ECE 770 T14/QIC 885: Quantum Electronics & Photonics

Lecture 11

Instructor: A. H. Majedi, University of Waterloo, Spring 2013

Abstract and Objectives of Lecture 11

EM Field- Atom interaction is the name of the game for this lecture. We start by discussion of EM-Field/matter interaction from field perspective, specifically Hamiltonian of the systems comprises EM Field, matter and their interaction, from classical, semi-classical and quantum point of views. After some introductory remarks, we consider the simplest quantum model of an atom (real one or artificial one); two-level system. Since the EM fields are time-varying, we focus on the temporal dynamics of the system in Schrodinger and interaction pictures, developing time-dependent perturbation theory to solve Schrodinger equation. By focusing on the sinusoidal perturbation, as it is in case of EM field, we solve first-order perturbation equation (weak-field limit) to come up with transition probability between two states and introduce the Rabi oscillation phenomenon. By introducing rotating-wave approximation, we solve the same problem without perturbation assumption (strong field case) for comparison. We formally cast, what we have achieved so far, to formulate the stimulated emission and absorption of EM radiation. To complete the discussion, spontaneous emission will be discussed following the semiclassical treatment originally presented by A. Einstein. In order to calculate the spontaneous transition probabilities, we will present dipole selection rules and eventually generalize the discussion to a multi-level system.

Topics of Lecture 11

8-1) EM Field-Matter Interaction

8-2) Atom/EM Field Interaction

8-3) Two-Level Quantum System

8-4) Rabi Oscillation

8-5) Emission and Absorption of EM Radiation

8-6) Spontaneous Emission (Semi-Classical)

8-7) Dipole Selection Rules

8-8) Time-Dependent Perturbation Theory for Multi-Level Systems

References & Suggested Readings

1- P.L. Hagelstien, S. D. Senturia, T.P. Orlando, *Introductory Applied Quantum and Statistical Mechanics*, Wiley, 2005, Chapters 21 and 22.

2- D.J. Griffith, *Introduction to Quantum Mechanics*, 2^{nd} ed., PH, 2005, Chapter 9.

3- A.F.J. Levi, *Applied Quantum Mechanics*, 2^{nd}*ed.*, Cambridge Press, 2006, Chapter 8.

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

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

6- J. Weiner, P.-T.Ho, *Light-Matter Interaction Volume 1*, JW&S, 2003, Chapters 1, 2, 3, 4 and 5.