**Quantum electronics and photonics**

Prof. Gabriele Ferrini

***COURSE AIMS AND INTENDED LEARNING OUTCOMES***

The main objective of the course is to provide the basic knowledge for the light matter interaction. The acquired knowledge will allow students to understand the most important physical processes behind the working principles of many optoelectronic instruments and devices. Particular attention will be dedicated to the physics of lasers and to the coherent interaction between radiation and atomic systems.

The course is divided in two parts. The first one will focus on the problem of the radiation-matter interaction adopting the semiclassical approach. In the second part, we will introduce the basic concepts necessary to understand the second quantization of the electro-magnetic field and to capture the quantum nature of many phenomena that have been discussed in the first part of the course.

***COURSE CONTENT***

-The two-level system interacting with an e.m. field.

-The optical Bloch equations (R. P. Feynman, F. L. Vernon, R. W. Hellwarth, J. Appl. Phys. 28, 49 (1957))

- Consequences of Bloch equations: Rabi frequency, rotating wave approximation, polarization, population inversion, optical nutation, free induction decay, photon echo.

-Optical linear response, macroscopic polarization density, population inversion density, dispersion, absorption and the power broadening (dynamical Stark effect).

-Homogeneously and inhomogeneously broadenend transitions, saturation intensity, hole burning.

-Traveling wave amplification, incoherent (or adiabatic) interaction (Frantz and Nodvik, J. App. Phys. 24, 2346 (1963)).

- Light Amplification by Stimulated Emission of Radiation. The cavity and atomic rate equations. Three levels and four level systems. Examples of laser systems.

- Extension of the semiclassical treatment, quantization of the electromagnetic field.

- Extension to N interacting systems. Density matrix.

***READING LIST***

B. E. A. Saleh, M. C. Teich*, Fundamentals of Photonics****,*** Wiley-Interscience, 2007.

E. Rosencher, B. Vinter***,*** *Optoelectronics*, Cambridge University Press, 2002.

A. Yariv, *Quantum Electronics*, John Wiley & Sons, 1989.

R. Loudon, *The Quantum Theory of Light*, Oxford University Press, 1973.

O. Svelto & D.C. Hanna, *Principle of Lasers*, Springer 1998.

***TEACHING METHOD***

Lectures, notes handed out in class and seminars. The exercises deal with specific aspects of the theory presented in class, examples and comments. The active participation of the students is strongly encouraged via group discussions and individual questions.

***ASSESSMENT METHOD AND CRITERIA***

The exam consists in an essay and an oral examination.

The essay will focus on a topic of the course that is of particular interest to the student. The evaluation of the essay will take into account the quality and effectiveness of the presentation and above all the degree of personal elaboration of concepts by the student.

General remarks

The oral examination aims to assess the degree of assimilation of the concepts illustrated in the lectures. The student should be able discuss technical questions or problems from the examiners both in words and by writing equations and figures on the blackboard. The questions and/or problems will focus on selected topics of the program, not excluding references to prerequisites or connections between parts of the same. The evaluation of the oral examination will take into account the students’ depth of knowledge and their ability in problem solving. A particular emphasis will be on the degree of personal elaboration of the topics by the candidate.

Covid-19

In case the current Covid-19 health emergency does not allow frontal teaching, remote teaching will be carried out following procedures that will be promptly notified to students.

***NOTES***

In order to understand the material presented in the course, the student must have previously attended the courses on classical electromagnetism and optics.

Prof. Ferrini receives in his office every day by appointment.