Witnessing single-photon entanglement with continuous-variable measurements

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Quantum information protocols are commonly based on two kinds of encoding. Some experiments are performed with 'discrete-variables', where the information is encoded in a two dimensional Hilbert space, for instance on the presence or absence of single-photons. Other experiments focus on the 'continuous-variable' approach, where the information is encoded in an infinite-dimensional Hilbert space, for instance on the quadrature components of light. Both encodings have advantages and drawbacks when they come to sophisticated protocols. Mixing the two approaches has recently led to a so-called 'hybrid quantum information' aiming at merging the best properties of both [1]. After a general overview of this approach, I will focus here on a novel hybrid protocol for witnessing single-photon entanglement using the continuous-variable toolbox.

Single-photon entangled states, i.e. states describing two optical paths sharing a single-photon, constitute the simplest form of entanglement. Yet they provide a valuable resource in quantum information. Specifically, they lie at the heart of quantum networks, as they can be used for quantum teleportation, swapped and purified with linear optics. The main drawback of such entanglement is the difficulty in measuring it. Existing methods have at least three drawbacks: they require assumptions on the size of the Hilbert space, they use post-selection or they need to recombine the entangled modes, which is difficult in the context of large-scale networks.

In Ref. [2], we recently proposed and experimentally tested a hybrid entanglement witness that avoids these drawbacks. Significantly, it uses local homodyning only and does not rely on assumption about the Hilbert space dimension of the measured system. We performed this demonstration using as a primary resource a high-fidelity single-photon source recently developed in our group and based on a type-II optical parametric oscillator [3].

[1] P. van Loock, Optical hybrid approaches to quantum information, Laser and Photonics Review 5, 167 (2010).

[2] O. Morin, J.-D. Bancal, M. Ho, P. Sekatski, V. D'Auria, N. Gisin, J. Laurat, N. Sangouard, Witnessing trustworthy single-photon entanglement with local homodyne measurements, Phys. Rev. Lett. 110, 130401 (2013).

[3] O. Morin, V. D'Auria, C. Fabre, J. Laurat, A high-fidelity single-photon source based on a type-II optical parametric oscillator, Optics Letters 37, 17 (2012).