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Nonclassical properties and generation of superposition state of excited coherent states of motion of trapped ion

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Abstract. We have studied the intensity squeezing of superposition state of excited coherent states and proposed a new method to prepare superposition state of excited coherent states of vibrational motion of trapped ion. This method is based on the interaction of a single trapped ion with two traveling wave light fields with different frequencies. An obvious merit of this method is that it works without application of the perturbation theory.

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Key words: trapped ion, excited coherent states, intensity squeezing

1 Introduction

In the past years, great efforts has been made to prepare a variety of nonclassical states of atoms and ion owing to their potential practical applications such as precision spectroscopy [1] and quantum computation [2]. So far many schemes have been proposed to prepare Fock states of the vibrational motion of the trapped ion, for example, by advantage of quantum jump effects [3], or by applying two-color laser fields successively [4]. Squeezed states of motion of trapped ion can be generated by applying two standing wave laser fields with different frequency [5], or by Raman transition in two trapped ions [6]. The squeezed states of light fields can be prepared in high-Q cavity [7,8]. The entanglement of coherent motional states of multiple trapped ions can be generated [9, 10]. In addition, the authors of Ref. [11] have investigated the excitation coherent state and proposed a scheme for its preparation based on perturbation theory. The authors of Ref. [12] investigated nonclassical properties of states generated by the superposition of excitation coherent state. They found that effect of the phase of coherence states on the evolution of mean photon number and squeezed properties. The authors of Ref. [13] investigated Wigner function for the photon-added even

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and odd coherent state. Schemes for generation of these states have been proposed, but they are all based on perturbation theory.

In this paper, we investigate the intensity squeezing of excited Schrödinger cat states and propose a method to prepare the excited Schrödinger cat states of vibrational motion of trapped ion. This method is based on interaction of a single trapped ion with carrier and blue side traveling wave light fields. The excited coherent state of the motion of the ion can be produced by controlling the interaction time of the ion with fields.

2 Intensity squeezing of excited Schrödinger cat states

The excited Schrödinger cat states is defined as

$$\left|\varphi^{(m)}\right\rangle_{\pm}=\frac{1}{\sqrt{N}}(a^{+})^{m}\left(|\alpha\rangle+e^{i\phi}|\alpha\rangle\right), \tag{1a}$$

$$N=2m!\left(L_m(-|\alpha|^2)+\cos\phi\, L_m(|\alpha|^2)e^{-2|\alpha|^2}\right), \tag{1b}$$

where N is a normalized constant, $L_m(-x)$ is Laguerre polynomial, $\alpha=|\alpha|e^{i\theta}=re^{i\theta}$. Here we study intensity squeezing of the excited Schrödinger cat states. For this goal we define orthogonal Hermite operators X_1 and X_2 as

$$X_1=\frac{1}{2}(a^2+a^{+2}), \qquad X_2=\frac{1}{2}(a^{+2}-a^2). \tag{2}$$

The fluctuation of the operators X_i satisfies

$$\Delta X_1\Delta X_2\geq\frac{|\langle C\rangle|}{2}, \tag{3a}$$

where

$$\Delta X_i=\sqrt{\langle X_i^2\rangle-\langle X_i\rangle^2}, \qquad C=[X,Y]. \tag{3b}$$

If the fluctuation of the operator X_i in a state satisfies the relation

$$S_i=\frac{\Delta X_i-\left|\langle C\rangle\right|}{2}<0, \tag{4}$$

we then say this state has the property of intensity squeezing. Using the formulae

$$a^n(a^{+})^m=\sum_{k=0}^{m}\frac{m!n!(a^{+})^k a^{k+n-m}}{(m-n)!(n-m+k)!k!}, \tag{5}$$

and expression of the associated Laguerre polynomial

$$L_m^{(l)}(-x)=\sum_{n=0}^{m}\frac{(m+l)!}{(m-n)!n!(l+n)!}(-x)^n, \tag{6}$$