Bistable control of phase transition of an optomechanical SSH chain by radiation pressure

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Introduction: Nanomechanics has been successfully used to control nanophotonic devices [1]. On the other hand, radiation pressure (that is, optical force) back-acting on nanomechanics has also been studied [2]. Optomechanical bistability is a typical phenomenon of this backaction [3]. Topological configurations of optomechanics is an emerging research field [4], and in this paper, we theoretically investigate the topological-trivial phase transition controlled by emplying optomechanical bistability.

Results: The investigated system is shown in Fig. 1(a). It is a Su–Schrieffer–Heeger (SSH) chain composed of nanobeam photonic crystal (PhC) cavities. In each unit cell, one site is movable and the other is fixed. The bonding modes (red-red or blue-blue, as shown) generating attractive force inside cells drive the movable structure to the right [note: the antibonding modes between cells generate negligible force]. Thus, the coupling rates are modified [the intra one (t_A) increases by $+\Delta t$ (gap narrowing) while the inter one (t_B) decreases by $-\Delta t$ (gap broadening)]. Figure 1(b) shows the eigenfrequencies of a 5-cell system as functions of Δt. The red curve is the desired mode in Fig. 1(a). $(t_A+\Delta t)/(t_B-\Delta t) = 1$ is the transition point between topological and trivial phases. According to theoretical model [inset in Fig. 1(c)], when a pump light sweeps around initial eigenfrequency ($\Delta t = 0$) of the system, optomechanical nonlinearity happens [see Fig. 1(c,d)]. Swept from higher to lower frequency, the system goes into trivial phase; while swept in the opposite direction, it is always in topological phase. Inset in Fig. 1(d) shows COMSOL-simulated mode profiles corresponding to the theoretically calculated two phases. **Conclusively,** we demonstrate the control of topological-trivial phase transition by operating the radiation-pressure-induced bistable states.

References: [1] S. Iwamoto *et al., Appl. Phys. Lett.* **88**, 011104 (2006). [2] M. Notomi *et al.*, *Phys. Rev. Lett.* **97**, 023903 (2006). [3] F. Tian *et al.*, *Opt. Lett.* **38**, 3394 (2013). [4] A. Youssefi *et al.*, *Nature* **612**, 666 (2022).

Acknowledgements: CREST (JPMJCR19T1) and KAKENHI (22H00298).

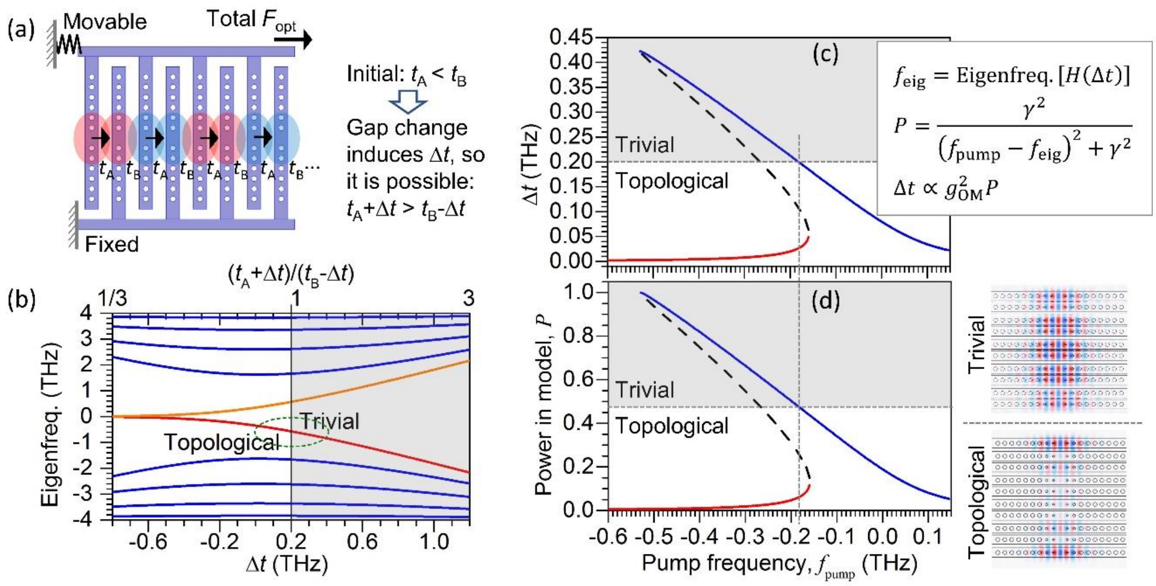

Fig. 1. (a) Schematic of optomechanical SSH chain. t_A & t_B: intra and inter coupling rates, respectively. (b) Eigenfrequency of the model as a function of coupling rate change (Δ*t*). (c,d) Radiation-pressure-induced bistable states. Inset in (c): equation set for the calculation. *H*: Hamiltonian of the system. *γ*: dissipation rate of cavities. g_{OM}: optomechanical coupling constant. Inset in (d): COMSOL-simulated mode profiles of trivial and topological phases.