Preparation of W, GHZ, and two-qutrit states using bimodal cavities

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Abstract. We show how one can prepare three-qubit entangled states like W-states, Greenberger–Horne–Zeilinger states as well as two-qutrit entangled states using the multi-atom two-mode entanglement. We propose a technique of preparing such a multi-particle entanglement using stimulated Raman adiabatic passage. We consider a collection of three-level atoms in A configuration simultaneously interacting with a resonant two-mode cavity for this purpose. Our approach permits a variety of multi-particle extensions.

1. Introduction

Entanglement between two qubits can be produced only if there is some kind of interaction between the qubits [1–4]. This could be the exchange interaction between the two spins or the dipole–dipole interaction between, say, two atoms. The entanglement produced by direct interaction has been extensively studied [5]. However the direct interaction falls very rapidly as the distance between qubits increases. It turns out that in such situations one could produce entanglement using cavity fields [6]. The non-interacting atoms get coupled because of the interaction with a common quantized field. Agarwal et al. had shown earlier [7], how coherently prepared atoms, on interaction with the vacuum of the cavity field produce mesoscopic superpositions which exhibit the same type of entanglement character as the Greenberger–Horne–Zeilinger (GHZ) states. There have been many proposals for producing entanglement using cavities [8, 9]. Haroche and his co-workers have produced a variety of entanglement using cavity quantum electrodynamics (QED) based schemes. In this paper we show how bimodal cavities can be used for producing multi-atom and bimodal field entanglement and how this entanglement can be used to produce a variety of entangled states such as W-states [10], GHZ states [11] and two-qutrit states [12]. We consider the interaction of N three-level atoms in A configuration interacting with a bimodal cavity for this purpose. The entangled states thus prepared are comprised of ground states of the three-level atoms.

We note that W-states, GHZ states and a host of other types of multi-mode states of the radiation field have been realized using the fields produced in the process of downconversion by using appropriate detection schemes [13, 14]. Further entanglement between atoms has also been realized by suitable projection schemes [15–17]. Detection procedures have also been found to be useful in implementing non-deterministic logic gates [18].