Electromagnetic Responses of 3D Topological Insulators

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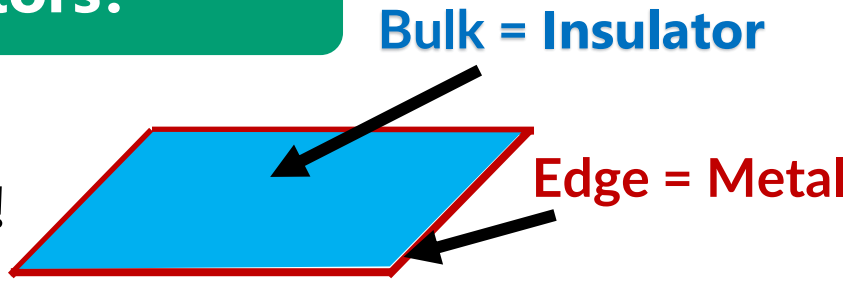
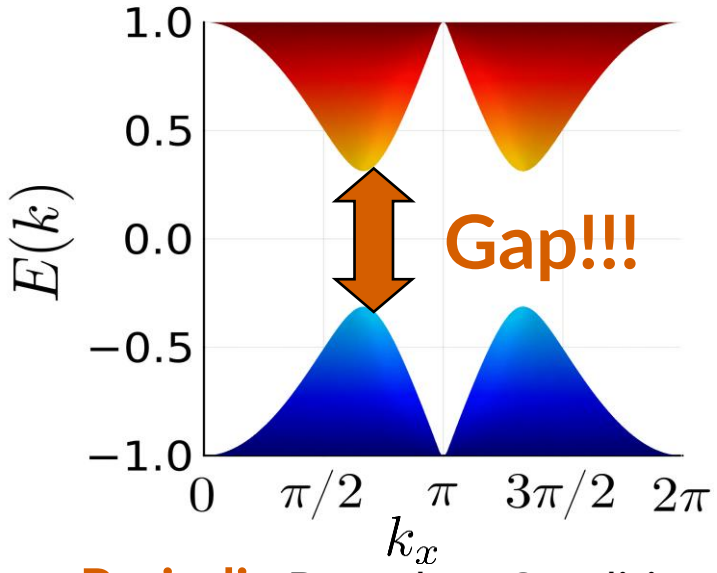
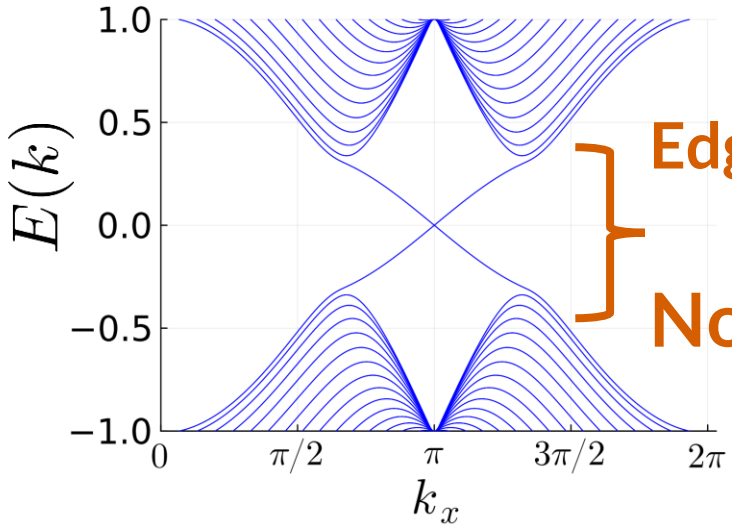
1. What are Topological Insulators?

- **Bulk → Energy Gap = Insulator!**
- **Edge → No Energy Gap = Metal!**





Periodic Boundary Condition



Open Boundary Condition

Question How do the **Maxwell Equations** change in Topological Insulators?

2. Electromagnetic Responses

The **Modified** Maxwell Equations in 3D Topological Insulators

$$\nabla \cdot \boldsymbol{D} = 4\pi\rho$$

$$\nabla \times \boldsymbol{H} - \frac{1}{c}\frac{\partial \boldsymbol{D}}{\partial t} = \frac{4\pi}{c}\boldsymbol{j}$$

$$\nabla \cdot \boldsymbol{B} = 0$$

$$\nabla \times \boldsymbol{E} + \frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} = 0$$

$$\boldsymbol{D} = \boldsymbol{E} + 4\pi\boldsymbol{P} + \frac{\alpha}{\pi}\theta\boldsymbol{B} = \epsilon\boldsymbol{E} + \frac{\alpha}{\pi}\theta\boldsymbol{B}$$

$$\boldsymbol{H} = \boldsymbol{B} - 4\pi\boldsymbol{M} + \frac{\alpha}{\pi}\theta\boldsymbol{E} = \frac{\boldsymbol{B}}{\mu} + \frac{\alpha}{\pi}\theta\boldsymbol{E}$$

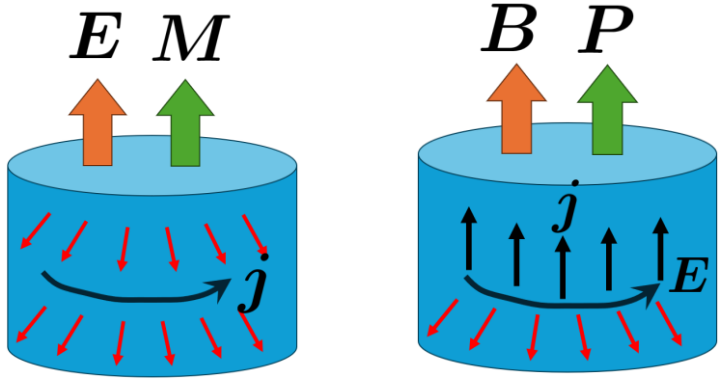
α: Fine structure constant $\quad \theta = \pi$: Axion Field

⇨ **Axion Electrodynamics**

X.-L. Qi, T. L. Hughes, and S.-C. Zhang, PRB (2008).

$$\boldsymbol{M} \propto \boldsymbol{E}, \boldsymbol{P} \propto \boldsymbol{B}$$

⇨ **Topological Magnetoelectric Effect**



Other Phenomena

- Surface half-integer quantum hall effect
- Image magnetic monopole
- Witten effect

3. Axion Electrodynamics in Materials

⇨ **If you are interested, come to my poster!!!**