Abstract of the PhD thesis

Entanglement Sources and Testing the Foundations of Quantum Theory"

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Entangled states are the basic tool in a variety of experimental demonstrations of the most nonclassical aspects of quantum theory. Photons, which can be entangled (by different methods) in energy, momentum, and emission time, became also basic source for applications in quantum information, communication, and computation. Because of its importance there is huge ongoing effort for the production and characterization of entanglement of various quantum systems. In this thesis we engineer and develop a new source to produce entanglement with better visibility and high production rates. Using 3nm bandwidth filter we achieved rate of > 4_105 2-photon coincidences per second. For two photon entangled states it gives interference visibility of > 96%. Moreover, by using two independent copies of such a source to do four photon Hong-Ou-Mandel interference we achieved a heralded Hong-Ou-Mandel dip of visibility > 84%. The developed source is quite good for a variety of applications including production of multiphoton entangled states. In addition, we used the developed source to implement a new method to detect entanglement of different states using a measurement-device-independent entanglement witness. By preparing a set of two photon Werner states covering the range from maximally entangled singlet state j ⍰i to maximally mixed states 1, we manage to implement measurement-device independent entanglement witness with a good agreement with theory. In the measurement device-independent protocols there is no requirement of assuming perfect implementations and neither the measurement devices have to be trusted. We also, proposed a new method to derive new set of multipartite multisetting Bell inequalities which have lower order correlations. The set of inequalities can be violated by some states for which the general Werner-Wolf-Weinfurter- ˙ Zukowski-Brukner inequalities can not give any violation. Finally, we describe how the ”exclusivity principle” provides upper bounds to quantum correlations when applied to two complementary experiments. The principle states that the sum of probabilities of a set of events which are pairwise exclusive never exceeds one. We discuss in details a two-city experiment to explains the maximum quantum violation of the Clauser-Horne-Simony-Holt (CHSH) inequality and other complementary noncontextuality inequality. In this experiment the exclusivity principle provides completely tight bounds on both experiments and not only that, but these bounds predicted by the exclusivity principle are exactly same as those predicted by quantum theory. Our results indicate the impossibility of super-quantum correlations satisfying the exclusivity principle for the CHSH inequality experiment.