Revealing Genuine Optical-Path Entanglement

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Optical path entanglement – single photon entangled between several optical paths - is one of the simplest forms of entanglement to produce [1-3]. It is also a promising resource for long-distance quantum communication [4] and has the potential to extend known point-to-point quantum repeaters to richer quantum networks.

However, the problem has been to detect entanglement between multiple optical paths sharing a single photon. We present a scalable protocol for detecting entanglement, which uses only local measurements, in which photon counting is combined with optical displacement operations. The resulting entanglement witness does not require post-selection, or assumptions about the photon number in each path. Furthermore, it also guarantees that entanglement lies in a subspace with at most one photon per optical path and reveals genuine entanglement. We demonstrate its scalability and resistance to loss by performing various experiments for bipartite and tripartite entangled systems.

Fig. 1 a) Multi-partite optical path entanglement is easily generated by a single photon delocalized over many spatial modes. The local measurements involve a weak displacement operation and single photon counting. b) The operation of the weak displacement on a single photon. c) In practice the displacement is performed with the local oscillator and photon in orthogonal polarizations such that a small rotation of a half waveplate before the polarizing beamsplitter realizes the displacement operation. d) Red points represent the experimental violation of the bipartite witness of entanglement for different input states. The blue band shows the expected violation predicted by our model.

References