A Comparative Analysis of Quantum Entanglement Entropy in Topological Insulators and Weyl Semimetals

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Abstract. This study explores the nuanced phenomena of quantum entanglement entropy within topological insulators and Weyl semimetals, two pivotal classes of quantum materials. By employing holographic duality and tensor network approaches, we delineate key differences in entanglement scaling, unveiling potential implications for quantum computing. Our findings reveal distinct entropic signatures that could drive future material innovations and deepen comprehension of non-trivial topological phases.

Keywords: Quantum Entanglement Entropy, Topological Insulators, Weyl Semimetals, Holographic Duality, Tensor Networks, Quantum Computing, Topological Phases, Spintronics

Introduction

In the realm of condensed matter physics, the investigation of quantum materials such as topological insulators and Weyl semimetals has garnered unprecedented attention. This surge of interest is driven by their potential to revolutionize quantum computing and spintronics applications. As we edge closer to the era of quantum technology, understanding the fundamental properties of these materials is crucial. One such property is quantum entanglement entropy, a measure that provides profound insights into the entanglement structure and quantum phase transitions within these systems. Topological insulators, characterized by their insulating interior and conductive surface states, have demonstrated remarkable potential in hosting robust quantum states immune to local perturbations. Meanwhile, Weyl semimetals, distinguished by their linear dispersion and topological protection, offer a distinct arena for exploring chiral anomalies and novel quantum phenomena. However, the entanglement characteristics of these materials remain insufficiently explored, warranting a comprehensive comparative analysis. This article systematically evaluates quantum entanglement entropy across topological insulators and Weyl semimetals. By employing advanced theoretical frameworks such as holographic duality and tensor network methods, we aim to elucidate the entropic landscapes of these fascinating materials. Following a detailed methodological exposition, we present our findings on the comparative entanglement signatures observed. The discussion illuminates the broader implications for quantum material science and potential technological applications.

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