Heralding Probability Optimization for Nonclassical Light Generated by Photon Counting on Gaussian States

Jaromír Fiurášek

Department of Optics, Faculty of Science, Palacký Univeristy,
17. listopadu 12, 779 00 Olomouc, Czech Republic

Generation of highly non-classical quantum states of light such as Fock states, Gottesman-Kitaev-Preskill states, superpositions of coherent states, or states exhibiting nonlinear squeezing is essential for optical quantum computing, quantum error correction, quantum metrology and sensing. Arguably the most popular and fruitful approach to engineering such sophisticated quantum states of optical fields consists of conditional heralding schemes, where photon counting measurements on a part of multimode Gaussian state herald successful preparation of the state in signal mode, see Fig. 1(a). Such conditional quantum state generation schemes encompass a majority of both early and recent experiments in the field.

Recently, maximization of the heralding probability for such conditional state preparation schemes has gained significant attention [1-4]. Although generic optimization algorithms can be utilized to maximize the heralding probability, it turns out that this problem can be formulated as finding solution to a system of polynomial equations. Consequently, techniques such as Gröbner basis construction or homotopy continuation can be applied to efficiently find the optimal configuration that maximizes the heralding probability. Here we develop this approach in detail for both single and multiple heralding modes. Our approach greatly benefits from the stellar (or Bargmann) representation of quantum states of bosonic systems and the concept of core states [5].

We show that for a single heralding mode the maximization of the heralding probability p_S can be performed analytically [4] and we investigate the dependence of p_S on the number of counted photons, see Fig. 1(b). Our approach can seamlessly incorporate a bound on the available quadrature squeezing which is highly practically relevant, because the unconstrained optimization may yield squeezing levels that are not experimentally available yet. Our results provide tools for optimization of engineering sophisticated quantum states of light with complex structure in Fock basis and phase space.

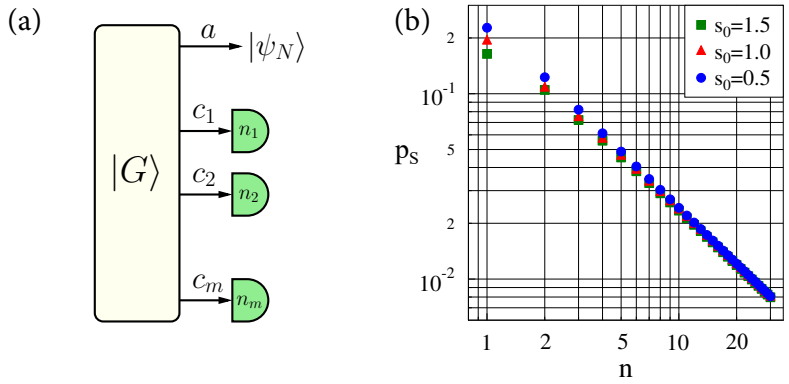

FIG. 1: (a) Conditional generation of nonclassical state $|\psi_N\rangle$ by photon counting measurements on part of multimode Gaussian state $|G\rangle$. (b) Dependence of the maximum heralding probability p_S of state $|\psi_n\rangle \propto (\hat{a}^\dagger + s_0\hat{a})^n|0\rangle$ on the number of counted photons n for single heralding mode.

References

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