HYPERSMART MATTER

→ Marc Serra Garcia (started in 2021)

We aim at using mechanical degrees of freedom to store and process information, with the goal of building zero or ultra-low power processors, embodying intelligence in robotic structures and understanding the ultimate energy limits of computation. We pursue this goal through a combination of experimental and theoretical efforts. On the experimental front, we invent algorithms to simulate and design large-scale nonlinear and stochastic elastic systems, while on the experimental front we fabricate elastic structures, with scales ranging from centimeters to nanometers, with precisely controlled nonlinearity and dissipation. ques from statistical mechanics to describe cellular force generation.

Highlights

- We demonstrated that elastic systems could perform machine learning tasks such as distinguishing between pairs of words; all while consuming zero power.
- We developed a methodology to design information-processing mechanical systems by combining a large number of elementary nonlinear interactions on a first step followed by a second step that consists of mapping them to geometric features of the structure.
- We demonstrated a variety of topological wave phenomena in mechanical systems by applying our design method to topological models.

Plans

In the coming years, we aim to take advantage of the ultralow dissipation and high nonlinearity of mechanical systems to answer both fundamental and applied questions. On the fundamental side, we aim to demonstrate mechanical logic gates that operate near the ultimate thermodynamic limits of computing. On the applied side, we aim to build zero-power sparse event detection systems that use mechanical neural networks to recognize events while consuming zero standby power – enabling novel battery-less edge computing systems. We will demonstrate this by building a passive voice activated switch.

Key research items

1. T. Dubček, D. Moreno-Garcia, T. Haag, H.R. Thomsen, T.S. Becker, C. Bärlocher, F. Andersson, S.D. Huber, D.-J. van Manen, L. Guillermo Villanueva, J.O.A. Robertsson and M. Serra-Garcia, *Binary classification of spoken words with passive elastic metastructures,* arXiv:2111.08503 (2021) *

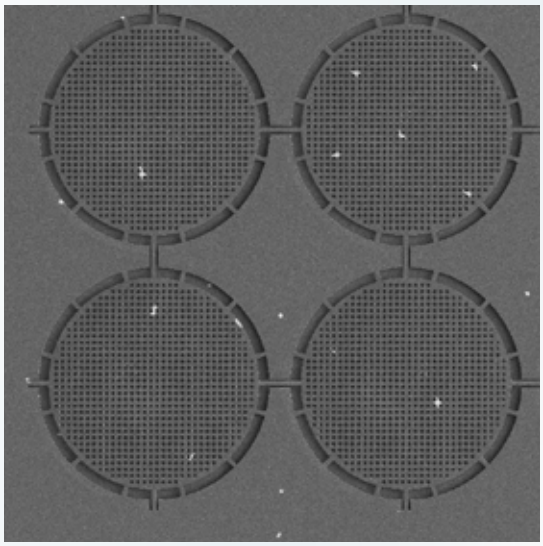
2. M. Serra-Garcia, *Turing complete mechanical processor via automated nonlinear system design*, Phys. Rev, E. 100, 042202 (2019) *

3. M. Serra-Garcia, V. Peri, R. Süsstrunk, O.R. Bilal, T. Larsen, L. Guillermo Villanueva and S.D. Huber, *Observation of a phononic quadrupole topological insulator*, Nature 555, 342-345 (2018). *

4. K.H. Matlack, M. Serra-Garcia, A. Palermo, S.D. Huber and C. Daraio, *Designing perturbative metamaterials from discrete models*, Nat. Mater. 17, 323-328 (2018) *

5. J. Robertsson, M. Serra-Garcia, T. Dubček and D.-J. van Manen, *Zero-power operable classification device and switching device and voice-operated powerless wake-up switch*, European Patent Application EP4181163A1 (2021) *

*Work from before joining AMOLF



Fragment of a mechanical neural network for zero-power speech processing.