CHAPTER ONE

Introduction

1.1 Historical review

The end of the 19 th century marks the transition from purely classical optics era to quantum optics ; Max Planck's proposed in 1900 that an oscillating electric system does not impart energy to the electromagnetic field in a continuous manner but in finite amounts of energy **[1.1]**. There are various questions remained unanswered through classical optics especially the reason for the spectral characteristics of black-body radiation **[1.2]**. Classical optics failed to explain the phenomena of black-body radiation and this led Planck to introduce the concept of energy "quanta" to resolve the problem of the black-body radiation. Planck introduced the first step towards the quantum theory of light and has deeply influenced our fundamental understanding of light and matter. The discovery of the quantum nature of light has revolutionised the physics of optics and mark the beginning of the new age of optics.

In the classical world, everything appears to wind down to a final halt, but in the quantum world, motion seems to be an inherent property of every systems. The presence of quantum motion in every system led Planck to introduce the concept of zero point energy into physics **[1.3]**. This concept successfully explained the existence of energy in the vacuum state. Since according to quantum mechanics, physical quantities have a tendency to fluctuate even in the apparent quietness of vacuum state , pairs of particle are constantly appearing and disappearing. Such fluctuations contribute energy to the vacuum. Therefore, vacuum is defined as a state of the lowest energy **[1.4]**. The vacuum state is the state of electromagnetic field in which no photons are excited in any of the field modes. It has an interesting property that though no excitations are present, the total energy density does not vanish. The energy of the vacuum state is called the zero point energy.

In the development of quantum theory, there are a significant number of theorist who believed that quantization of radiation is unnecessary but only matter is quantized to explain all the physical effects **[1.5]**. We call this type of approach the semi-classical approach. There are certain phenomena such as photoelectric effect successfully explained by this approach. This dissertation however concentrates on some theoretical problems in the interaction of the electromagnetic field with matter where both field and matter are quantized.

1.2 Aim and Objective

The outline of the dissertation is as follows. Following the present chapter, chapter two is concerned with some aspects of the theory and fundamental concepts of quantum optics. We begin with the formulation of quantum mechanics relevant to the interaction of radiation with matter. Certain mathematical topics are essential for quantum mechanics, not only as computational tools, but because they form the most effective language in terms of which the theory can be formulated. These topics include the theory of linear vector spaces and linear operators. Quantum mechanics does not predict a deterministic course of events, but rather the probabilities of various alternative possible events. Therefore the statistical states in quantum theory is also discussed.

In chapter three, we deal with the analytical solution for the atomic master equation for the reduced atomic density operator for the coherently driven Dicke model interacting with a normal vacuum and used a symbolic manipulating software to obtain the absorption-dispersion spectra. Absorption-dispersion spectra have received considerable attention in recent years; see M.Fleischhauer et al. (1992) **[1.6]**, M.O.Scully (1991) **[1.7]**, M.O.Scully et al. (1992) **[1.8]**, H.Y.Ling et al. (1994) **[1.9]** and H.Friedmann et al. (1995) **[1.10]**. We study the effect of dipole-dipole interaction on the absorption-dispersion spectra of a two-atom system on a resonance under the action of an external coherent driving field. It would be interesting to see how dipole-dipole interaction could change the spectrum.

The main theme of chapter four is almost similar with chapter three but the case and method are different. We examined an off-resonance case without the inclusion of dipole-dipole interaction and using the secular approximation technique to get the analytical expression for the absorption-dispersion spectra for a system of two two-level atoms. This technique has been applied to a variety of atom-field interaction problems with considerable success. See Agarwal et al.(1979) **[1.11]**, Kilin (1980) **[1.12]**, Hassan et al. (1982) **[1.13]**, Cordes (1982) **[1.14]** and Lawande et al. (1985) **[1.15]**. The results obtained are in excellent agreement with numerical ones.

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