Abstract

Non-classical correlations present an wide range of complexity and variation in the multipartite setup that is yet to be explored to its full extent. In particular, correlations between many parties that are not separable in any bipartition can be referred as "strongly" non-classical. In this dissertation aimed to investigate such strong non-classical correlation especially in the multipartite scenario.

The first candidate exhibiting such "strong" non-classicality that we consider are the k-uniform N-partite states. These states are such that it becomes maximally mixed if reduced to a k-partite state considering any permutation of the subsystems and referred as a natural generalization of the maximally entangled Bell states. We propose a generator scheme to construct such states. We also find k-uniform N-partite states with highest possible purity when one such pure state does not exist. These state possess the most multipartite correlations among all quantum states of the same purity.

Following the construction of the states displaying strong multipartite correlations, we next propose an information-theoretic quantifier that can address such correlations. This quantifier, namely N-dependence, quantifies the information gained from the cooperation among different subsystems about a particular subsystem within a multipartite system. This quantifier is distinct from measures of multipartite correlations as it does not satisfy all their postulates. We show that N-dependence can have several applications such as in symmetric quantum secret sharing.

We next take a step further and provide an metrological aspect of strong non-classicality. We, in a composite system scenario, propose a multiphase estimation scheme using a setup consisting of 3-,4-mode Mach-Zehnder interferometer. We show that it is possible to attain the fundamentally imposed limit on measurement precision, i.e., the Heisenberg limit, achievable by noiseless composite quantum systems. We present a scheme for simultaneous estimation of $d-1$ phases for a d-mode system.

Lastly, we investigate another notion of strong non-classicality which has major significance in understanding of the advantages that the quantum world has to offer, namely genuine multipartite nonlocality (GMNL). We consider two different notion of GMNL and present numerical evidence to investigate the violations of the constraints corresponding to these different notions of GMNL by a number of multipartite quantum states. As an indicator of non-classicality, we employ two measures: strength of nonlocality and probability of violation.