Measurement-induced quantum state engineering and emulation of strong optical nonlinearities

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We experimentally perform conditional quantum operations on weak states of light in order to implement highly non-trivial state transformations. Coherently combining sequences of single photon additions and subtractions [1] has recently allowed us to orthogonalize any input light state and to generate coherent superpositions of the input and output states, thus producing arbitrary continuous-variable qubits [2].

Now we show that appropriate combinations of the above elementary quantum operations can faithfully emulate the effect of a strong Kerr nonlinearity on weak states of light. We experimentally demonstrate a nonlinear phase shift at the single-photon level by using weak coherent states as probes and characterizing the output non-Gaussian states with quantum tomography [3]. The strong nonlinearity is clearly witnessed as a change of sign of specific off-diagonal elements of the density matrix expressed in the basis of Fock states.

Both the generation of arbitrary continuous-variable qubits and the emulation of strong Kerr nonlinearities at the single-photon level represent crucial enabling tools for optical quantum technologies and for advanced quantum information processing.

References

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