Curriculum Vitae – Bolei Deng

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Education and Training

1/2022-Present	Massachusetts Institute of Technology, Cambridge, MA **Postdoctoral Fellow**, Computer Science and Artificial Intelligence Laboratory **Postdoctoral Fellow**, School of Engineering Advisors: Prof. Wojciech Matusik and Prof. Xuanhe Zhao
2021-2022	Harvard University, Cambridge, MA **Postdoctoral Fellow**, School of Engineering and Applied Science Advisor: Prof. Katia Bertoldi
2016-2021	Harvard University, Cambridge, MA **Ph. D.**, Materials Science & Mechanical Engineering **Secondary Field** in Computational Science and Engineering Advisor: Prof. Katia Bertoldi
2012-2016	Zhejiang University, Hangzhou, China **B. S.**, Engineering Mechanics

Research Keywords

Metamaterials, Nonlinear waves, Micro-structures, Phase transitions, Soft robotics, Multi-stable structures, Instability, Machine learning

Publications

Peer-Reviewed Journal Publications (ORCID ID: 0000-0003-2589-2837; † equal contribution)

1. **Bolei Deng**†, Mohamed Zanaty†, Antonio E. Forte, Katia Bertoldi. "Topological solitons makes metamaterials crawl" ***Phys. Rev. Appl.***, 17, 014004 (2022).
2. S Li†, **Bolei Deng**†, et al. "Liquid-induced topological transformations of cellular microstructures" ***Nature***, 592, 386-391 (2021).
3. **Bolei Deng**, Jordan R. Raney, Katia Bertoldi, Vincent Tournat. "Nonlinear waves in flexible mechanical metamaterials" ***J. Appl. Phys.***, 130, 040901 (2021).
4. **Bolei Deng**†, S Yu†, AE Forte, V Tournat, K Bertoldi. "Characterization, stability, and application of domain walls in flexible mechanical metamaterials" ***PNAS***, 117, 31002-31009 (2020).
5. **Bolei Deng**, L Chen, D Wei, V Tournat, K Bertoldi. "Pulse-driven robot: Motion via solitary waves" ***Science Advances***, 6(18), eaaz1166 (2020).
6. **Bolei Deng**, J Li, V Tournat, PK Purohit, K Bertoldi. "Dynamics of mechanical metamaterials: A framework to connect phonons, nonlinear periodic waves and solitons" ***J. Mech. Phys. Solids***, 147, 104233 (2020).
7. **Bolei Deng**, P Wang, V Tournat, K Bertoldi. "Nonlinear transition waves in free-standing bistable chains" ***J. Mech. Phys. Solids***, 136, 103661 (2020).
8. **Bolei Deng**, V Tournat, P Wang, K Bertoldi. "Anomalous collisions of elastic vector solitons in mechanical metamaterials" ***Phys. Rev. Lett.***, 122, 044101 (2019).
9. **Bolei Deng**, C Mo, V Tournat, K Bertoldi, JR Raney. "Focusing and mode separation of elastic vector solitons in a 2D soft mechanical metamaterial" ***Phys. Rev. Lett.***, 123, 024101 (2019).
10. **Bolei Deng**, Y Zhang, Q He, V Tournat, P Wang, K Bertoldi. "Nonlinear transition waves in free-standing bistable chains" ***New J. Phys.***, 21, 073008 (2019).

11. **Bolei Deng**, P Wang, Q He, V Tournat, K Bertoldi. "Metamaterials with amplitude gap for elastic solitons" ***Nature Communications***, 9, 1-8 (2018).
12. **Bolei Deng**, V Tournat, K Bertoldi. "Effect of predeformation on the propagation of vector solitons in flexible mechanical metamaterials" ***Phys. Rev. E***, 98, 053001 (2018).
13. **Bolei Deng**, JR Raney, V Tournat, K Bertoldi. "Elastic vector solitons in soft architected materials" ***Phys. Rev. Lett.***, 118, 204102 (2017).
14. **Bolei Deng**, H Li, H Tzou. "Optimal positions for multiple flexoelectric actuations on beams" ***ASME IMECE,*** 57564 (2015).
15. **Bolei Deng**, H Li, H Tzou. "Flexoelectric actuation and vibration control of ring shells" ***ASME IDETC/CIE,*** 47994 (2015).
16. N Vasios, **Bolei Deng**, B Gorissen, K Bertoldi. "Universally bistable shells with nonzero Gaussian curvature for two-way transition waves" ***Nature Communications***, 12, 1-9 (2021).
17. A Zareei, **Bolei Deng**, K Bertoldi. "Harnessing transition waves to realize deployable structures" ***PNAS***, 117, 4015-4020 (2020).
18. J Li†, AE Forte†, Bolei Deng, A Rafsanjani, K Bertoldi. "Kirigami-Inspired Inflatables with Programmable Shapes" ***Advanced Materials***, 32, 2001863 (2020).
19. A Rafsanjani†, J Li†, **Bolei Deng**, K Bertoldi. "Propagation of pop ups in kirigami shells" ***PNAS***, 116, 8200-8205 (2019).
20. X Guo, VE Gusev, V Tournat, **Bolei Deng**, K Bertoldi. "Frequency-doubling effect in acoustic refection by a nonlinear, architected rotating-square metasurface" ***Phys. Rev. E***, 99, 052209 (2019).
21. M Fan, **Bolei Deng**, H Tzou. "Multiflexoelectric actuation and control of beams" ***AIAA Journal***, 57, 5503-5513 (2019).
22. M Fan, **Bolei Deng**, H Tzou. "Dynamic flexoelectric actuation and vibration control of beams" ***J. Vib. Acoust.***, 140(4) (2018).
23. H Tzou, **Bolei Deng**, H Li. "Flexoelectric actuation and vibration control of ring shells" ***J. Vib. Acoust.***, 139(3) (2017).

Proposal Writing Experience

1. "Collaborative Research: Programming Non-linear Waves in Compliant Mechanical Metamaterials", 2020
   Major contributor: Bolei Deng. PIs: Katia Bertoldi, Harvard University; Jordan R. Raney, University of Pennsylvania; Vincent Tournat, CNRS, France.
   Funding Agency: ***NSF***
   Status: Funded.
2. "Actively Reconfigurable and Asymmetrical Topological Mechanical Metamaterials", 2019
   Major contributor: Bolei Deng on section "Active nonlinear metamaterials with controlled topological domain walls". PI: Michael J. Leamy, Georgia Institute of Technology.
   Funding Agency: ***MURI***, Active Topological Mechanical Metamaterials.
   Status: Not funded.

Mentoring and Teaching Experience

- *Research Mentor*, Harvard, 2016 - present
  Mentored exchange students on designing research projects, experimental/numerical skills, interpreting results and doing presentations. Including:
  - Qi Jiang, 2020, Tsinghua University, China (current Ph.D. student at Princeton University).
  - Clement Despres, Le Mans University, France.
  - Jian Li, 2019-2020, Zhejiang University, China.
  - Siqin Yu, 2019, Tsinghua University, China (current Ph.D. student at Stanford University).
  - Liyuan Chen, 2018-2019, Zhejiang University, China (current Ph.D. student at Harvard University).
  - Yuning Zhang, 2018, Peking University, China (current Ph.D. student at University of Michigan).

- Qi He, 2017-2018, Tsinghua University, China (current Ph.D. student at MIT).
- Zhihang Qin, 2017-2018, Tongji University, China (current Ph.D. student at National University of Singapore).
- Lei Kan, 2016, Tsinghua University, China.

- *Teaching Assistant*, Harvard University, Spring 2018.
  "Introduction to the mechanics of materials" (ES120, Instructor: Prof. Joost Vlassak).
- *SEAS Research Open House*, Harvard University, November 2020.
  Advertising Bertoldi Group to undergraduate students.

Selected Presentations

1. "Inverse design of mechanical metamaterials with target nonlinear responses", HDR Faculty Seminars, Online, 2021.
2. "Liquid-induced topological transformations of cellular microstructures", MRSEC IRG 1 Meeting, Boston, 2021.
3. "Liquid-induced topological transformations of cellular microstructures", SIAM, Online, 2021.
4. "Liquid-induced topological transformations of cellular microstructures", APS March Meeting, Online, 2021.
5. "Liquid-induced topological transformations of cellular microstructures", Physical Science Seminar Series, Harvard University, Boston, MA, 2020.
6. "Programmed topological transformations of cellular microstructures through liquid-induced transient softening and assembly", EASF Forum, Online, 2020.
7. "Pulse-driven robot: Motion via solitary waves", MRS Fall, Boston, MA, 2019.
8. "Pulse-driven robot: Motion via solitary waves", IMECE, Salt Lake City, UT, 2019.
9. "Focusing and mode separation of elastic vector solitons in a 2D soft mechanical metamaterial", SES, St. Louis, MO, 2019.
10. "Anomalous collisions of elastic vector solitons in mechanical metamaterials", APS March Meeting, Boston, MA, 2019.
11. "Metamaterials with amplitude gap for elastic solitons", ESMC, Bologna, Italy, 2018.
12. "Nonlinear waves in LEGOs structures", IMECE, Tampa, FL, 2017.
13. "Elastic vector solitons in soft architected materials", Phononics, Changsha, China, 2017.
14. "Flexoelectric actuation and vibration control of ring shells", IDETC/CIE, Boston, MA, 2015.

Selected Posters

1. "Harnessing topological vector solitons for locomotion", APS March Meeting, Online, 2021
2. "Characterization, stability, and application of domain walls in flexible mechanical metamaterials", APS March Meeting, Online, 2021

Academic Service

Reviewer for Scientific Journals (reviewed **30+** articles): Physical Review Letters, Physical Review Applied, Physical Review X, Physical Review B, Physical Review E, Extreme Mechanics Letters, New Journal of Physics.

Research Summary

Phase Transitions in Mechanical Metamaterials

- **Liquid-induced topological transformation of microstructures.** I designed a two-tiered dynamic strategy to achieve reversible transformations of the microstructures topologies that can be applied to a wide range of material compositions and geometries. Our approach only requires exposing the structure to a droplet of liquid that first infiltrates and softens the material at the molecular scale, and then, upon evaporation, forms a network of localized capillary forces at the architectural scale that zip the edges of the softened lattice into a new topological structure, which subsequently re-stiffens.

- **Liquid-loaded transition waves in microstructures.** I proposed a bistable microstructure that can support the propagation of transition waves at micro-scale. The geometry of the microstructure is carefully designed such that upon swelling each unit is loaded into the stable state with higher energy. Upon triggering, the units sequentially jump from the higher energy state to the lower one, providing a powerful platform to deliver mechanical signals. Together with mechanical logic gate designs, such cellular structures can be used to build micro-scale mechanical computers.
- **Domain walls in mechanical metamaterials.** I experimentally, numerically, and analytically studied the emergence of domain walls upon uniaxial compression in a mechanical metamaterial. My study unveils how domain walls link local defects to global responses of the system and unlock additional functionalities, including information encryption, stiffness tuning, and wave guiding.

Elastic Vector Solitons in Mechanical Metamaterials

For the first time in mechanical systems, I observed the propagation of vector solitons based on rotating-square systems, where the rotational and translational components couple together and propagate at the same velocity. The vectorial nature of such solitons gives rise to a zoo of exotic mechanical phenomena:

- **Amplitude gaps**. I discovered that vector solitons of certain amplitudes become dispersive and fail to propagate. Such amplitude range is defined as "amplitude gap" of solitons as an analog to frequency bandgap of linear waves. I developed a mathematical model that is able to predict amplitude gaps analytically. The theoretical completeness allowed me to design functional devices such as soliton splitter and diode that can effectively manipulate the propagation of solitons.
- **Anomalous collisions.** Solitons normally cross each other as if they never met (except for a phase shift). While depending on their amplitudes, vector solitons either go through, reflect or even scatter each other upon collision. I systematically studied such anomalous collisions and proposed methods to detect, control or destruct a propagating soliton via collisions.
- **Mode separation and sound bullet.** I discovered that when propagating in two-dimensional space vector solitons, depending on propagation direction may break up to different modes with various polarizations and velocities. In addition, I also presented the experimental evidence of sound bullets.

Soft Robots Driven by Nonlinear Waves

- **Slinky robot driven by solitons.** I harnessed the propagation of nonlinear waves in a Slinky to make it crawl. By combining experimental and theoretical methods, I showed that the efficiency of such locomotion maximizes when the initiated pulses are solitons. The simple Slinky robot can move on a wide range of surfaces and even steer.
- **Metamaterials driven by topological solitons.** I demonstrated that a multistable metamaterial can harness topological vector solitons to become a crawling robot with robust performance. Specifically, the rotational component of the topological soliton is used to modify the friction coefficient locally and the translation component to generate peristaltic movements. Unconventionally, here all features required for crawling are encompassed into the mechanics of the robot instead of the controller, and complex paths can be programed via controlling the propagation of the topological solitons.

Other Types of Nonlinear Waves in Mechanical Metamaterials

- **Rarefaction solitons.** I studied nonlinear waves in a chain of buckled beams and found that such structures do not support typical compressive solitons but only support rarefaction solitons.

- **Cnoidal waves.** I discovered a general class of nonlinear wave solutions, namely cnoidal waves based on Jacobi elliptic functions. The cnoidal wave solutions extend from linear waves (or phonons) to solitons, while covering also a wide family of nonlinear periodic waves.