NON-HERMITIAN DEGENERACIES AND PT SYMMETRIC SCATTERING IN ELASTIC METAMATERIALS

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Abstract

Mechanical metamaterials and phononic crystals, composed of periodic cellular unit cells, have attracted significant interest for their ability to exhibit unique behaviors, such as stop bands, negative effective parameters, and wave manipulation capabilities. The standard first step in the design and analysis of such systems is to perform eigen-frequency calculations based on Bloch-Floquet periodicity. This approach allows for the prediction of the material's response under various conditions by leveraging the periodic nature of the unit cells.

In this work, we explore the band structure and scattering of in-plane stress waves in these microstructured systems. Of particular interest is the emergence of exceptional points (EPs)-non-Hermitian degeneracies in the eigen-parameter space where the system operator becomes deficient. Remarkably, these EPs can appear in elastic (lossless) media when parameterized with real-valued frequencies and tangential wave vectors. These EP pairs are not confined to the original stop bands but can also emerge in all-mode pass bands, giving rise to new stop bands and scattering phenomena. When mechanical gain is theoretically introduced to balance loss in a parity-time symmetric structure, EP pairs also emerge in the scattering matrix spectrum. These pairs lead to striking effects such as amplification of transmission above unity and single-sided reflectivity, both indicating broken phase symmetry.

We show the appearance of such EPs in various cellular and layered metamaterials and analyze the scattering phenomena occurring near and at these points. The observed PT-symmetry broken phases and unidirectional reflectivity have significant implications for the design and application of metamaterials such as sensing devices. This study presents an efficient modeling approach, highlighting the importance of modal chirality and symmetry in the loss/gain-embedded mechanical metamaterials.

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