Post-doc: Topological Anderson insulators with acoustic waves

Keywords: Wave propagation, metamaterials, topological insulators, disorder.

Introduction and objectives

Metamaterials is now a rich and mature field of research, with a wide range of potential applications for mechanical waves. One can think of the possibilities in waveguiding, for instance to redirect seismic energy to a target location, or in isolation for soundproofing.

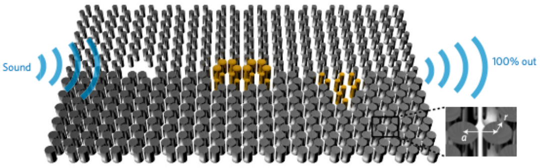

Figure 1: Illustration of topological edge waves. From [3].

These artificial materials usually rely on a given periodic structure, which gives the waves exotic propagation properties. A key question in this context is whether these properties are maintained in the presence of irregularities or defects. In the last decade, the field of topological wave insulators has emerged from analogies with electrons in metals, to realize wave guiding with strong robustness against defects [5].

Within this class of structures, a very peculiar one has been predicted called the Topological Anderson Insulator (TAI). In this type of structure, the waveguiding properties arise *because* of disorder, making it inherently robust to fabrication defects and imperfections. Although well understood in the context of electrons, it is an open question whether this peculiar behavior can be observed with mechanical waves. The aim of this project is to identify a suitable mechanical structure displaying the TAI properties.

Research problem

Certain periodic materials can have non trivial topological phases. In such phases, at frequencies inside a gap, some waves can still propagate but localized near the boundary, or an interface between two structures with different unit cell motif. These waves have the peculiar properties of being topologically protected: they cannot disappear by continuous changes of the material parameters unless the gap is closed. This protection also induces robustness against defects or small disorder, usually manifested by high transmission across them.

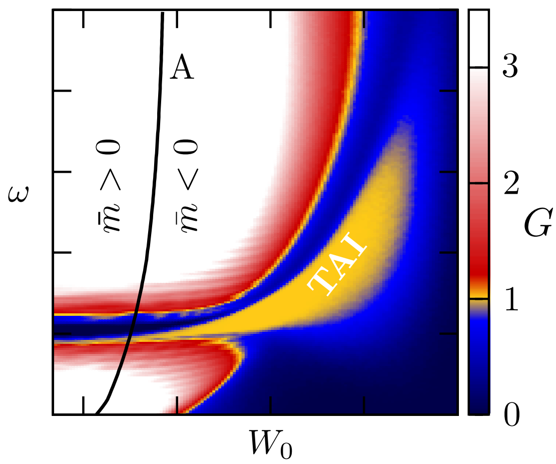

Figure 2: Value of conductance G in the plane frequency ω *versus* disorder strength W_0. In red regions, waves are propagating, in blue regions they are evanescent. The yellow region is the TAI phase. Adapted from [4].

However, at higher disorder edge waves disappear as propagation is suppressed even along the boundary. The system has been driven from a topological phase to a trivial phase by disorder. More surprisingly, the converse phenomenon is possible: a clean trivial material (no edge waves) can be turned into a topological one by adding a small amount of disorder. This peculiar phase has been referred to as a “Topological Anderson Insulator” [2].

The difficulty to observe such a phase is that disorder has two competing effects: on the one hand it can drive the system toward a topological phase through changes the effective (homogenized) medium parameters, but on the other hand propagation is inhibited due to backscattering. In electronic systems (Quantum Spin Hall effect), backscattering is strongly suppressed due to the unique properties of the electronic spin. For classical waves however, the analogy with the quantum spin Hall effect is always approximate, and hence, backscattering can be induced even by weak disorder.

Method

To overcome this difficulty in mechanical systems, the first step will be to identify topological configuration with very low backscattering in a mechanical system. The second step will be to tweak the system to a trivial phase and then add disorder to drive it into a TAI phase. Many topological configurations have been obtained for mechanical waves, however, their transport properties across defects are still poorly known.

The most promising model is obtained by connecting resonators on a honeycomb lattice, and breaking inversion symmetry by having two different resonance frequencies. We will analyze the propagation of topological waves in such a network arranged in a ribbon shape, that is, with a longitudinal size much longer than its transverse one. For this, we will use tools of scattering theory in waveguides [6] adapted to discrete systems [1]. The objective will be to optimize the base configuration to obtain the highest robustness against disorder. The next step will be the use of disorder, either in the resonator frequencies or coupling, to change the topological phase, thereby obtaining a Topological Anderson Insulator.

Practical informations

The project will be hosted by the *Laboratoire de Mécanique et d'Acoustique* (LMA) in Marseille. This project could also lead to collaborations with the *Fresnel Institute*, where similar structures are investigated in the context of electromagnetic waves.

Supervisors:

	Antonin Coutant	Cédric Bellis
Mail:	coutant@lma.cnrs-mrs.fr	bellis@lma.cnrs-mrs.fr

How to apply: Please send an email to Antonin Coutant or Cédric Bellis with a CV, list of publications and the contact information of at least one person who can recommend you, before the 15$^{\text{th}}$ of June.

Duration: 1 year.

Salary: Between 2466€ Brut (1982€ net) if less than a year experience and 2891€ Brut (2323€ net) for more than 3 years experience.

Application deadline: 15 June 2022.

References

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