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Editorial

An Overview Non Reciprocity and Reversibility

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EDITORIAL

Non-reciprocity—asymmetric transmission of energy between any two points in space—is receiving increasing interest in many areas of physics, including optics electromagnetism, elasticity and acoustic. Focusing on elastic systems, non-reciprocity has been successfully exploited to realize selective signal transmission logic elements direction-dependent insulators and switches. To achieve such remarkable behaviors, both active and passive strategies have been proposed. On the one hand, non-reciprocity for linear waves has been obtained either by imparting a rotation to the medium or by introducing activated materials with time-modulated properties in space and time to break time-reversal symmetry.

On the other hand, non-reciprocity has also been demonstrated in passive media by harnessing nonlinear phenomena. In particular, mechanical metamaterials with two or more stable equilibrium states have recently emerged as a powerful platform to realize non-reciprocity, as they support only unidirectional transition wave propagation when comprising an array of bistable building blocks with asymmetric energy wells. However, although this strategy is appealing for its simplicity and robustness, it typically leads to nonreversible wave propagation since these systems release a net amount of energy upon propagation of the pulses and needs to be manually "recharged" (i.e., all elements need to be reset to their higher energy well) to sustain a second wave.

Here, we demonstrate the realization of a multistable mechanical metamaterial for which non-reciprocity and reversibility can be independently programmed. Such control of the dynamic response is made possible by the rich and highly tunable behavior of shallow arches, as their energy landscape can be easily adjusted to exhibit target energy barriers as well as symmetric or asymmetric wells. We first show that chains comprising identical arches with symmetric energy wells support the propagation of nonlinear pulses that sequentially switch the elements to their inverted stable configuration. However, although such signal propagation is reciprocal and reversible, it is not stable as the wave evolves during propagation.

Then, we demonstrate that by carefully designing the arches and their arrangement to break symmetry either at the structural or element level, we can enable not only stable propagation of the signal but also a wide range of nonreciprocal behaviors. For example, a reversible diode can be created by connecting shallow arches with symmetric but graded on-site energy potentials (Further, a tunable nonreciprocal chain, which enables propagation of different transition waves in opposite directions, can be obtained by alternating shallow arches with symmetric and asymmetric energy potentials. As such, our work opens avenues for the design of the next generation of nonlinear structures and devices with robust, nonreciprocal elastic wave-steering capabilities.

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