NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

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# Topological Phase Transition in a 1D Phononic Crystal

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## Introduction

❖ **Zak Phase** $\theta_n = \int_{BZ} dk\, A_{n,k}$

- Topological invariant of $n$-th Bloch band in one-dimensional (1D) crystals
- Geometric phase (Berry phase) picked up by a particle while moving across the Brillouin Zone (BZ)
- Well-defined up to an integer multiple of $2\pi$ for gapped Bloch bands

❖ **Berry Connection** $A_{n,k} = i\,\langle n(k)|\partial_k|n(k)\rangle$

- $|n(k)\rangle$: Bloch wavefunction with 1D wavevector $k$
- Accumulated Berry phase per unit change in wavevector $k$

❖ **Parity Symmetry**

- Symmetric under sign-flipping of spatial coordinates
- Leads to quantized Zak phase: 0 or $\pi$ (Zak, 1989)
- Edge state is possible within band gap: localized between materials with distinct Zak phase → **topology!**

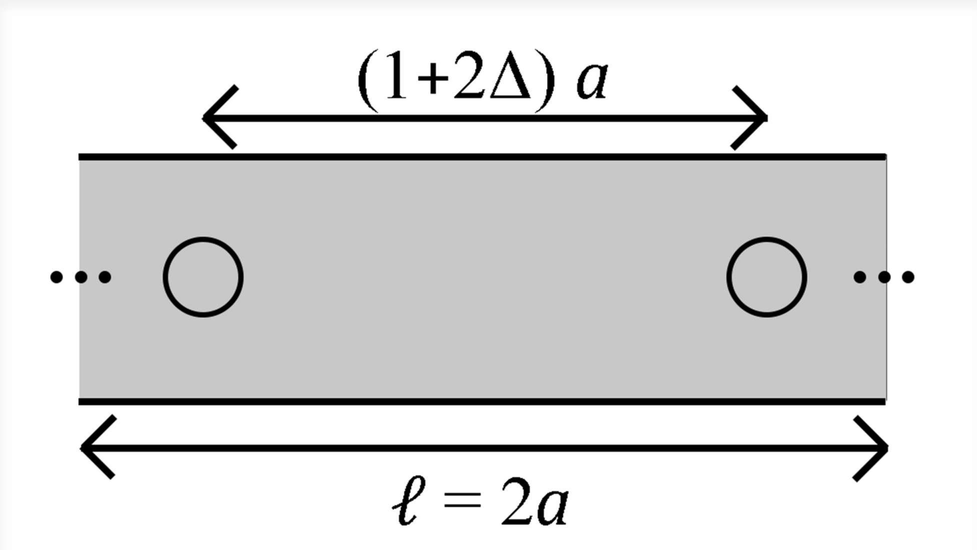
## Aim

To study topological phase transition in 1D phononic crystals with parity symmetry and distinct Zak phase.

## Methodology

❖ **Structure of the Phononic Crystal (Zangeneh et al., 2019)**

1D lattices filled with air and two obstructing cylinders in each unit cell, where the unit cell is symmetric about its center.



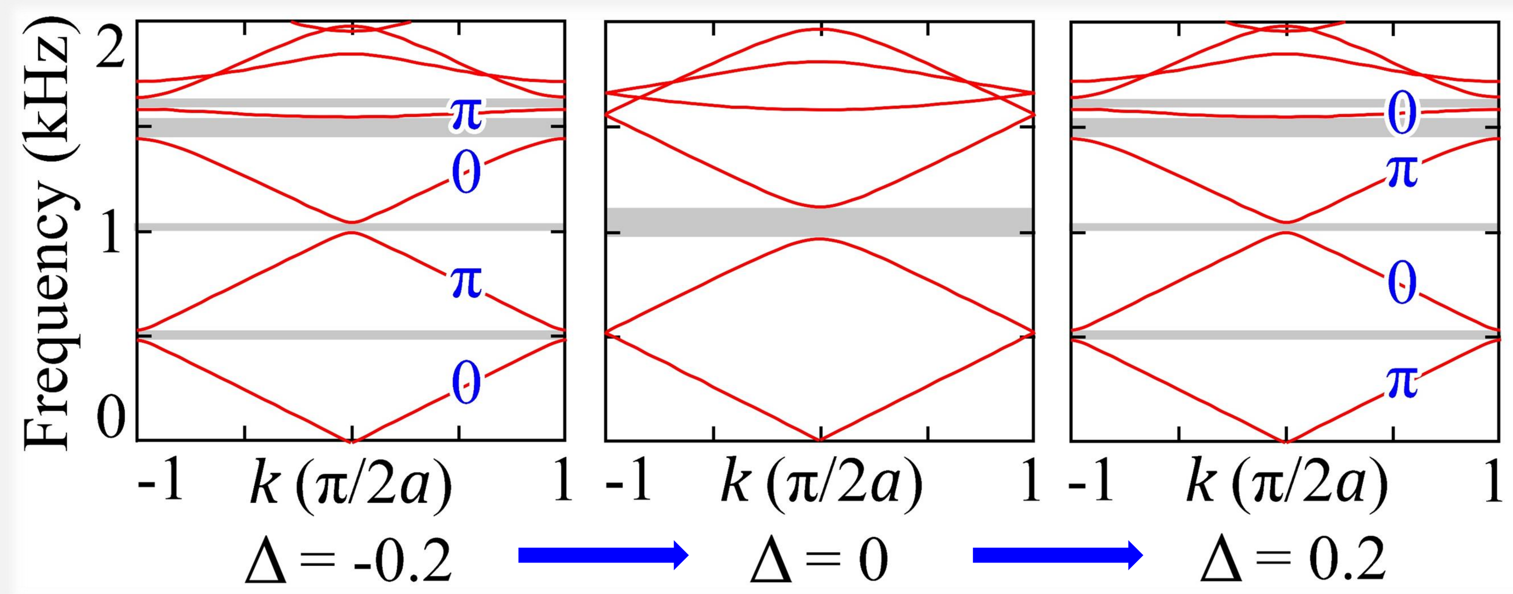

❖ **Simulations and Numerical Analysis**

- Bulk material simulation for band diagrams of different crystals and pressure field distribution in a unit cell
- Zak phase computation for different bands in discretized Brillouin Zone (Wang et al., 2019)
- Observation of $\Delta$ value for topological phase transition
- Wave scattering simulation for localized edge state

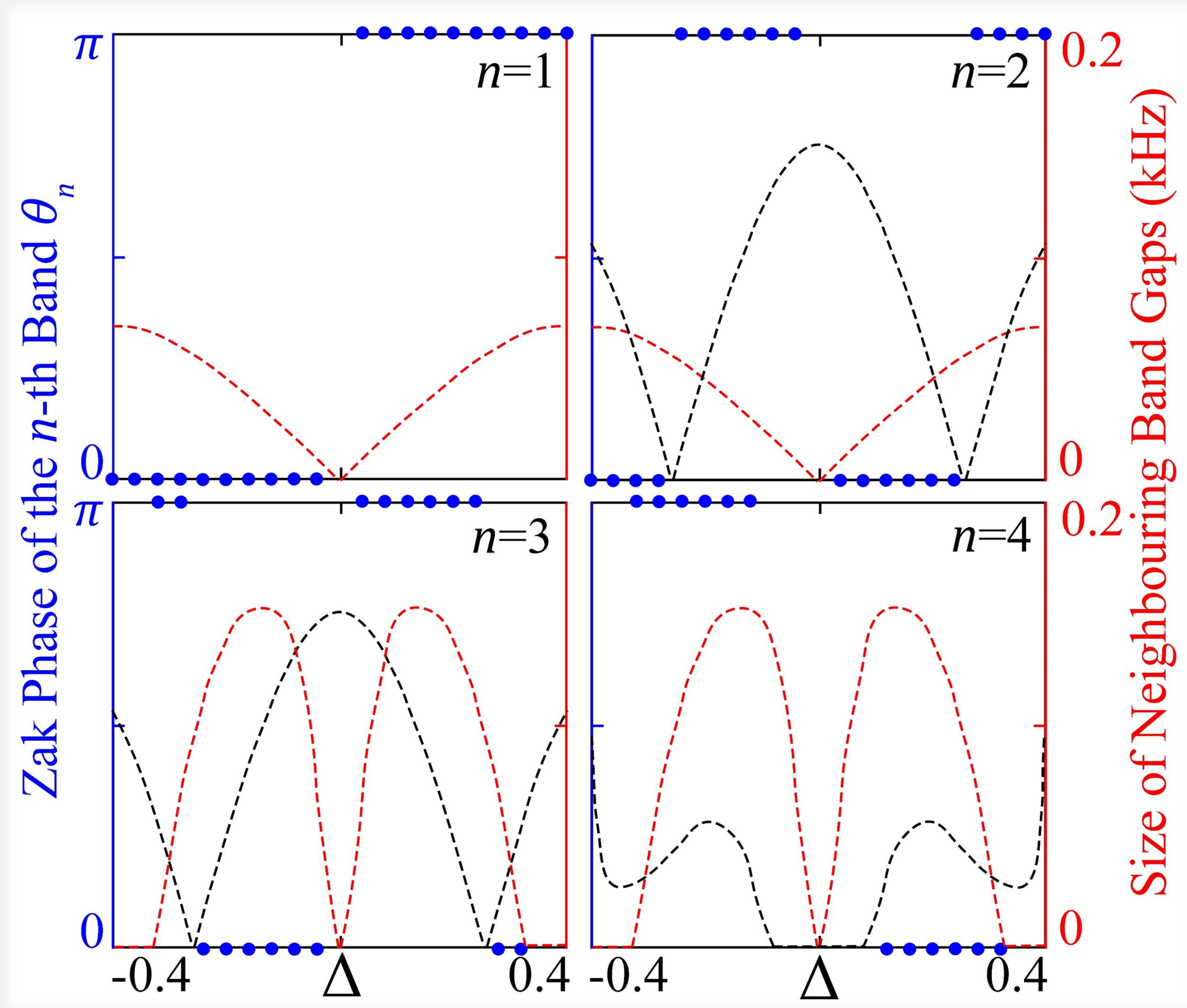
## Results and Discussion

❖ **Band Diagrams and Topological Phase Transition**

- Distinct Zak phase for opposite $\Delta$ in first four bands

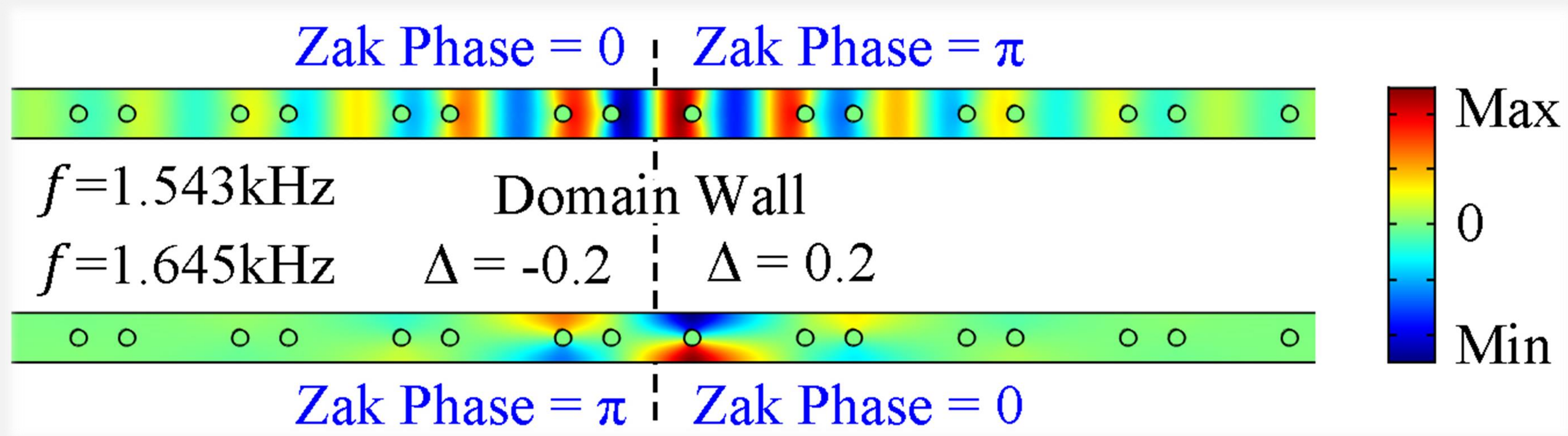



- Zak phase changes at $\Delta = 0$ when band gap closes and reopens




❖ **Pressure Field Distribution of Localized Edge State**

- Localized at domain wall between 1D lattices of distinct Zak phases (0 and $\pi$) → topological phase transition!




## References

Zak, J. (1989). Berry's phase for energy bands in solids. *Physical review letters*, *62*(23), 2747.

Zangeneh-Nejad, F., & Fleury, R. (2019). Topological fano resonances. *Physical review letters*, *122*(1), 014301.

Wang, H. X., Guo, G. Y., & Jiang, J. H. (2019). Band topology in classical waves: Wilson-loop approach to topological numbers and fragile topology. *New Journal of Physics*, *21*(9), 093029.