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Investigating Topological Modes in One Dimensional Acoustic and Elastic Waveguides

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Abstract

Periodic structures are known to exhibit interesting dynamic behaviour, such as band gaps. Recently, many novel applications have been found for periodic mechanical systems, the so called Phononic Crystals (PC), based on phenomena known as topological modes. One of such modes is the interface mode, which is particularly investigated in this work in the ligth of two fundamental tools: dispersion relation diagrams and the concept of geometric phase (GP).

Key words:

phononic crystals, topological modes, geometric phase.

Introduction

PCs can be built by periodically arranging unitary cells. Dispersion diagrams, like the example shown in Image 1 A, illustrate the relation between spatial (wavenumber) and time (angular velocity) frequencies. This diagrams clearly reveal band gaps at a high enough time frequency. Such gaps can only be explained by wave propagation theory, happening due to reflections caused by the impedance mismatch at the discontinuities of this systems.

Topological modes are topologically protected, meaning their existence is guaranteed under certain conditions and they are robust under local perturbations. In this work we focus on interface modes, which have been previously verified by this research group[1]. An interface mode is detected at an interference in time and space (the interface of two PCs) and can be induced by connecting two PCs with different topological phases (Zak Phase for each gap and reflection phase for each bulk band).

Results and Discussion

We made numerical simulations that try to reproduce the experiment by Xiao at al[2], and then we investigated the dispersion diagram using theoretical developments that have been proved before[3]. Zak phase has been calculated, and the symmetry of the edge states has been verified also. The edge states alone are enough to predict the occurrence of interface modes.

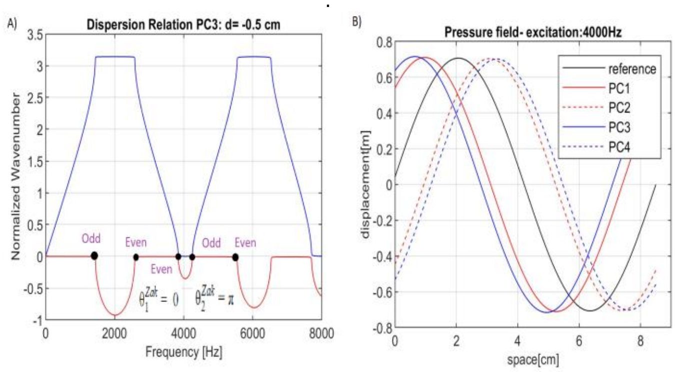

Image 1. A) Dispersion relation with the GP of first and second isolated bulk bands. Symmetries of the band-edge modes are highlighted in purple. B) Simulation used to indirectly measure reflection phases

Image 1 B shows the distribution of the acoustic pressure simulated to calculate the sign of the reflection phase. This is an alternative way to predict interface modes. The result shows that, for a frequency inside the second common band gap of 4 acoustic PCs, some exhibit topologically different gaps, meaning that an interface mode can be produced by connecting the right pair of PCs.

Simulations with rods consisting in two materials, which propagate elastic waves, have also been done. Image 3 shows the frequency response in terms of acceleration for an appropriate pair of such rods. It illustrates the interference associated with the interface mode.

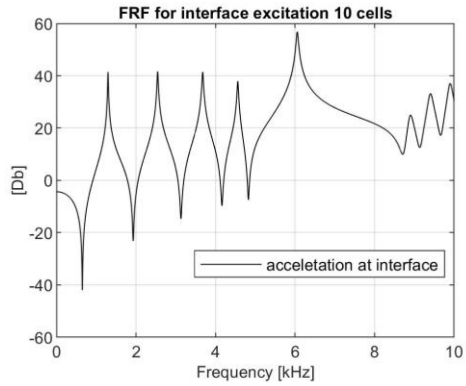

Image 3. FRF for an arrangement of elastic PCs which exhibit interface mode

Conclusions

Our numerical results agree with the work by Xiao et al.[3] Our research group is working to expand the well-known results of photonic crystals to acoustic and elastic waves. The author is currently trying to obtain results for a PC that consists in a rod with two materials, to reproduce experimental data that has already been collected.

Acknowledgement

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