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Title of the thesis : Quantum Entanglement and its Applications

Abstract

- We addressed the issue of interference and which-way information in the context of 3-slit interference experiments. A new path distinguishability based on Unambiguous Quantum State Discrimination (UQSD) is introduced. An inequality is derived which puts a bound on how much fringe visibility and which-way information can be obtained simultaneously. It is argued that this bound is tight. For 2-slit interference, we derive a new duality relation which reduces to Englert's duality relation and Greenberger-Yasin's duality relation, in different limits.

- We derived a generalized wave-particle duality relation for arbitrary multipath quantum interference phenomena. Beyond the conventional notion of the wave nature of a quantum system, i.e., the interference fringe visibility, we introduced a quantifier as the normalized quantum coherence, recently defined in the framework of quantum information theory. To witness the particle nature, we quantified the path distinguishability based on unambiguous quantum state discrimination. Then, the Bohr complementarity principle for multipath quantum interference can be stated as a duality relation between the quantum coherence and the path distinguishability. For two-path interference, the quantum coherence is identical to the interference fringe visibility, and the relation reduces to the well-known complementarity relation. The duality relation continues to hold in the case where mixedness is introduced due to possible decoherence effects.

- We analyzed a recently proposed multi-path relation (Bagan et al., 2016) which claims to be in Englert's form. With an explicit example of three pure detector state, we showed that their relation doesnot satisfy the basic criterion of complementarity, as simultaneous increase of their path quantifier and wave quantifier was possible. We also derived a relation similar to Englert's one to fill the exigency and to explicate its equivalence with our earlier proposed relation.

This new relation is shown to be tight, and reduces to the known duality relation for the case N = 2.

- We proposed and analysed a modified ghost-interference experiment, and showed that revealing the particle-nature of a particle passing through a double-slit hides the wave-nature of a spatially separated particle which it is entangled with. We derived a nonlocal duality relation, which connects the path distinguishability of one particle to the interference visibility of the other. It extends Bohr's principle of complementarity to a nonlocal scenario. We also proposed a ghost quantum eraser in which, erasing the which-path information of one particle brings back the interference fringes of the other.

- We theoretically analyzed the three-slit ghost interference experiment with entangled photons, using wave-packet dynamics. Also a non-local duality relation for three slit setup is derived which connects the path distinguishability of one photon to the interference visibility of the other.

- We use the entanglement as a resource to propose a new Quantum Key Distribution method in which Alice sends pairs of qubits to Bob; each is in one of four possible states. Bob uses one qubit to generate a secure key and the other to generate an auxiliary key. For each pair he randomly decides which qubit to use for which key. The auxiliary key has to be added to Bob's secure key in order to match Alice's secure key. This scheme provides an additional layer of security over the standard BB84 protocol.