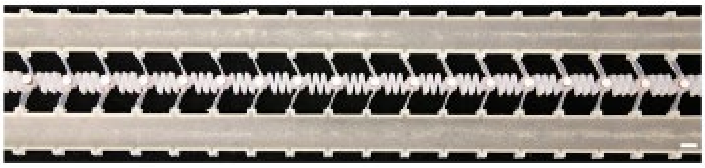
Nonlinear waves in reconfigurable structures

Waves, mechanics, instabilities

Internship offer with a possible PhD funding



Architected structures composed of bistable elements can propagate solitons [1,2,3] (picture taken from [3]). Can we design the structure at the scale of the unit cell to support other nonlinear waves ? Can we use these waves to reconfigure

Context. Recent advances in additive manufacturing have enabled the rapid development of flexible mechanical metamaterials. Exotic properties, programmed on the scale of the unit cell, have been demonstrated in the linear regime, opening up potential applications in the fields of waveguides, energy absorbers and insulators. The exploration of nonlinear regimes have also begun, with a particular interest for structures composed of bistable unit cells [1]. A strong impact on such a system provokes the switching of the first cell via a snap-through instability, which triggers its neighbour and so on, such that this transition wave reconfigures the whole structure [2,3]. These new works open many doors with fundamental and applicative perspectives. But, to this day, the detailed behaviour of the bistable unit cell is often overlooked and mostly solitons, a small portion of possible nonlinear waves, have been experimentally studied.

Objectives. The objective of this internship is to design architected structures capable of global or local reconfiguration. To this end, we will use strongly nonlinear waves propagating in carefully designed structures constituted of bistable buckled beams. The goal is to tailor the nonlinearities of the unit cell to allow the propagation of target nonlinear waves, with a particular interest for large amplitude (cnoids), and modulated (breathers [4]) waves which will act on the structure to trigger local or global reconfigurations. In this context, the dynamical behaviour of the unit cell is crucial. An important part of the work will be devoted to the study of dynamical mechanical instabilities, with a particular interest for snap-through [5], to find new means of controlling the instability. The approach will mix experimental and theoretical work.

Profile. We are looking for a student enrolled in a master's degree in physics, mechanics, acoustics or related fields, with a taste for nonlinear physics, mechanics and wave physics, and motivated by experimental research in fundamental physics. They will develop skills in both modelling and experimentation.

Environment. This internship may lead to a PhD, with funding already secured through the doctoral school. The student will conduct their research at the Laboratory of Acoustics of Le Mans University (LAUM), which specialises in acoustics and wave physics. They will join the Elastic Waves in Complex Media team, focusing on the propagation of elastic waves in systems with atypical behavior (such as soft metamaterials, granular media, unstable, or multi-stable systems). Depending on the student's motivation, international mobility with a partner team at Harvard University could be arranged.

Duration and starting date: 5 to 6 months from February 2025.
Location: Laboratory of Acoustics of Le Mans University (LAUM), Le Mans, France
Contacts. For questions or to submit your application::

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References.

[1] B. Deng; J. R. Raney; K. Bertoldi; V. Tournat, Nonlinear waves in flexible mechanical metamaterials. Journal of Applied Physics, 130(4) (2021)
[2] L. Jin, R. Khajehtourian, J. Mueller, A. Rafsanjani, V. Tournat, K. Bertoldi, D. M. Kochmann, Guided transition waves in multistable mechanical metamaterials, Proc. Natl. Acad. Sci. 201913228 (2020).)
[3] J. Raney, et al. Stable propagation of mechanical signals in soft media using stored elastic energy. PNAS, 113(35):9722–9727, (2016)
[4] A. Demiquel, V. Achilleos, G. Theocharis, V. Tournat, Modulation instability in nonlinear flexible mechanical metamaterials. Physical Review E, 107(5), 054212 (2023).
[5] M. Gomez, D. Moulton, D. Vella. Critical slowing down in purely elastic 'snap-through'instabilities. Nature Physics, 13(2):142–145, 2017.