別記様式第５号

論文審査の要旨

博士の専攻分野の名称	博　士　（　理学　　　）	氏名	JI MING
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論　文　題　目

On the Origin of Nonclassical Relations Between Different Measurement Contexts
(異なる測定文脈間の非古典的関係の起源について)

論文審査担当者

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〔論文審査の要旨〕

The present research is an in-depth study of the manner in which the mathematical formalism of quantum theory results in statistics that exceed classical limits. As shown by the Kochen-Specker theorem, the statistics observed in separate quantum measurements cannot be explained by a measurement independent reality. This dependence of reality on measurement contexts can be demonstrated experimentally by violations of inequalities that describe the bounds of non-contextual models. In the present study, it is shown that the relations between Hilbert space vectors representing different measurement outcomes determine an alternative relation between incompatible measurement contexts, requiring a quantitative violation of non-contextual limits that can be traced back to quantum interference effects.

Chapter 1 introduces quantum contextuality.
Chapter 2 shows how the logical conditions of an inequality violation define a quantum state that necessarily violates non-contextual logic. A quantum mechanical bound for this necessary form of quantum contextuality is derived as the first result of the thesis.
Chapter 3 shows that the orthogonality relations between different measurement contexts result in additional relations between Hilbert space inner products. It is then possible to derive the necessary inequality violation for a given scenario from only two independent inner products, even though the minimal number of independent measurement contexts is at least five. This quantitative relation between two inner products and the necessary inequality violation is the second result of the thesis.

Chapter 4 introduces weak values to analyze the relation between inner products in more detail. Since weak values can be used to trace the path of a particle through a quantum interferometer, an interferometric setup is constructed for the simplest contextuality scenario. The analysis shows that contextuality corresponds to the impossibility of assigning photon paths in the interferometer. It is shown that contextuality can be traced back to interferences between paths that are orthogonal to either the initial condition or the post-selected output. It should be noted that the relation between contextuality and interferences between initial and final conditions was discovered in close cooperation with Dr. Jonte Hance, as appropriately acknowledged and referenced in the thesis.
Chapter 5 applies the results of chapter 4 to the problem of quantum non-locality by mapping the quantum statistics of two qubits onto a single interferometer. The results indicate that quantum non-locality is a consequence of quantum interference, suggesting that quantum entanglement is only a sub-set of a wider class of non-classical correlations.

The results presented in this thesis greatly advance our understanding of non-classical statistics by explaining how quantum superpositions and the associated interference effects describe the relation between different measurement contexts. Most significantly, the thesis shows why quantum interference effects are fundamentally different from classical either/or alternatives. The results indicate that a fundamental revision of the concept of quantum interference is necessary, an insight that may have far reaching implications for the design of future quantum information architectures.

Based on the above evaluation, the author of this thesis is deemed to be fully qualified to be awarded the degree of Doctor of Science.

備考：審査の要旨は，1,500 字以内とする。