MECHANICAL METAMATERIALS

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The Mechanical Metamaterials group designs, creates and studies flexible mechanical metamaterials. We use a condensed-matter perspective, using concepts from spin-ices, frustration and glasses, holography and topology, to venture into unexplored design spaces of geometrically complex, rationally designed materials. In particular we are spearheading the evolution of mechanical metamaterials towards 'machine materials' with unprecedented properties that far exceed those of ordinary materials, including programmability, shape-morphing, and information processing. Our research, carried out both at AMOLF and at Leiden University, combines experimental, theoretical, and numerical approaches.

Highlights

- We designed and created the first metamaterial that autonomously executes self-folding via a mechanical pathway with embedded error correction [1].
- We uncovered a characteristic length scale in mechanical metamaterials and showed how to manipulate and leverage it for enhanced functionalities [2].
- We developed a combinatorial design method for pluripotent origami metamaterials [3].
- We realized non-trivial sequential pathways, memory effects and elementary counting in experiments on frustrated sheets [5]

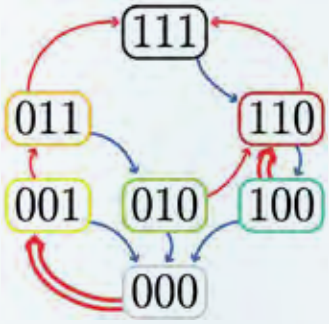
Plans

Our current work, partly supported by an ERC-Advanced grant, investigates the emergent information processing capabilities of frustrated media, and develops metamaterials for targeted computations. A key concept are interacting material bits called hysterons, which generically occur in materials with local bistable elements. Driving such a material – such as a frustrated crumple or a carefully designed metamaterial – leads to complex deformation pathways. These encode finite state machines, the paradigm of sequential computing. We are now developing design, training and learning strategies to firmly establish a new class of matter which we term *finite state materials*.

Key research items

1. C. Coulais, A. Sabbadini, F. Vink and M. van Hecke, *Multi-step self-guided pathways for shape-changing metamaterials*, Nature 561, 512 (2018)
2. C. Coulais, C. Kettenis and M. van Hecke, *A characteristic length scale causes anomalous size effects and boundary programmability in mechanical metamaterials*, Nat. Phys. 14, 40 (2018)
3. P. Dieleman N. Vasmel S. Waitukaitis and M. van Hecke, *Jigsaw puzzle design of pluripotent origami*, Nat. Phys. 16, 63 (2020)
4. A. Meeussen, *Imperfections: using defects to program designer matter*, PhD thesis (2021). In 2020, Anne was awarded the Young Speaker Award at the annual 'FYSICA' meeting; in 2021, Anne received her PhD cum laude, and her thesis received the 2021 Ehrenfest-Afanassjewa award of the Dutch Physics Council.
5. H. Bense and M. van Hecke, *Complex pathways and memory in compressed corrugated sheets*, PNAS 118, 1 (2021)

The complex pathways of a 'crumpled metasheet' (inset) encode elementary computations.



The rubber computer