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Abstract. We present theoretically and experimentally a prototype of gyroscopic metamaterial composed by chain or planar network of gyroscopes, which permits circular polarization and dynamic tunability when manipulating mechanical waves. One-dimensional gyroscopic chain, and two-dimensional networks with both angular and rectangular cells have been investigated. Three types of pass bands have been found by tuning the gyroscope angular momentum: higher and lower frequency parts transmits different circular polarized waves with opposite directions, and the middle part transmit both. Pass bands of scalable frequency ranges for forward circular polarized and backward circular polarized waves can be designed by such dynamic tunability. We classified the gyroscopic metamaterials into two types: free type and constrained type. It is found the two types show opposite circular polarization direction. The rotation effect to the linearly polarized mechanical waves has also been found in the band transmitting both forward and backward circular polarized waves, similar to the Faraday rotation effect of magneto-optical materials to the linearly polarized light.

Introduction

Photonic and phononic crystals or metamaterials offer the possibility of controlling and manipulating electromagnetic or acoustic waves by opening a gap with a given range of frequencies [1]. Chiral metamaterials, such as spirals and helices resulted in optical activity in which the differential polarization response of the material depends on whether the incident wave is left- or right-circularly polarized [2, 3]. In this study, the circular polarization and optical rotation effect are amazingly found for our gyroscopic metamaterials. The one-dimensional results, such as circular polarization and optical rotation effect have been demonstrated in Figure 1.

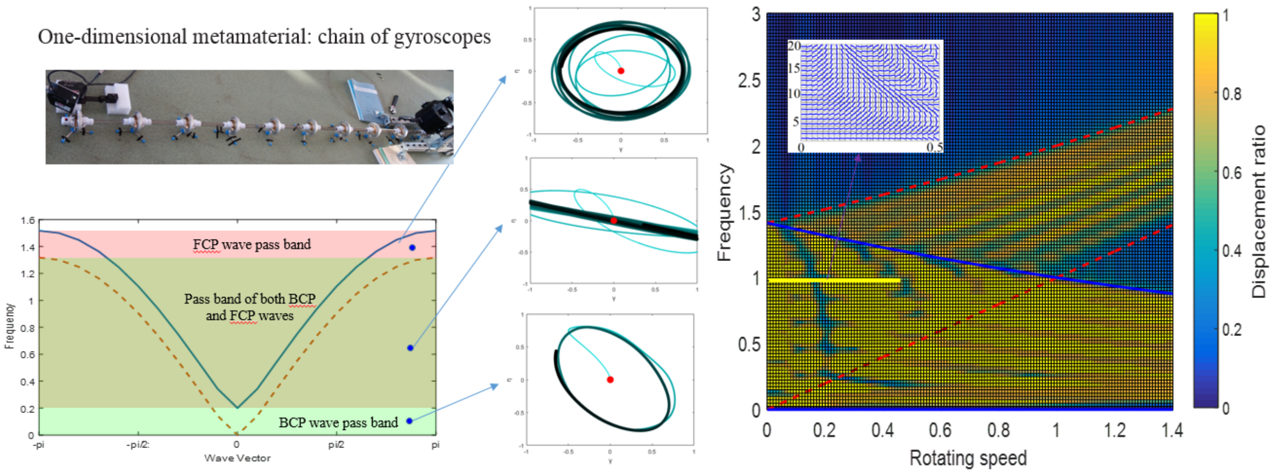

Figure 1: The experiment setup, band gaps and numerical simulations of one-dimensional gyroscopic metamaterial.

Results and discussion

The chiral band structures of both one-dimensional and two-dimensional gyroscopic metamaterials are studied. For gyroscopic metamaterials with triangular cell behave as circular polarizer by transformation mechanism, and gyroscopic metamaterials with rectangular cell present circular polarizer by wave filtering mechanism. All gyroscopic metamaterials show both acoustic and optic dispersions. For the free type, the lower acoustic dispersion gives rise to backward circular polarized waves and the higher optic dispersion transmits forward circular polarized waves. While the two dispersions of the constrained type just show the opposite circular polarized directions. Partial pass band, complete pass band, stop band can be tunned by the rotating velocity of the gyroscopes.

References

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[3] [3] Muraoka, T., Kinbara, K. & Aida, T. (2006) Nature, 440: 512-515