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Generation of squeezed atomic states in cavity QED

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Abstract. A squeezed atomic state is that state of a system of two-level atoms for which the intrinsic quantum noise in a process of measurement is less than the minimum noise obtained by using a spin coherent state. It is shown that such a state is generated in certain time intervals when a non-squeezed atomic state evolves on interaction with a single mode coherent field inside a lossless cavity. The atoms are assumed to undergo one-photon or two-photon transitions between the given two levels. The maximum atomic squeezing is found as a function of the number of atoms and the field strength. The effect of the field-dependent Stark shift is investigated in the case of the atoms undergoing two-photon transitions.

Keywords. Atomic squeezing; coherent state; Stark shift; quantum noise; uncertainty relation.

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1. Introduction

A squeezed state of the electromagnetic (e.m.) field is useful in achieving sub-quantum noise in a process of measurement. In the same way, one expects to achieve sub-quantum noise in a process of measurement involving spins or equivalently atoms by use of particular kind of states which may be called squeezed spin or squeezed atomic states in analogy with the case of the e.m. field. Of particular interest to us here are the measurement processes involving two-level atoms. Clearly, because of their usefulness as a means of reducing quantum noise, the methods of generation of such states are of particular interest. In this paper we propose the methods of generation of squeezed states of two-level atoms in cavity QED. Since a system of two-level atoms is mathematically equivalent to a system of spin-$1/2s$, we will use the terms atoms and spins interchangeably.

The method described here is in terms of a system of two-level atoms interacting with a single e.m. mode in a lossless cavity. We consider two cases of atomic transition. One is when the transition between the levels is by means of absorption or emission of one photon and the other is when that process is mediated by two photons at a time. Those processes are described by the one-photon or two-photon Jaynes–Cummings hamiltonian as the case may be. In each case we determine the maximum attainable squeezing as a function of the number of atoms and that of the strength of the cavity field. The two-photon process leads to an intensity dependent level shift known as the Stark shift. We