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Ph.D. Pre-Thesis Submission Seminar

Name of the student : H. B. Crispin (R151405)
Name of the supervisor : Dr. R. Arun, Department of Physics, CUTN
Title of the thesis : "**Vacuum-mediated coherence effects in laser-driven atoms"**
Date and time : **1.07.2021 (Thursday) and 4.00 p.m.**
Google Meet Link: https://meet.google.com/zjp-xhmz-twz :

Abstract

Since the emergence of quantum mechanics, interference effects have attracted the attention of many scientists. Particularly, quantum interference in atomic systems have been extensively studied theoretically and experimentally. Interference between different transition pathways in an atom gives rise to remarkable phenomena such as coherent population trapping, lasing without inversion, and electromagnetically induced transparency. These novel effects require the application of external coherent fields. However, quantum interference effects can naturally occur in the spontaneous emission of atoms. Spontaneous emission is a fundamental process in which an atom in an excited state decays to the ground state by emitting a photon in a random direction. This is due to the interaction of the atom with the surrounding electromagnetic vacuum field and is the reason for most of the visible light around us. In atomic systems, interference between different spontaneous decay pathways is possible if identical photons are emitted by two or more excited atomic states decaying to a common ground state. Such decay-induced interferences lead to the creation of coherence between the upper levels by the electromagnetic vacuum field. Therefore, interference effects of this kind are also known as vacuum-induced coherence (VIC) in the literature. So far, it has been difficult to realize VIC effects in atoms due to the stringent condition that the relevant atomic dipole matrix elements be nonorthogonal. This requirement is rarely met in atomic systems. In this work, we investigate the influence of vacuum induced coherence in realistic level schemes with nonorthogonal transition dipole moments. First, we consider a driven four-level atom in J=1/2 to J=1/2 configuration. The stringent conditions for VIC are naturally satisfied in this system. Also, the level structure is experimentally realizable in $^{198}Hg^{+}$ ions. It is thus a suitable candidate to probe for the VIC effects. We find that the resonance fluorescence and the squeezing spectrum of this atomic system exhibits a strong signature of VIC effects. The spectral profile is significantly modified due to the presence of VIC. Also, phase control of fluorescence and squeezing is demonstrated. Second, we propose an alternative scheme for the simulation of quantum interference effects in atomic systems where the conditions for VIC are not fulfilled. Specifically, we focus on the three-level V-type atom that has received much attention in previous studies. We demonstrate that it is possible to simulate VIC effects in the fluorescence spectrum of this system via polarization-selective detection of the emitted light. The induced-interference leads to interesting features such as enhancement and/or suppression of the sidebands and disappearance of fluorescence.

References:

1. H. B. Crispin and R. Arun, Fluorescence control through vacuum induced coherences, J. Phys. B: At. Mol. Opt. Phys. **52**, 075402 (2019).
2. H. B. Crispin and R. Arun, Squeezing in resonance fluorescence via vacuum induced coherences, J. Phys. B: At. Mol. Opt. Phys. **53**, 055402 (2020).
3. H. B. Crispin, Simulating quantum interference effects in the fluorescence of a V-system with perpendicular dipole moments, J. Phys. B: At. Mol. Opt. Phys. **54**, 075402 (2021).

All are Welcome