ECE 770 T14/QIC 885: Quantum Electronics & Photonics

Lecture 12

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Abstract and Objectives of Lecture 12

We continue our discussion of Atom-EM field interaction by considering the quantized EM field. Our main achievement will be the prediction of spontaneous emission. This treatment will be shown to be useful where the number of photons involved in the interaction is very small as the particle-like behavior of EM field is more pronounced. We will find transition probabilities for absorption and emission versus number of photons. Cavity Quantum Electrodynamics will be the next topic of our interest as we re-explore the effect of a single-mode quantized field in the cavity with two-level system in hope of having stronger interaction. By brief discussion on how we can characterize non-ideal cavity, we explore two distinct regimes of atom-field interaction, namely weak and strong. We will quantify both of these regimes in terms of three important parameters, atom-photon coupling, photon decay rate and non-resonant decay rate. In weak coupling regime, we will calculate the spontaneous emission rate in the cavity and introducing the **Purcell effect**. In strong coupling, we will give the results of **Jaynes-Cummings model** and introduce the **dressed states** of the atom-photon system. The vacuum Rabi Splitting will be discussed briefly afterwards.

Then, we turn our attention to photon-electron interaction. No new formalism is required and the discussion is pretty straightforward as dipole interaction $\hat{d}\ .\ \hat{\mathbf{E}}(r,t)$ is replaced by interaction Hamiltonian $\frac{q}{m}\hat{p}\ .\ \hat{\mathbf{A}}(r,t)$. We consider the interaction of photon with free-electron and bound electron and discuss the famous statement of "free-electron can neither emit nor absorb photon". We finish up our course at this point with some concluding remarks.

Topics of Lecture 12

8-9) Interaction of Atom with Quantized EM Field

9) Cavity Quantum Electrodynamics

9-1) Non-Ideal Cavity Resonator

9-2) Atom-cavity Coupling

9-3) Weak Atom-Photon Coupling

9-4) Strong Atom-Field Coupling

9-5) Electron-Photon Interaction

References & Suggested Readings

1- M. Fox, *Quantum Optics, An Introduction*, Oxford, 2006, Chapters 9 and 10.

2- N. Zettili, *Quantum Mechanics, Concepts and Applications*, 2^{nd} ed., JW&S, 2009, Chapter 10.

3- C. Gerry and P. Knight, *Introductory Quantum Optics*, Cambridge, 2005, Chapter 4.

4- D. Marcuse, *Principles of Quantum Electronics*, Ap, 1980, Chapter 4.

5- J. Weiner, P.-T.Ho, *Light-Matter Interaction Volume 1*, JW&S, 2003, Chapters 4, 5 and 6.