PHYSICAL MATH SEMINAR

Dynamics of multistable mechanical metamaterials: recent results on nonlinear waves, transition fronts and their interactions

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ABSTRACT:

The class of flexible mechanical metamaterials, which encompasses architected materials composed of highly compliant parts connecting much stiffer and heavier parts, has recently been systematically explored thanks to emerging techniques for their realization and accurate lumped-parameter models describing their dynamics. Examples of such metamaterials include kirigami, origami, elastic lattices with various topologies composed of rotating mass units connected by thin, flexible hinges, or systems of coupled buckled beams… These metamaterials can undergo large deformations and are known to support a wide variety of nonlinear waves, such as vector solitons, breathers, cnoidal waves, among others. Interestingly, by designing these materials with multistable inclusions, such as elastically coupled bistable mechanical units, we can observe phenomena such as transition waves. The transition wave presents itself as a progressive front travelling through the material as the multistable units sequentially switch from one equilibrium state to another, eventually leading to a partial or full reconfiguration of the structure.

In this talk, I will highlight the fundamentals and a selection of recent results on nonlinear waves in flexible mechanical metamaterials and in particular transition waves in multistable metamaterials. Through theoretical, numerical and experimental examples, I will discuss some salient properties of these nonlinear waves and their interactions. While in the case of zero damping we find the wave dynamics generally obey the nonlinear Klein-Gordon equations, the presence of a significant nonzero damping heavily influences the multistable response and permits transition fronts that result from nonlinear reaction-diffusion equations. This class of flexible metamaterials thus gives rise to the emergence of specific properties not necessarily found in other waves supported by discrete and/or nonlinear media, and which can be rationally harnessed, e.g., strong non-reciprocity, robustness of the wave profile, extreme amplitude-dependent behavior… These metamaterials and their dynamics can therefore be designed and implemented for applications involving the local or global reconfiguration of a medium, the manipulation of a mechanical memory, the control of waves in space and time, mechanical computing and more generally to be the vector for embedded material intelligence.

TUESDAY, MARCH 4, 2025

2:30 PM – 3:30 PM

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