# Optical hybrid entangler by superposing two Gaussian operations

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Nonlinear interaction between quantum systems aims to expand the range of available quantum interactions. The current experimental tools of quantum optics allow for an efficient linear control of light, admitting a complete set of multi-mode unitary interactions with Hamiltonians quadratic in powers of quadrature operations. To include the discrete nature in the protocols, the oscillators need to be supplemented with cavity quantum electrodynamics with atoms, quantum mechanics with trapped ions or circuit quantum electrodynamics. An interesting nonlinear interaction bridging the continuous and discrete systems is characterized by an strong dispersive non-demolition interaction Hamiltonian [1]. By controlling the initial state and by selecting a specific measurement outcome of the discrete system, the continuous oscillator can be conditionally transformed as per application of a superposition of two unitary operators.

In this talk I will present a conditional implementation of superpositions of Gaussian operations on different modes of light [2]. These operations are conditional entanglers generating non-Gaussian entanglement between two modes of propagating light beams. The all-optical operations emulate weak effects of highly nonlinear operations only available when light interacts with individual atoms. In particular, I will explain about schemes to implement superposition of coherent displacements and squeezings on two beams of light and discuss physical properties of generated non-Gaussian entanglement. These methods together with high quality of optical tomography of highly non-classical states allow understanding non-Gaussian entangling processes.

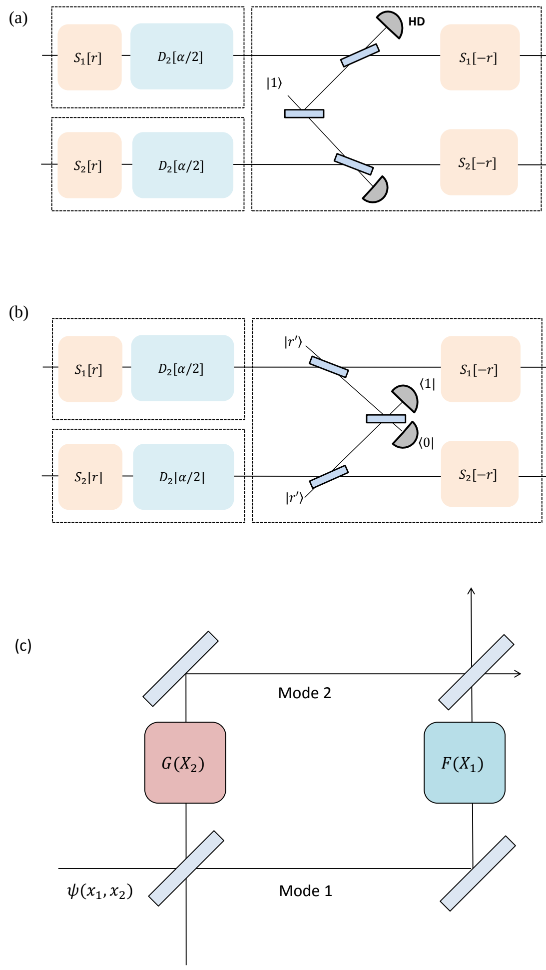


FIG. 1. (a) A feasible scheme to achieve the (anti-)symmetrical superposition of two displacements operators by a delocalized photon addition. A squeezing operation can be applied to enhance the amount of entanglement generated by the entangler. (b) An equivalent setup achieving the same entangler based on delocalized photon subtraction. Here we use the squeezed states as ancillas, which are measured by the single photon detector made of avalanche photodiodes. (c) A MZI-like setup achieving a nonlocal operation in an alternative way by applying local operation $F(\hat{X}_1)$ and $G(\hat{X}_2)$ on each arm.

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[1] S. Haroche and J.-M. Raimond, *Exploring the Quantum: Atoms, Cavities, and Photons.* Oxford University Press, Oxford (2006).

[2] K. Park, P. Marek, and R. Filip, Phys. Rev. A **91**, 033814 (2015).