NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE
Odyssey Research Programme
School of Physical and Mathematical Sciences

Repulsive Casimir Effect In Chern Insulator

Presented by Tiang Bi Hong
Supervised by Asst Prof Lu Bing Sui

Introduction

- Casimir Effect: Force induced between two surfaces by fluctuations of the quantum electrodynamics vacuum
- Topological Insulator: a group of materials which conduct electron along its surface (edge state) but not its interior.
- Chern Insulator: a subgroup of Topological Insulator which has nonzero Chern number (C)

Aim

To review the Casimir effect in Chern Insulator [1,2] and investigate some potential future works.

Motivation & Significance

- Why choose Chern Insulator?

Chern Insulator has many unique features and important applications, eg: quantum Hall effect.

•Why is it important？

- Potential repulsive Casimir effect which may resolve the stiction issues in nanodevices.
- Detect topological quantization of Chern Insulator by Casimir force's far field behaviour

Theoretical Approach

1. Tight-binding model [1]: determine Hamiltonian and hence the conductivity tensor $\sigma_{ij}(w)$:
2. Obtain reflection coefficient [1] from $\sigma_{ij}(w)$ by solving Maxwell equations:

$$R_{ss} = -\frac{2\pi}{\Delta}\left(\frac{\sigma_{xx}}{\lambda} + 2\pi\left(\sigma_{xx}^2 + \sigma_{xy}^2\right)\right)$$

$$R_{pp} = \frac{2\pi}{\Delta}\left(\lambda\sigma_{xx} + 2\pi\left(\sigma_{xx}^2 + \sigma_{xy}^2\right)\right)$$

$$R_{sp} = R_{ps} = \frac{2\pi}{\Delta}\sigma_{xy}$$

$$\Delta = 1 + 2\pi\sigma_{xx}\left(\frac{1}{\lambda} + \lambda\right) + 4\pi^2\left(\sigma_{xx}^2 + \sigma_{xy}^2\right)$$

3. Substitute reflection coefficients into Casimir-Lifshitz expression [2]:

$$\frac{E(d)}{A\hbar} = \int_0^\infty \frac{d\xi}{2\pi}\int \frac{d^2k_\parallel}{4\pi^2}\log\det[1 - R_1{}' \cdot R_2 e^{-2k_z d}]$$

4. Asymptotic Limits:
   a) Zero-frequency limit [4] (valid for far field):

$$E(d) = -\frac{\hbar c}{8\pi^2 d^3}\operatorname{Re}\operatorname{Li}_4\left(\frac{C_1 C_2 \alpha^2}{(C_1\alpha + i)(C_2\alpha + i)}\right)$$

   b) Far field limit (valid for $|C|\alpha < 1$):

$$E(d) \approx \frac{\hbar c\alpha^2 C_1 C_2}{8\pi^2 d^3}$$

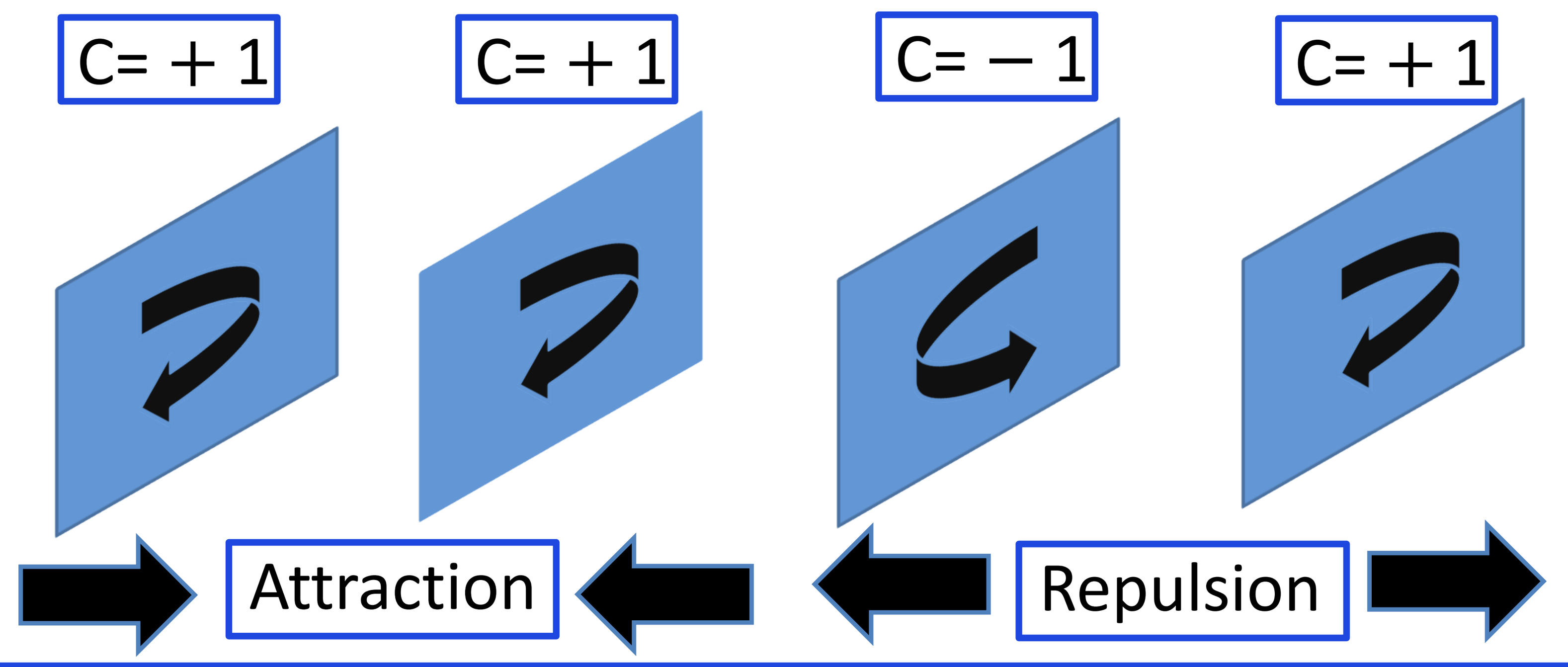
   c) Large Chern number limit ($|C|\alpha \to \infty$), the Chern Insulators behaves like 2 perfect conductors:

$$E(d) \to -\frac{\hbar c\pi^2}{720 d^3}$$

   d) Near field Limit [1] (valid for $|C|\alpha < 1$):

$$E(d) \approx -\frac{3\hbar c\sqrt{\alpha}}{128 d^{5/2}}\frac{\sqrt{s_{xx,1}s_{xx,2}}}{\sqrt{s_{xx,1}} + \sqrt{s_{xx,2}}}$$

Conclusion



Future Works

Currently, we are investigating the impact of the substrate thickness, i.e. if it can control the strength of Casimir force or change it to attractive, and if so, calculate the critical thickness for repulsive Casimir effect. Next, we also consider the effect of random Dirac mass on Chern Insulator caused by non-uniform distribution of dopants on the surface. Moreover, we try to expand the results from zero temperature limit to low finite temperature.

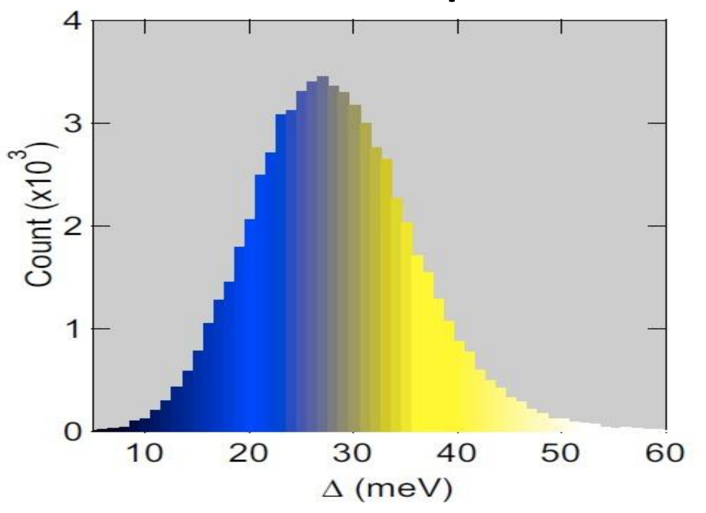


Fig.1: The non-uniform distribution of Dirac mass across the surface [3]

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Reference

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