Strain-induced tunability of topological properties in phononic crystals

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Abstract

The investigation of phononic crystals and their topological properties has opened fascinating avenues for manipulating wave propagation in materials. However, most of the considered systems in the literature are based on static designs, with no possibility of modulating response or of adapting to varying external conditions. In this study, we investigate the possibility of introducing dynamic control of topological properties in phononic crystals by means of varying strain fields. We consider two examples of this concept.
In the first case, we investigate the mechanical modulation of topological modes in a one-dimensional Su–Schrieffer–Heeger (SSH) chain with a central defect, in which an edge mode emerges due to topological protection. By introducing lateral compression, we exploit the stress state of the chain under buckling to tune the edge mode frequency and modify the protected state(s). This setup can be viewed as analogous to a quantum system, where an external field couples to the degrees of freedom of the system, realized here mechanically as strain-induced coupling between the masses in the chain.
The second example extends the approach to a 2D system, i.e. an auxetic mass-spring lattice consisting of hinged masses connected by multiple springs, focusing on its dynamic elastic properties and topological wave aspects as a function of the overall stress state of the lattice. Here, we establish an analytical formulation of the linearized incremental problem, enabling the construction of band diagrams for variable geometric parameters and external load, and highlighting the occurrence of Dirac cones and band gap opening by removing symmetry. The predictions are compared to FEM simulations of the corresponding continuous model consisting in a thin slab with oriented cuts, revealing a relation between auxeticity and topologically protected modes which can be potentially exploited for tunable waveguide applications.

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