Contribution ID: **222** Type: **Oral presentation**

Measurement of Nonlocal Observables and Its Applications

Tuesday, 10 July 2018 11:00 (30 minutes)

The measurement of quantum nonlocal observables lies at the foundations of quantum theory. We report an implementation of the von Neumann instantaneous measurements of nonlocal observables which becomes possible due to technological achievements in creating hyperentangled photons. Tests of reliability and of the nondemolition property of the measurements have been performed with high precision showing the suitability of the scheme as a basic ingredient of numerous quantum information protocols. Based on the concept of modular values, we performed the experimental extraction of the weak values of nonlocal observables. Our results overcome the absence of nonlocal observables in the physical Hamiltonian and the shortage in extracting nonlocal weak values from high order approximation, therefore significantly simplify the task of obtainning nonlocal weak values. Our methods and results can be applied to demonstrate the failure of the product rule with strong measurements or in the scenario of weak values. We also show that the nonlocal wave function can also be directly measured via our method.

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Session Classification: Workshop on Quantum Foundations and Quantum Information