Three-dimensional Resonant Elastic Metamaterials

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We present the design and experimental realization of a three-dimensional anisotropic elastic metamaterial, which can generate dipolar and rotational resonances that are separately tunable. Due to the anisotropy, each resonant type are not degenerate along different spatial directions. Repeating the subwavelength unit cells in different orientations can lead to two distinct types of one-dimensional arrays. These arrays are essentially elastic rods, which are three-dimensional objects that can withstand longitudinal, flexural and torsional vibrations. Eigenmodes and band structure analyses show the systems can have distinctive responses to each type of polarized excitations. Indefinite dynamic mass and negative moment of inertia of the unit cell are responsible for these exotic effects. In particular, we demonstrate that only longitudinal wave can propagate within a finite frequency regime, whereas transverse waves meet a bandgap – a property conventionally found only in fluids. Experiments show good agreement with theoretical predictions and simulations. Our findings can see applications in many scenarios such as civil engineering and seismic wave control.