Measurement-induced nonlinearities in two-mode systems

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Abstract

We present a theoretical investigation of the measurement induced nonlinearity in two-mode interferometer. We discuss the occurrence of two-mode squeezing, entanglement and nonclassical correlation verifying the violation of the Cauchy-Schwarz inequality in such a system. The influence of the phase and detection probability on the induced nonlinearity is analysed.

In optics, nonlinear effects can lead to various transformations of light. Parametric down-conversion (PDC) and four-wave mixing (FWM) are nonlinear effects that can generate entangled photons, quadrature squeezing, and other nonclassical effects. The generation of these effects typically requires strong light intensities. Another way of creating such nonlinear transformations in quantum optics is creating so-called measurement-induced nonlinearities (MINL) [1, 2, 3], where nonlinear effects can be acquired by applying detection. The advantage of using detection compared to PDC and FWM is that fewer incident photons are required to generate nonclassical effects. However, acquired effects have a probabilistic nature. In our work, we model a two-mode interferometer with different input states such as a coherent state and a single photon state and apply the detection to each channel, Fig. 1(left). We analyse the acquired nonclassical properties such as entanglement, two-mode squeezing $\Delta(\hat{X}_a - \hat{X}_b) < \Delta_{vac}$, $\hat{X}_i = (\hat{a}_i + \hat{a}_i^\dagger)/\sqrt{2}$ and the violation of the Cauchy-Schwarz inequality $I < 0$ (Eq. (1)) in the output state.

$$I = \frac{\sqrt{\langle a^{\dagger 2} a^2 \rangle \langle b^{\dagger 2} b^2 \rangle}}{\langle a^\dagger a b^\dagger b \rangle} - 1 \tag{1}$$

With certain combinations of system parameters, the detection leads to two-mode squeezing, which is absent without detection, Fig. 1 (right). These results will be used for a theoretical description of quantum photonic chips with superconducting detectors embedded into an integrated platform.

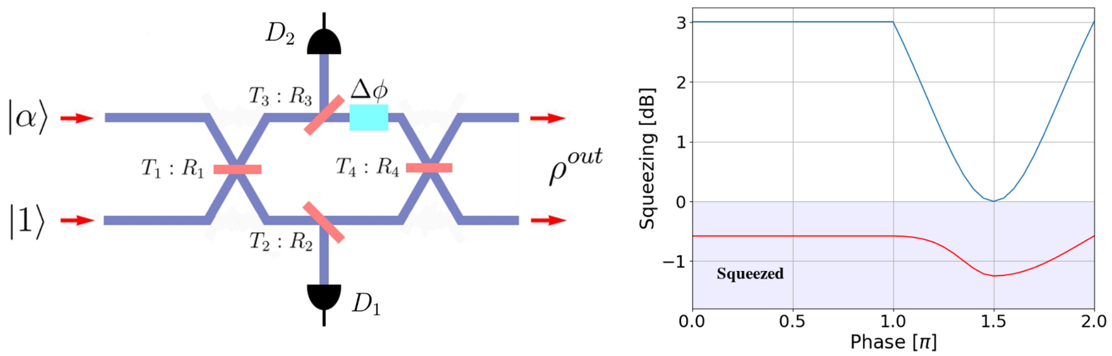

Fig. 1(left). A schematic representation of the investigated circuit: two waveguides (blue) with 4 beam-splitters (red), one phase modulator (cyan) and two detectors in the middle (black). Fig. 1(right). Two mode squeezing vs modulation phase. Input states are the coherent state with $\alpha = 1$ and a single photon state. The blue curve corresponds to a global maximum of squeezing for the interferometer without detectors. The red curve corresponds to a global maximum of squeezing for the scheme where only one of two detectors clicks with threshold probability higher than $P_{crit} = 0.1$. The dark area below 0 represents two-mode squeezed light.

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