Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Multi-scale analysis of the self-vibration of a liquid crystal elastomer fiber-spring system exposed to constant-gradient light

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Key words:

Self-vibration; Constant-gradient light; Liquid crystal elastomer; Multi-scale method; Fiber; Spring oscillator

Cite this as: Haiyang WU, Jiangfeng LOU, Yuntong DAI, Biao ZHANG, Kai LI, 2025. Multi-scale analysis of the self-vibration of a liquid crystal elastomer fiber-spring system exposed to constant-gradient light. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 26(7):652-665. https://doi.org/10.1631/jzus.A2400194

System Description

■ **The system consists of an LCE fiber, a spring, and a mass, where gradient light induces photothermal contraction in the fiber, leading to nonlinear self-oscillation.**

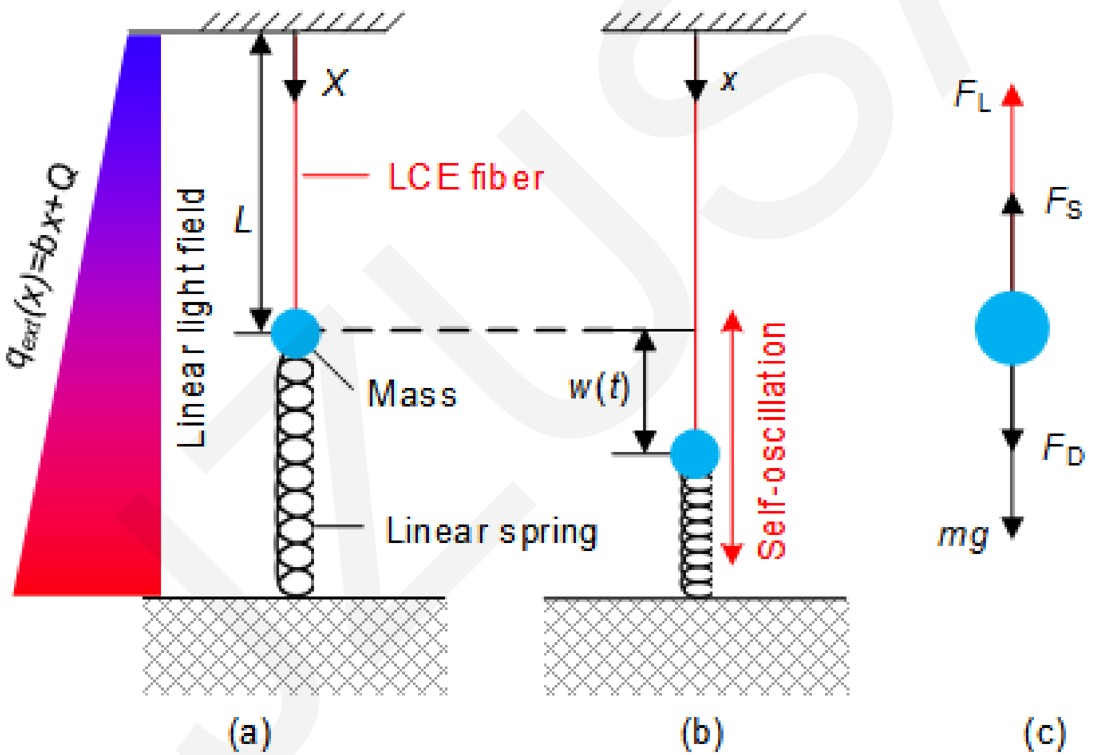
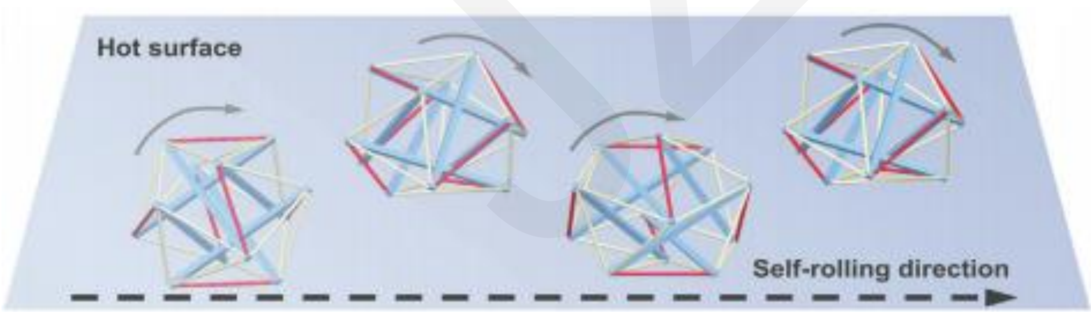


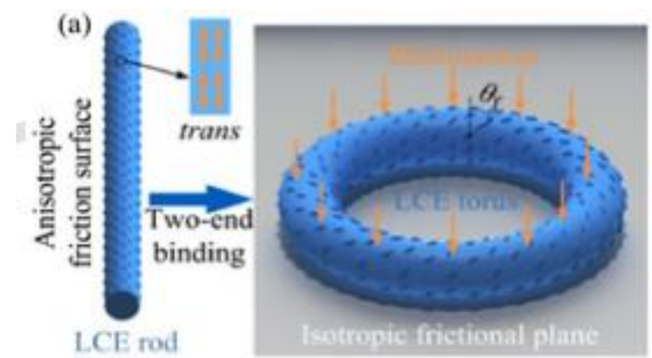
Fig. 1 System exposed to spatially-constant gradient light. (a) reference state; (b) current state; (c) force analysis

Innovation Highlights

- **Proposes an analytical modeling framework for self-vibrating systems based on the multi-scale method.**
- **Simulates and analyzes an LCE fiber-spring system under gradient light stimulation, revealing two motion regimes: static and self-vibrating.**
- **Systematically investigates how seven key parameters influence motion state, amplitude, and frequency, using the Hurwitz criterion.**
- **Confirms high consistency between analytical solutions and Runge-Kutta numerical results, significantly improving computational efficiency.**



Nat. Mater. 23, 1728–1735 (2024).



Int. J. Mech. Sci. 281, 109584 (2024).

Motion Regimes & Mechanism

■ Static and self-vibrating regimes

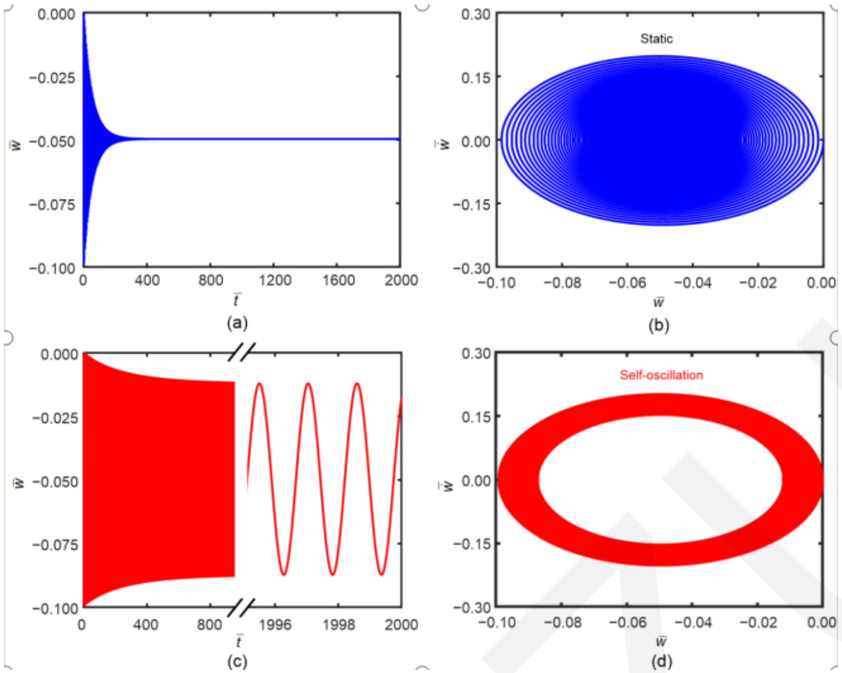


Fig. 2 Two motion regimes of the system.

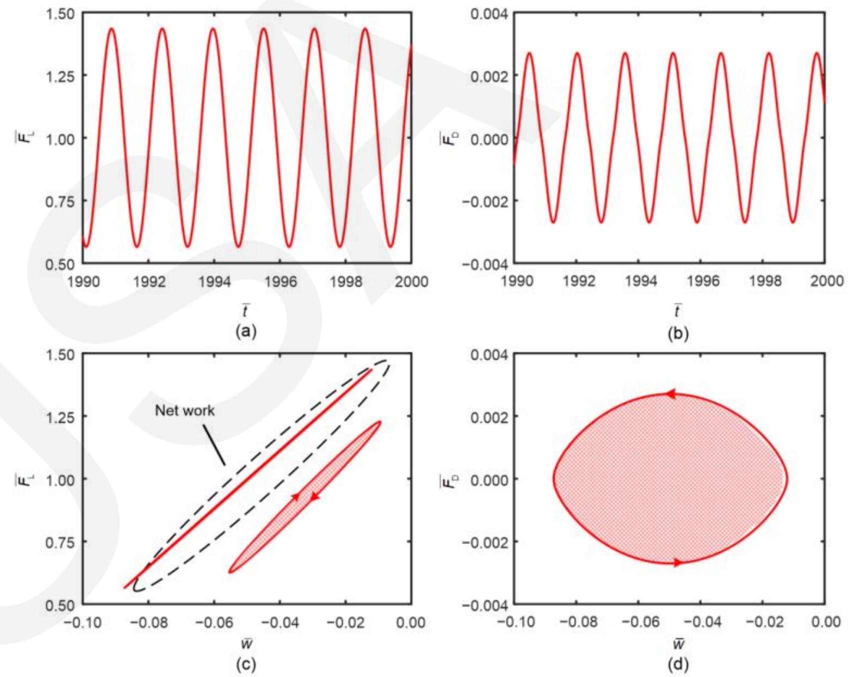
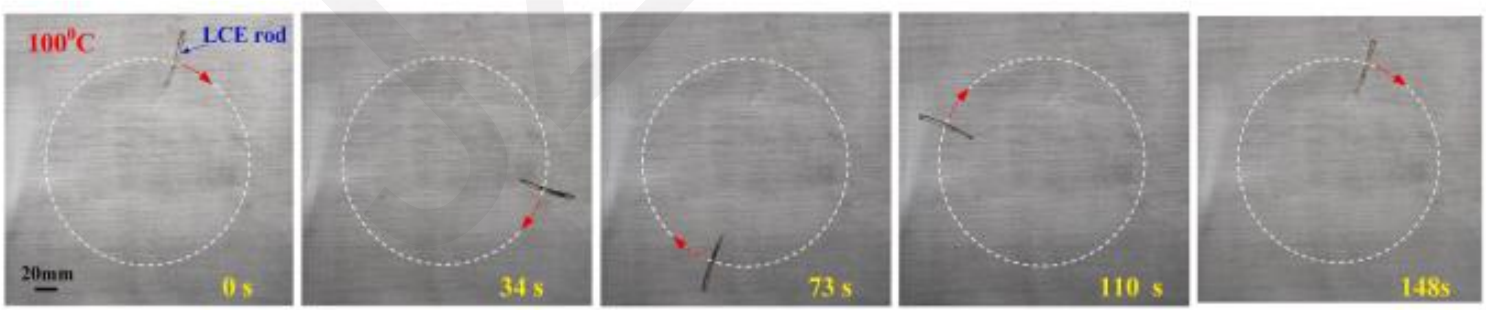


Fig. 3 Mechanism of self-vibration.



Int. J. Mech. Sci. 263, 108780 (2024).

Conclusions

- **This study develops an analytical multi-scale approach to describe the self-vibration behavior of an LCE fiber-spring system under gradient light stimulation, offering a computationally efficient alternative to conventional numerical methods, and clarifies how system parameters modulate vibration regimes, amplitude, and frequency, with results validated against numerical simulations.**

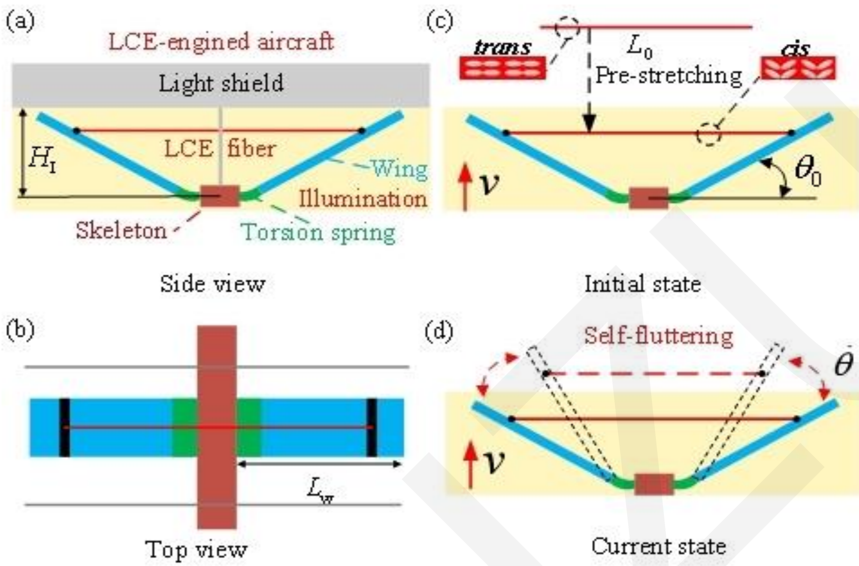


Fig. 4 LCE-based self-fluttering system.

Haiyang Wu, et al., 2024. Light-fueled self-fluttering aircraft with a liquid crystal elastomer-based engine. Communications in Nonlinear Science and Numerical Simulation,132:107942.

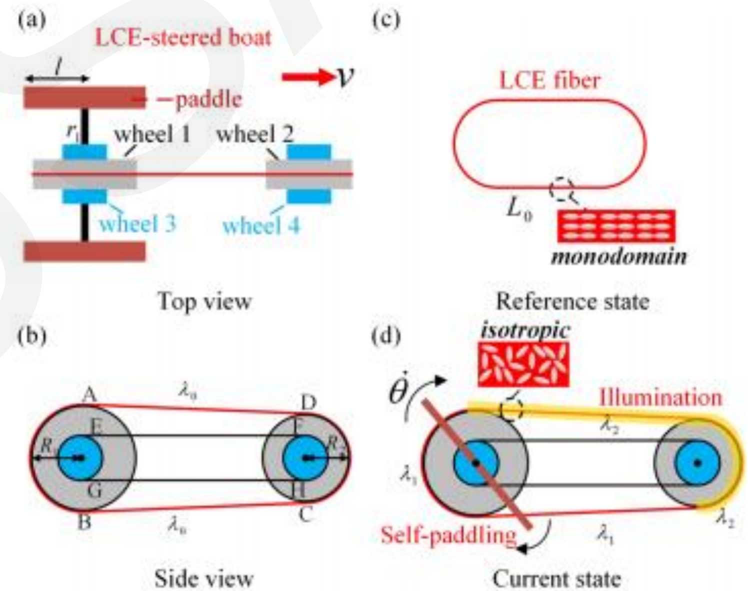


Fig. 5 LCE-based self-paddling system.

Haiyang Wu, et al., 2024. Modeling of a light-fueled self-paddling boat with a liquid crystal elastomer-based motor. Physical Review E,109:044705.

Related Work

- **Some other publications by the authors related to this research field are listed below:**

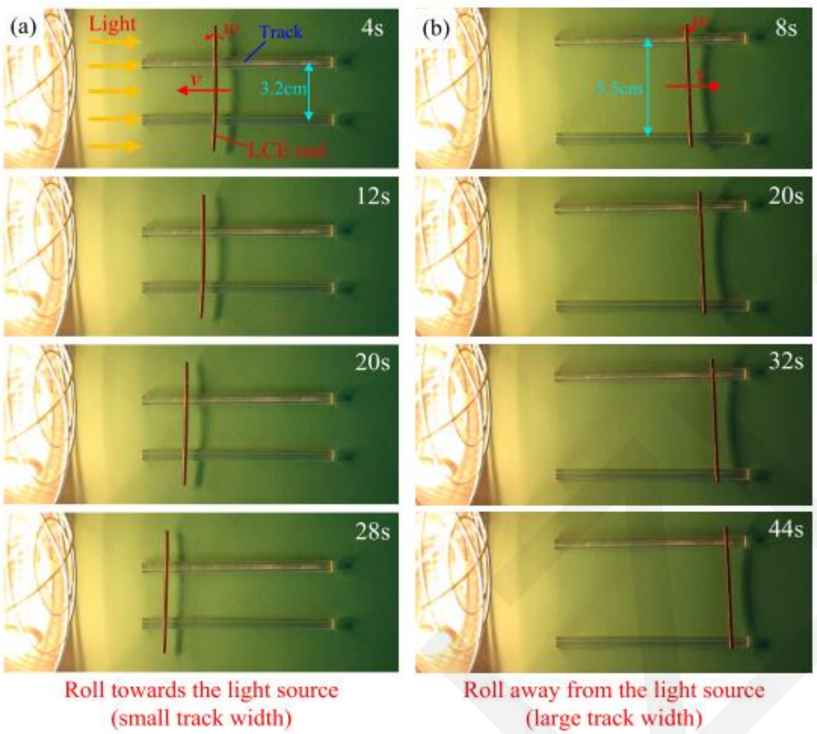


Fig. 6 Bidirectional self-rolling of the LCE rod under steady illumination.

Haiyang Wu, et al., 2025. Mechanics of light-fueled bidirectional self-rolling in a liquid crystal elastomer rod on a track. Chaos, Solitons & Fractals, 191:115901

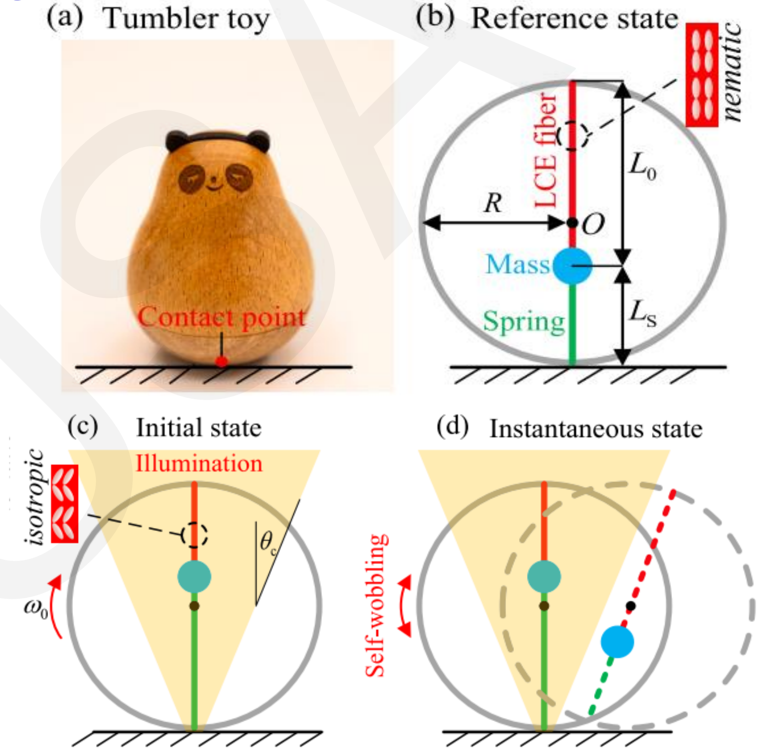


Fig. 7 Schematic of LCE-steered self-wobbling tumbler.

Haiyang Wu, et al., 2025. Modeling of a light-fueled liquid crystal elastomer-steered self-wobbling tumbler. Chaos, Solitons & Fractals, 191:115941.