AtMol Graduate course 2014/2015

All students are required to successfully complete a minimum of 45 credits from the range of Post- graduate Lectures taught within the department during Michaelmas and Epiphany terms of their first year. The choice of courses must be agreed with the PhD supervisor and in most cases must include a recognised core set of courses specific to a PhD in atomic and molecular physics.

Available Courses and Credits

Core Courses

- *Atom-Light Interactions* Dr. M. Jones (15 credits)

  The aim of the course is to provide the theoretical framework needed to understand research publications in AMO physics. Topics covered include: The two-level atom. Quantum mechanical treatment. Rabi oscillations. The Density matrix. Including spontaneous decay. Optical Bloch equations and steady state solutions. The dipole moment of an atom in a monochromatic field. Susceptibility. The importance of coherence in atom-light interactions. Three-level systems. CPT. EIT. Atoms in external fields. The Breit-Rabi diagram.

  The best graduate textbook is "Atom-Photon interactions" by Cohen-Tannoudji, Dupont-Roc and Grynberg (Wiley, 1992); closely followed by "The Quantum Theory of Light" by R Loudon (OUP). The book "Atomic Physics - an exploration through problems and solutions" by Budker, Kimball and DeMille has many useful and interesting problems. The best description of the Breit-Rabi diagram is in "Elementary atomic structure" G K Woodgate (OUP).

- *Data Analysis* Prof. I. Hughes and Dr. M. Hunt (7.5 credits)

  The first half of the course deals with measurements and their un- certainties. After a brief review of the topic at undergraduate level, we rapidly move on to more advanced concepts: the central limit theorem; correlations in error propagation; least-squares fitting; the concept of a "good fit", qualitative and quantitative; and hypothesis testing. Extensive use is made of the chi-squared statistic. The course is useful for experimentalists and theorists alike, as it allows both to answer questions such as "do the experimental results agree with the theory", "does the theory agree with the experimental results?", and for theorists "which model works best?".

  The first half of the course follows closely the treatment of I G Hughes and T P A Hase "Measurements and their Uncertainties" (OUP, 2010).

- *Quantum 1* Prof. S. Gardiner (7.5 credits)

  The course is divided into two halves. The first (1A) covers common and useful techniques and manipulations, such as scalings and reductions to minimal parameter sets, frame transformations, and dealing with explicitly time dependent Hamiltonians, specifically as applied to a two-level atom driven by a classical laser field. The second (1B) covers systems of identical particles, and the formalism of second quantisation, particularly as applied to a dilute Bose gas. We may also cover lattice systems, if time permits. **Note that both halves of the module must be completed in order to gain the credits**.

Optional Courses

- *Quantum 2* Dr. R. Potvliege (7.5 credits)

  The course reviews the essentials of quantum scattering, including cross section, phase shift, scattering length, shape resonances, quantum defect, an introduction to multichannel scattering and Feshbach resonances. The essentials of what concerns the interaction of an ensemble of atoms with light, including dipole-dipole interactions, will also be outlined. This course is timetabled as 2A and 2B. **Note that both halves of the module must be completed in order to gain the credits**.

- *The Structure and Spectroscopy of diatomic molecules* Dr. D. Carty (7.5 credits)

  The topics covered in this graduate course are as follows: diatomic molecules; valence-bond theory; molecular orbital theory; the structure of diatomic molecules; heteronuclear diatomic molecules; the H2 molecule; electronic states of diatomic molecules; the characteristics of electronic transitions; the physical reasons for molecular binding; rotation and vibration of diatomic molecules; rotational infrared, millimetre wave and microwave spectra; spectra of diatomic molecules; vibrational spectroscopy; electronic spectroscopy of diatomic molecules; the fates of electronically excited states. This course is a reading course. You will read the handouts given and each week for eight weeks you will answer some homework questions. At the end of each week, we will all meet and discuss the worked solution. Marks are assigned by peer assessment against this mark scheme.

- *Introduction to Optical engineering* Dr. S. Rolt (7.5 credits)

  The aim of this course is to provide a background or foundation knowledge in optics to enable the intelligent use of optical design software and also to provide some simple (stand alone) optical design tools. Topics covered include: introduction to geometrical optics; geometric and matrix optics (ray tracing); monochromatic aberrations; aspheric optics and chromatic aberration; diffraction and image quality; polarisation and birefringence.

- *Optical Systems Design* Prof. R. Sharples (7.5 credits)

  Aims: To introduce the design principles of lens and mirror optical systems and the evaluation of designs using modern computer techniques. The lectures will cover lens design, aberrations, optimization, tolerancing and image quality metrics. More details at http://astro.dur.ac.uk/ rsharp/opticaldesign.html Syllabus: Lecture 1: Introduction; Lecture 2: Sequential Systems; Lecture 3: Optimization; Lecture 4: Tolerancing; Lecture 5: Non-sequential etc.

- *Experimental skills* (7.5 credits) This module groups together some of the intensive training courses offered by the department in advanced experimental skills. It includes training in *Inventor* CAD software, mechanical workshop skills, and advanced LabView and FPGA programming.

- *Dipole physics* Prof. C. Adams (7.5 credits)

  In atomic, molecular and optical physics, dipoles play a key role. First we focus on induced electric dipoles and relate the microscopic dipolar response to macroscopic optical properties such as refractive index and scattering. In the context of the optical response we will consider topics such as non-linear optics, and slow and fast light. Second we discuss dipole-dipole interactions in various contexts from one dipole and surface to cavity QED and dipolar QED. Finally, we will explore how dipolar interactions can be exploited in various contexts.