Tunable auxetic metamaterials for simultaneous attenuation of airborne sound and elastic vibrations in all directions

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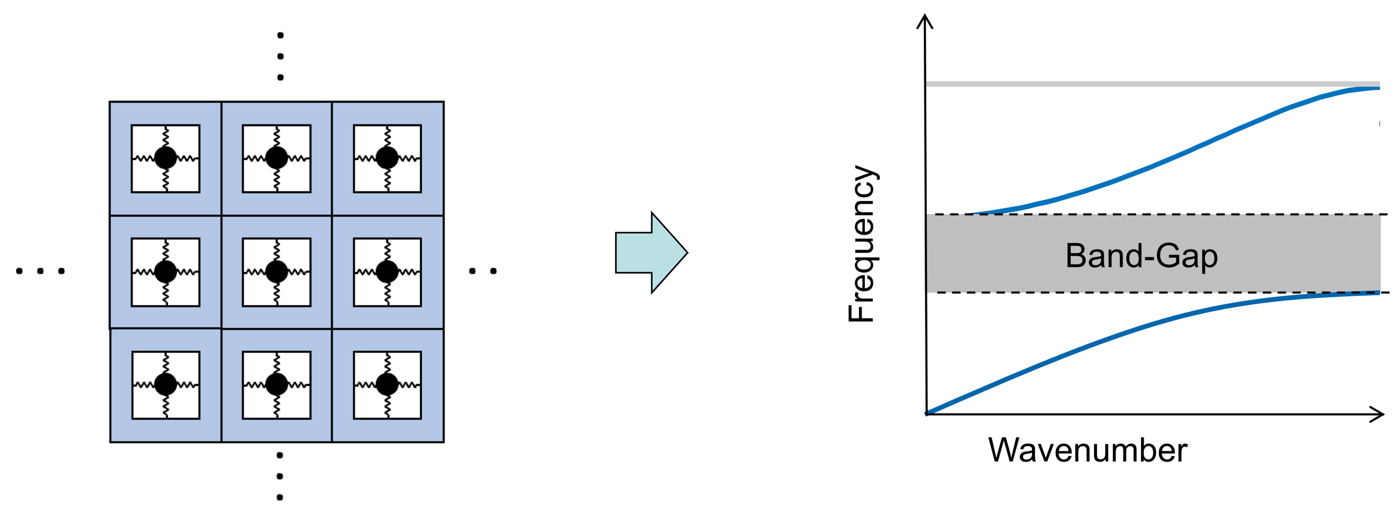
Wave Engineering through eXtreme & Intelligent matTEr

1. Introduction

Metamaterials are arrangements of basic building blocks (i.e., unit cell) that repeat in space, giving rise to intriguing dynamics such as bandgaps. [1]. In addition, Metamaterials have interesting properties, such as polar elasticity, and negative effective properties(Poisson's ratio, mass-density, and stiffness). [2-3]

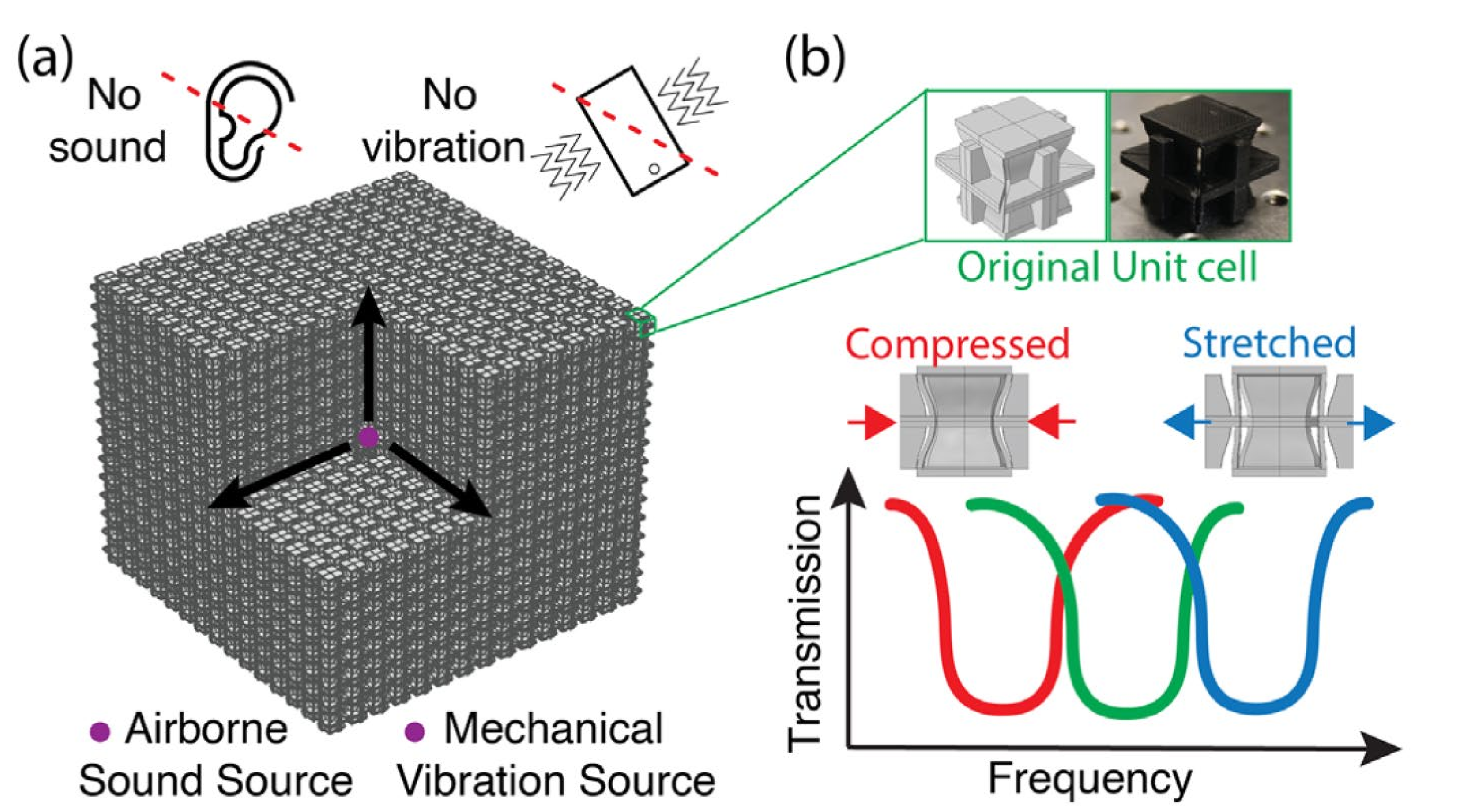


In the literature, researchers studied on metamaterials with remarkable properties and these studies can be loosely classified into three categories: [4-6]

(1) mechanical metamaterials (2) acoustic metamaterials (3) elastic metamaterials

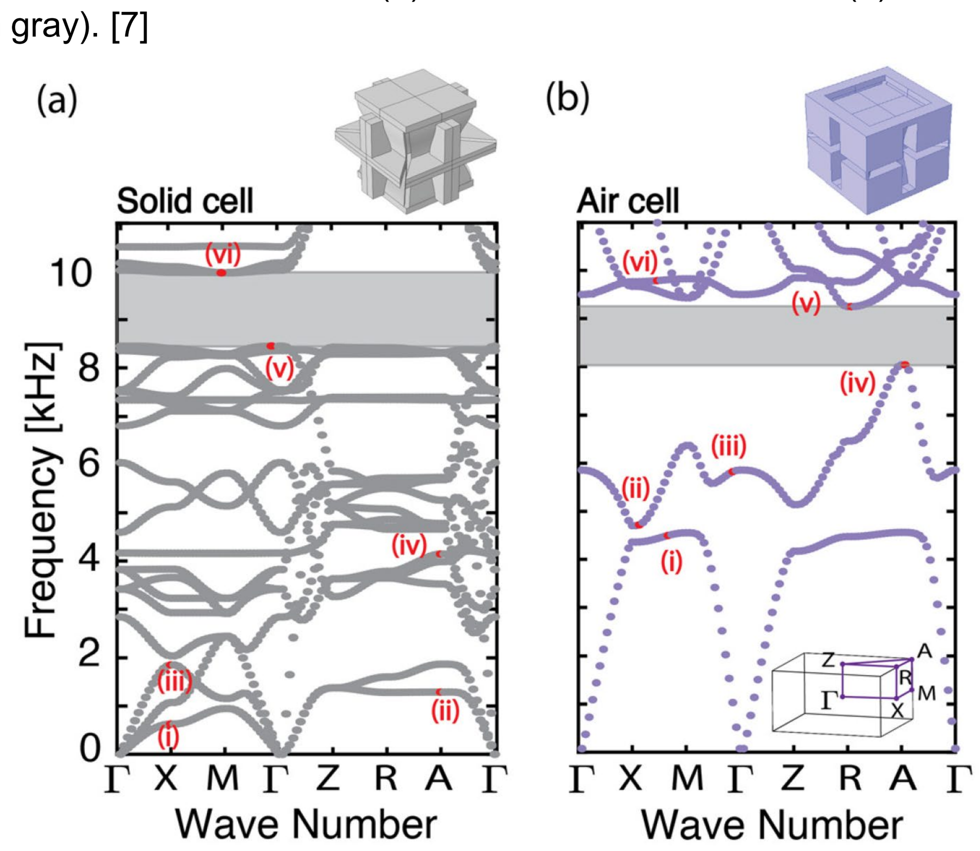
2. Concept

In this study, we study Auxetic vibro-acoustic metamaterial that can attenuate both elastic and acoustic waves. [7]



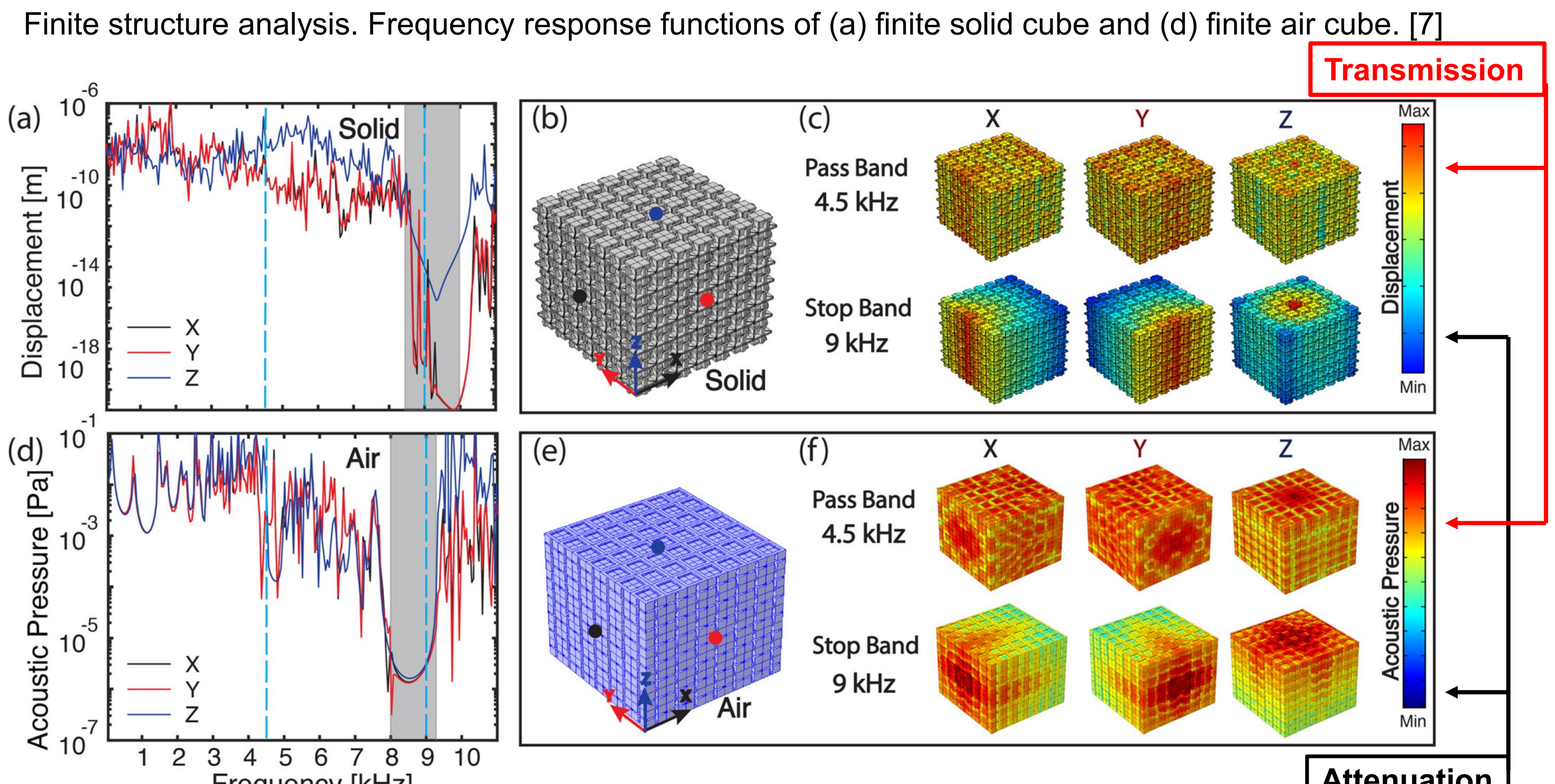
3. Unit cell analysis

Dispersion curves of the auxetic metamaterial for (a) mechanical vibrations and (b) airborne sound (bandgap regions are highlighted in gray). [7]

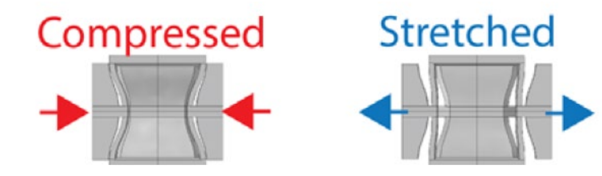


4. Finite structure analysis

Finite structure analysis. Frequency response functions of (a) finite solid cube and (d) finite air cube. [7]

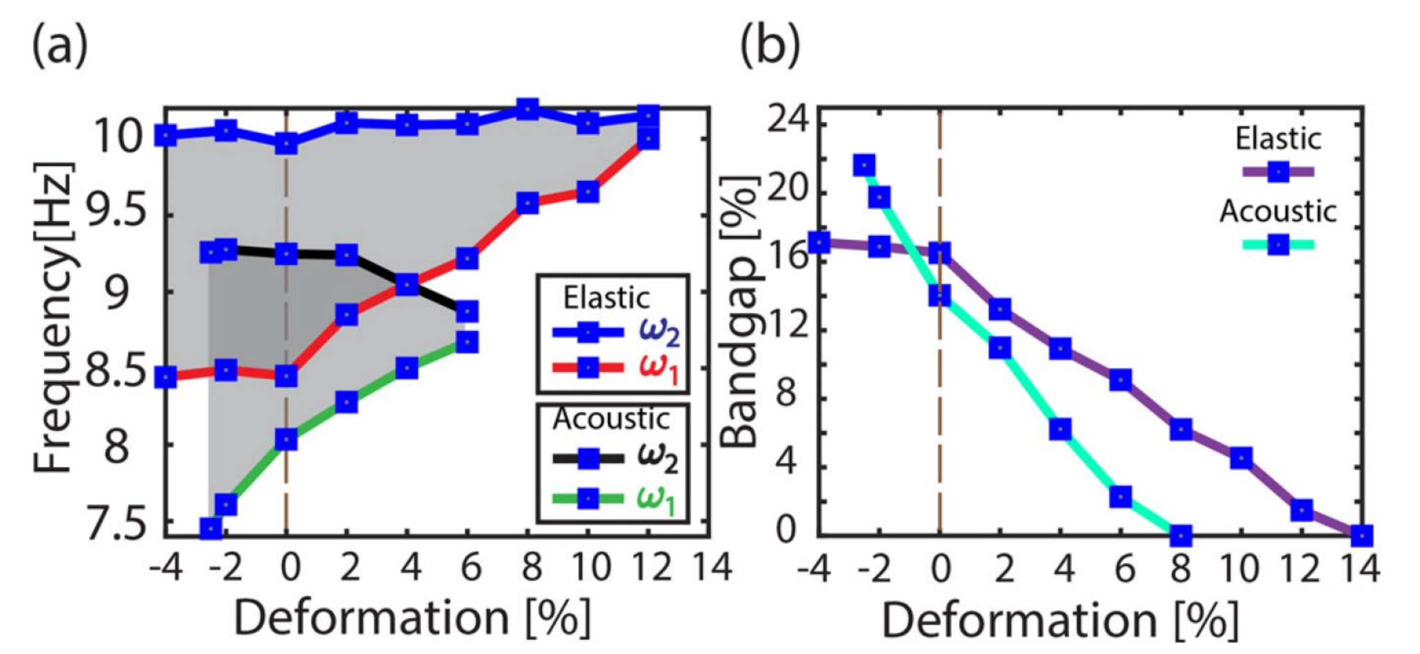


4. Tunability of the transmission



Numerical realization

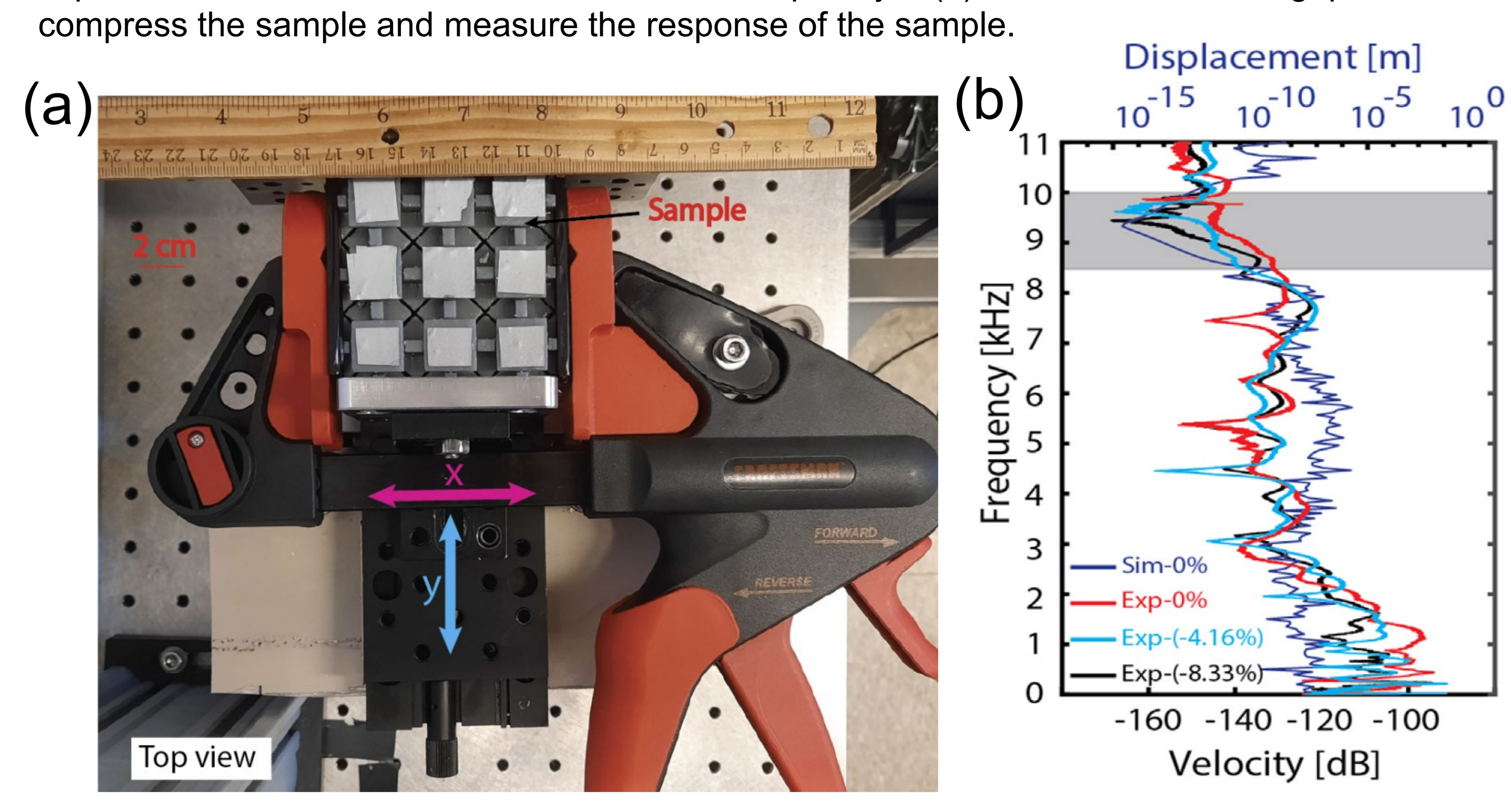
Band gap tuning. Change in the upper and lower bandgap frequency range as a function of deformation (%). (b) Relative bandgap size as a function of deformation (%).



5. Tunability of the transmission

Experimental realization

(a) We replicate the numeric experimentally and plot the response of both the numerical and experimental transmission as a function of frequency. (b) To tune the band gap we start to compress the sample and measure the response of the sample.



7. Conclusions

- We present a design methodology, simulations, and experiments of an auxetic, anisotropic metamaterial that can simultaneously attenuate both elastic vibrations and airborne sound in all directions.
- Due to the auxetic nature of the metamaterial, an applied load, either in compression or tension, causes a systematic shape change within the unit cell.
- The resulting transformation in geometry induces a shift in the attenuated frequency ranges for both sound and vibrations, independently.
- Our results can open new avenues for the design of tunable multi-functional metamaterials, with potential application in vibration and sound control.

References

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