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

M. Bellini\textsuperscript{1,2}, L.S. Costanzo\textsuperscript{1,2}, N. Biagi\textsuperscript{1,2}, A.S. Coelho\textsuperscript{3}, J. Fiurášek\textsuperscript{4}, A. Zavatta\textsuperscript{1,2}

\textsuperscript{1}Istituto Nazionale di Ottica (INO-CNR), Florence, Italy
\textsuperscript{2}LENS and Department of Physics, University of Firenze, Florence, Italy
\textsuperscript{3}Departamento de Engenharia Mecânica, Universidade Federal do Piauí, Teresina, PI, Brazil
\textsuperscript{4}Department of Optics, Palacky University, Olomouc, Czech Republic

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 \cite{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 \cite{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 \cite{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

\cite{1} M. Bellini and A. Zavatta, Manipulating light states by single-photon addition and subtraction, \textit{Progress in Optics}, \textbf{55}, 41-83 (2010)