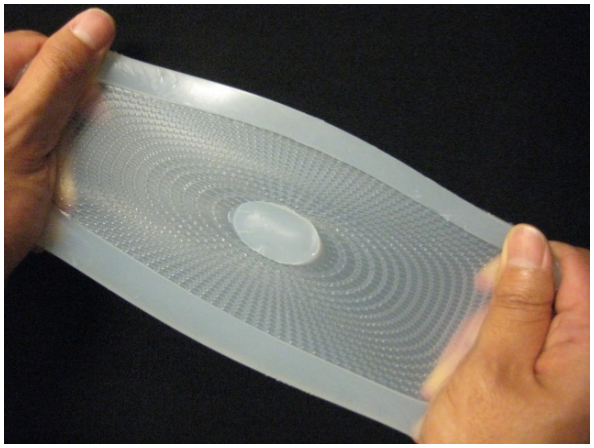

Fig. 1: Deformation of a flexible acoustic circuitry made of acoustic metamaterial network.

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