Indian J. Phys. **74B** (6), 471 -473 (2000)

I J P B
an international journal

Squeezing in CAHRS under short-time approximation

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Received 14 June 2000, accepted 18 September 2000

Abstract The nonclassical effect of squeezing of light in coherent antistokes hyper Raman scattering (CAHRS) is investigated under short-time approximation based on a fully quantum mechanical approach The occurrence of squeezing in amplitude and higher order squeezing-amplitude squared and amplitude cubed of the fundamental mode have been investigated The dependence of squeezing on photon number is brought out and the degree of squeezing in the first order and higher order are investigated.

Keywords Coherent antistokes Raman scattering, squeezing.

PACS Nos. 42 50 Dv, 42.65.Dr

1. Introduction

Squeezing of radiation [1] is a purely nonclassical phenomenon without any classical analogue. Squeezing is expected to manifest itself in optical processes in which the nonlinear response of the system to the radiation field plays an important role. Hence, one of the recent applications of nonlinear optical processes has been the generation of squeezed light. Squeezing has either been experimentally observed or theoretically predicted in nonlinear optical processes, such as harmonic generation [2,3], four-wave mixing processes [4,5], Raman [6,7], hyper raman [8] and multi-wave mixing [9] processes. In recent times, various higher order nonlinear optical processes, such as, coherent antistokes Raman scattering (CARS) and coherent antistokes hyper Raman scattering (CAHRS) have been used to obtain highly tunable laser sources at diverse frequencies. Due to their high nonlinearities, they can play important role in the generation of squeezed light. In a recent publication [10], we have studied the aspect of squeezing and higher order squeezing in CARS based on a fully quantum mechanical theory. In this paper, we intend to extend the technique to study of squeezing and higher order squeezing in coherent antistokes hyper Raman scattering. The occurrence of amplitude and higher order squeezing in the fundamental mode is investigated and the dependence of squeezing on photon number is also studied.

2. Definition of squeezing and higher order squeezing

Squeezed states are characterised by reduced quantum fluctuations in one quadrature component of the field at the expense of increased fluctuations in the other non-commutating component. It is possible to characterize the amplitude by its real and imaginary parts [7] as

$$X_1 = 1/2(A + A^+), \; X_2 = 1/2i(A - A^+), \tag{1}$$

where A and A^+ are the slowly varying operators useful in discussing squeezing defined as

$$A = a\exp(i\omega t), \; A^+ = a^+ \exp(-i\omega t), \tag{2}$$

for a single mode of the electromagnetic field of frequency ω and creation and annihilation operators a^+ and a respectively. These operators do not commute and obey the uncertainty relation

$$\Delta X_1 \Delta X_2 \geq 1/4. \tag{3}$$

A quantum state is squeezed in the X_1 direction if $\Delta X_1 < 1/2$ and is squeezed in the X_2 direction if $\Delta X_2 < 1/2$.

Amplitude squared squeezing [7,9] is defined in terms of operators Y_1 and Y_2 given by

$$Y_1 = 1/2(A^2 + A^{+2}), \; Y_2 = 1/2i(A^2 - A^{+2}), \tag{4}$$

and they obey the uncertainty relation

$$\Delta Y_1 \Delta Y_2 \geq \langle (N + 1/2) \rangle, \tag{5}$$

where $N = A^+A$ is the number operator.