THE SEARCH FOR EDGE STATES IN MECHANICAL METAMATERIALS

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EXTENDED ABSTRACT

Recent breakthroughs in condensed matter physics are opening new directions in band engineering and wave manipulation. Specifically, challenging the notions of reciprocity, time-reversal symmetry and sensitivity to defects in wave propagation may disrupt ways in which mechanical metamaterials are designed and employed, and may enable totally new functionalities. Non-reciprocity and topologically protected wave propagation will have profound implications on how stimuli and information are transmitted within materials, or how energy can be guided and steered so that its effects may be controlled or mitigated. The presentation will briefly introduce the state-of-the-art in this emerging field, and will present relevant initial investigations on mechanical lattices.

Spring mass system lattices, and plates with internal resonators will be presented as part of a framework which seeks for mechanical lattices that exhibit one-way, edge- bound, defect-immune, non-reciprocal wave motion. Helical edge waves are shown to be found within lattices that are composed of a set of disks connected through linear springs (Figure 1). Discrete one and two-dimensional spring mass lattices are investigated to show parallels with the quantum valley Hall effect and to obtain nontrivial bandgaps which support backscattering suppressed edge waves. Similar results are shown for a continuous plate with resonators which supports wave motion confined along the interface between two-media characterized by identical dispersion properties, yet different topological invariants.

This concept was recently implemented in the form of a continuous hexagonal elastic lattice cut-out of an acrylic plate (see Figure 2.a). The existence of interface modes was explored by adding masses at the nodes, to mimic the configuration of an hexagonal lattice consisting of springs and masses.
The behavior of this system was tested experimentally through a scanning Laser vibrometer, which measures the full-field transient response induced by a piezo exciter. The lattice is cut out of an acrylic square plate of size 12'' by 12'' and thickness of 1/16''. The hexagonal holes have a side of 0.3482'' and are separated 1/8'' from one another. The added masses consist of nickel-plated neodymium cylindrical magnets of .06'' of height and diameter of 1/8''. A linear and Z-shaped interface is introduced lattice by joining two lattices with opposite mass ratios (Figure 2.b). The resulting interface mode is verified by exciting the lattice at frequencies within the corresponding range. The response of the lattice as recorded experimentally is shown in Figure 3.c, where waveguiding along the designated path is demonstrated.

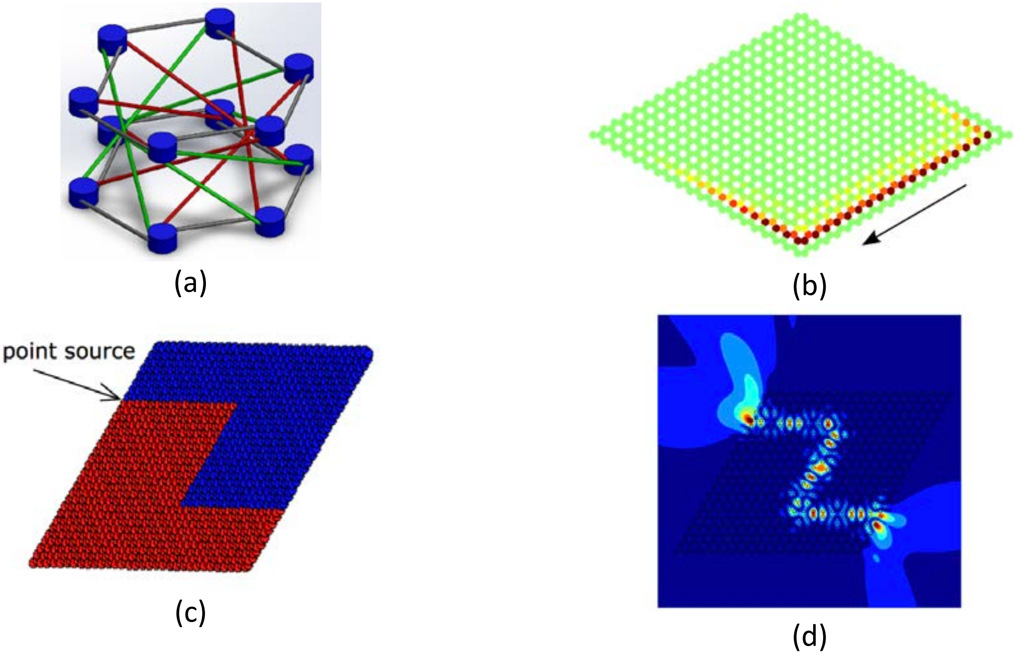

Figure 1: Unit cell of a bilayer hexagonal lattice (a) featuring helical edge states shown in (b). Plate domain with an interface (c) and traveling edge mode (d).

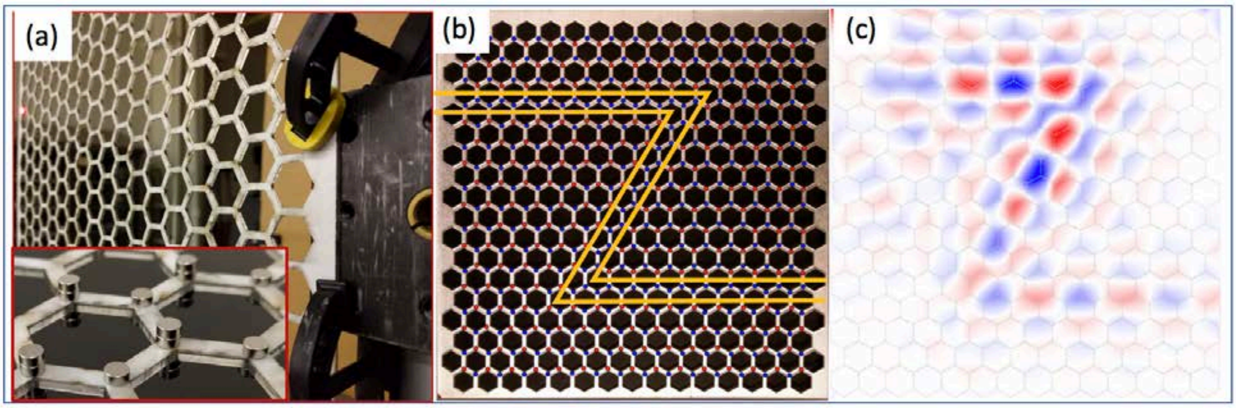

Figure 2: Continuous hexagonal elastic lattice implementing an analog of the quantum Valley Hall Effect (a), experimentally measured wave propagation along a 'Z-shaped interface (b,c).

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