

3 April 2018 Non-reciprocal acoustic transmission through a dissipative phononic crystal with asymmetric scatterers (Conference Presentation)

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Abstract

The existing concepts of non-reciprocity in propagation of acoustic or elastic waves are based either on nonlinear effects, or on local circulation of linear elastic fluid that leads to red or blue Doppler shift, depending on the direction of sound wave. The same concepts exist for electromagnetic non-reciprocity, where external magnetic field may produce the effect similar to local rotation of the medium. These two concepts originate from two known methods of breaking a time-reversal symmetry (T-symmetry), that is necessary for observation of nonreciprocal wave propagation. Both concepts require additional electrical or mechanical devices to be installed with their own power sources. Here we propose to explore viscosity of fluid as a natural factor of the T-symmetry breaking through energy dissipation. We report experimental observation of the nonreciprocal transmission of ultrasound through a water-submerged phononic crystals consisting of several layers of aluminum rods arranged in a square lattice. While viscous losses break the T-symmetry, making the wave propagation thermodynamically irreversible, the transmission remains reciprocal if the scatterers are symmetrical. To generate different energy losses for opposite directions of propagation, the P-symmetry of the crystal is broken by using asymmetric scatterers. Due to asymmetry, two sound waves propagating in the opposite directions produce different distributions of velocity and pressure that leads to different local absorption. Dissipation of acoustic energy occurs mostly near the surface of the scatterers and it strongly depends on surface roughnesses. Using two phononic crystal with smooth and rough aluminum rods we demonstrate low (2-5 dB) and high (10-15 dB) level of non-reciprocity within a wide range of frequencies, 300-600 kHz. Experimental results are in agreement with numerical simulations based on the Navier-Stokes equation. This nonreciprocal linear device is very cheap, robust and does not require energy source.