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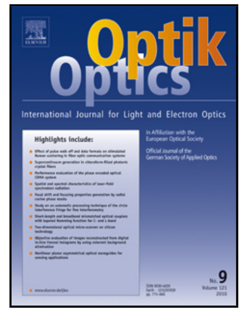

Title: Hermite polynomial excited squeezed vacuum state: generation and nonclassical properties

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Hermite polynomial excited squeezed vacuum state: generation and nonclassical properties

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We proposed a theretical scheme for generating a new kind of non-Gaussian state——Hermite polynomial excited squeezed vacuum states——by using parametric amplifier process and conditional measurement. Specially, two different single-mode squeezed vacuum states were injected into the signal and idler ports of parametric amplifier and m-photon was detected in idler output port, then the new non-Gaussian state is generated in signal port. It's normalization factor is found to be related with Legendre polynomials that corresponds to the success probability of such event. We investigated the nonclassical properties according to photon-number distribution, sub-Poissionian distribution, antibunching effect, quadrature squeezing effect, and Wigner function. It is shown that there is a wide range of nonclassical phenomen created by tuning the interaction parameters. Our study may provide a theoretical reference to generate nonclassical state for experiment.

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I. INTRODUCTION

The non-classical state has an important role in quantum information protocol and it is also a fundamental goal of the field of quantum optics to understand, generate, and ultimately manipulate nonclassical states of light [1–3]. Generally speaking, in order to realize effective quantum information processing (QIP) tasks, it is usually required to prepare more and more optical nonclassical states [4]. Thus, quantum state engineering has been a subject of increasing interest to prepare various novel nonclassical states [5, 6]. For example, the single-photon added coherent state [7] and single-photon-added thermal state [8], have been realized experimentally. Actually, these non-Gaussian operations including both addition and subtraction have been used to probe experimentally the quantum commutation rules [9].

Among many researches of quantum state engineering, photon addition and photon subtraction as well as their superposition are considered simple and effective methods for improving the nonclassical properties and the degree of entanglement as well as the performance of the quantum-key distribution [10–14]. For instance, the subtraction operation can increase the secure distance and the single-photon-added coherent source can present better performance in quantumkey distribution than all other existing sources. In addition, the superposition of both addition and subtraction can be used to not only increase the nonclassical property but also improve the degree of entanglement of entangled states such as two-mode squeezed states and entangled coherent states.

In fact, these above non-Gaussian operations can be achieved by using beam splitter and conditional measurement. When photon number state $|m\rangle$ as an idler mode and any signal state accident at two input ports of beam splitter, then the photon-subtraction operation a^m is obtained after the conditional measurement with non-photon counting at the idler mode of the output channels. In a similar way, when the vacuum as an idler mode and the conditional measurement with n-photon counting are used, the photon-addition operation $a^{\dagger m}$ is achieved. Recently, a scheme is proposed to generate the Laguerre polynomial excited coherent state (LPECS) via the unbalanced beam splitter with coherent state and Fock state $|m\rangle$ inputs and the measurement same as input state $|m\rangle$ (named as photon catalysis) [15]. It is found that the maximum degree of squeezing can be enhanced by increasing the photon number. Then this scheme is entended to two-mode case, that is to say, the multiphoton catalysis is used to enhance the degree of entanglement of the two-mode squeezed saueezed vacuum and the fidelity of teleportation of quantum state by using the new entangled resource [16]. It is shown that the catalysis operation with two-mode symmetrical single-photon operation can present the best performance for the enhancement of teleportation in the initial-low squeezing regime. All these results indicate that conditional measurement can be seen as a very useful way for preparing new quantum states, especially for such polynomial quantum states.

On the other hand, as another polynomial excited state, the Hermite polynomial state has been paid much attention due to the minimum uncertainty [17, 18] and nonclassicality of such quantum state can be enhanced by Hermite polynomial operation [19–21]. For instance, by applying theoretically the Hermite polynomial as a function of the coherent superposition of photon-creation and annilihation operators $(\mu a + va^{\dagger})$ on the single-mode squeezed vacuum, another non-Gaussian state, named as Hermite polynomial squeezed vacuum, is introduce [19]. Single photon subtraction/addition squeezed vacuum, Hermite polynomial subtraction/addition are its special cases. In addition, by extending the wave-packet states with a vortex structure to a general case, a kind of two-mode Hermite polynomial excited squeezed vacuum is introcuced [22]. However,