Empirical Investigation of Quantum Entanglement in Topological Insulators: A Case Study of Weyl Semimetals

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Abstract. This study delves into the quantum entanglement properties of topological insulators, with a specific focus on Weyl semimetals. Employing advanced entanglement entropy measures, we examine the role of surface states and their contribution to the entanglement spectrum. Our methodology integrates both theoretical models and experimental validations, providing a robust framework for understanding the quantum coherence in such materials. The findings reveal critical insights into the manipulation of quantum states, contributing to the potential development of quantum computing technologies.

Keywords: Quantum Entanglement, Topological Insulators, Weyl Semimetals, Entanglement Entropy, Quantum Computing

Introduction

Quantum entanglement remains one of the most perplexing yet promising phenomena in modern physics, offering insights into the fundamental nature of reality and potential applications in quantum computing. In recent years, topological insulators have emerged as pivotal platforms for studying entanglement due to their unique surface states and non-trivial topological order. These materials, characterized by an insulating bulk and conductive surface states, have garnered significant attention for their quantum mechanical properties and potential technological applications, including spintronics and quantum information processing. Weyl semimetals, a subset of topological insulators, present an intriguing case for entanglement studies. Their unique band structure allows for the observation of Weyl nodes, which act as monopoles in momentum space and give rise to exotic surface states known as Fermi arcs. These features make Weyl semimetals ideal candidates for exploring the intricacies of quantum entanglement and its practical implications. This paper aims to address the gap in understanding the entanglement properties of Weyl semimetals. We employ advanced entanglement entropy measures and provide experimental validation through state-of-the-art technologies. Our work is structured as follows: Section 2 reviews the theoretical background and recent advancements in the field; Section 3 outlines the experimental setup and methodologies; Section 4 discusses the results and their implications; and Section 5 offers a comprehensive conclusion alongside potential future research directions.

References

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