ETH zürich

Hybrid Phononic Crystal

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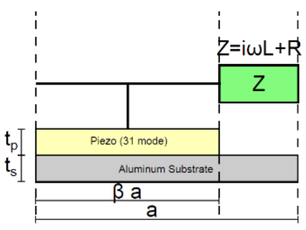
CMASLab

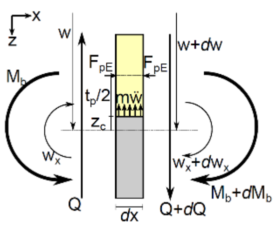
1 Introduction

Control of elastic waves with arrays of periodic piezoelectric shunts for attenuating mechanical vibrations has attracted increased interest in recent years. Most of the work has focused on arrays with locally shunted piezoelectric elements aimed at attenuating vibrations in structures. This project extends the functionality of the unit cell of periodic structures with piezoelectric elements. Here, the connectivity of the unit cells is defined by the propagation of both mechanical and electrical waves. This extension has a remarkable effect on the overall dispersive properties of the resulting medium.

2 Method overview

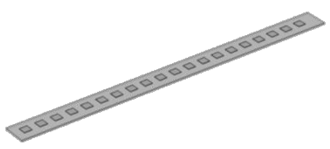
Analytical Models

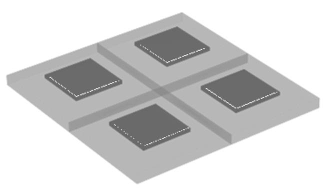




Analytical models have been developed using the Transfer Matrix Method, combined with Floquet periodic boundary conditions, to calculate the inverse dispersion solution for the interconnected unit cell, as seen in the figures above. These models are an efficient way to calculate the dispersion and obtain important information such as the spatial wave decay.

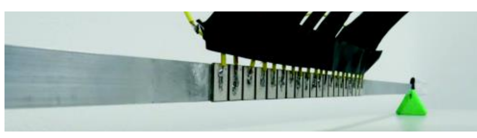
Numerical Models

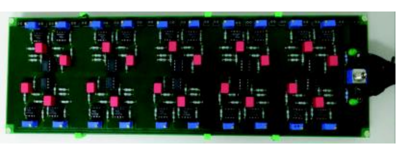




Numerical models have been developed, to study both finite samples (beam with piezoelectric elements, figure above left) and infinite samples (unit cell, figure above right). Most of the numerical calculations have been carried out in COMSOL due to the ease of implementing multi-physics coupling.

Experimental Testing





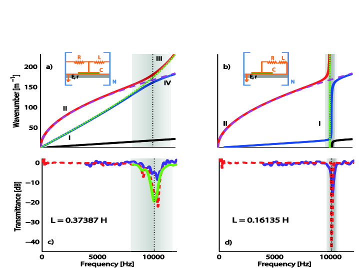
Analytical and numerical results were validated experimentally. In the figure above, we can see a beam with 20 piezoelectric elements attached to it, as well as a circuit board with the corresponding synthetic inductors. One of the difficulties in using RL shunts is the large dimensions of the electrical components, required to obtain the high inductance values, to achieve low frequency vibration damping.

3 Results and discussion

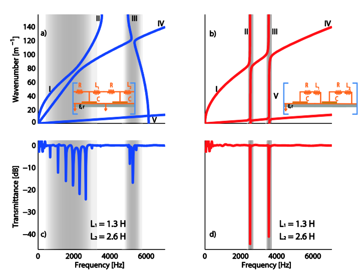
1D Wave Attenuation

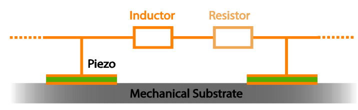
The dispersion and transmittance of a monoatomic cell of the hybrid medium (a,c), is investigated, and compared to a monoatomic cell of the locally shunted resonator (b,d). The hybrid medium gives way to eigenvalue phenomena corresponding to broad frequency attenuation, (c) while local resonators yield narrower, more pronounced attenuation regions (d). The hybrid medium was further investigated by considering a diatomic inductance cell (a,c), and comparing to a locally shunted diatomic resonator (b,d). The diatomic hybrid medium yields broader frequency attenuation over two separate regions as seen in (c).

Monoatomic



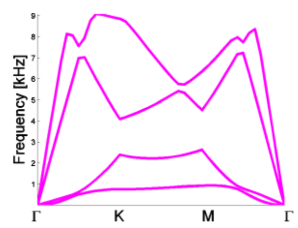
Diatomic

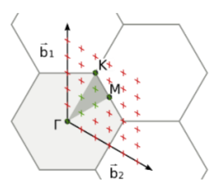




2D Wave Attenuation

The dispersion curves for the five 2D Bravais lattice configurations were studied (dispersion and irreducible Brillouin zone for the hexagonal lattice shown on the right) to investigate the existence of eigenvalue phenomena corresponding to attenuation regions. Numerical transmittance studies on finite plate samples with periodic arrangements were performed in COMSOL (figure below). The plate on the left has the shunt off, while the plate on the right has the shunt activated.





4 Project Outlook

- Miniaturize and digitalize electrical components to facilitate tuning at select frequencies, as well as ease of implementation.
- Increase technology readiness level by incorporating and testing the system on a structural or acoustic application.

5 References

Bergamini, Andrea E., et al. "Hybrid dispersive media with controllable wave propagation: A new take on smart materials." *Journal of Applied Physics* 118.15 (2015): 154310.

Partners

EMPA Materials Science & Technology

FNSNF Fonds National Suisse Schweizerischer Nationalfonds Fondo Nazionale Svizzero Swiss National Science Foundation

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