University of Strathclyde Science

Department of Physics
Class Information

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| **Class Code** | SUPASTA |
| **Class Name** | SUPA Semi-classical Theory of Atom-Light Interaction |
| **Level** | PhD, MSci |
| **Credit** | 24 |
| **Teaching Staff** | Prof. G-L Oppo |
| **Lecture/Tutorial Times/Locations** | Semester 1, Wednesday 1-3pm (SUPA rooms) |
| **Assessment Details** | For students attending more than 75% of classes: Essay (70%) and Talk (30%) on topics related to the course. For students attending less than 25% of the classes: 5 hours written examination. |
| **Homework Hand-in** | At lecturer's discretion. |
| **Pre-Requisites** | Good knowledge of basic Quantum Physics and Electromagnetism |
| **Syllabus** | **Background Material:** Quantum Physics. The Schrödinger equation. Dirac notation. Hermitian and Adjoint operators. Orthonormality. The quantum harmonic oscillator with raising and lowering operators.<br>**Semi-classical Theory of the Interaction of Laser Light with Two-Level Atoms:** Hamiltonian. Dipole interaction. Rotating wave approximation. The interaction representation. Density matrix and master equation. Deterministic Bloch equations. Rabi oscillations. Markovian master equation (the decay terms). Lindblad form of the master equation. Complete Bloch equations.<br>**Stationary Solutions of the Bloch Equations:** Energy level population densities. Absorption and dispersion. The complex susceptibility<br>**Semi-classical Theory of the Interaction of Laser Light with Three-Level Atoms:** Interaction Hamiltonians. Density matrix evolution. Complete Bloch equations. The $\Lambda$ configuration: Coherent Population Trapping (CPT). Electromagnetically Induced Transparency (EIT). Enhanced refractive indices. Slow light. The V configuration. Sub-natural linewidths. The ladder configuration. Resonant population inversion,<br>**Semi-classical effects on the incident field and in optical cavities:** Density matrix and propagation of a coherent field in an atomic medium. Nonlinear Schrödinger equation. Self-focusing and spatial solitons. Optical cavities and resonators. Mean field limit. Maxwell-Bloch equations. Nonlinear absorbers. Optical bistability. Diffraction. Pattern formation. Cavity solitons. Parametric down conversion. Optical parametric oscillators. Second Harmonic Generation (time permitting) |
| **Learning Outcomes** | By the end of the course a student shall;<br>1. Be familiar with interaction representations and density matrix approaches to describe light-matter interactions<br>2. Be familiar with absorption, dispersion and population inversion<br>3. Be familiar with CPT, EIT, slow light and sub-natural linewidhts<br>4. Be familiar with the nonlinear Schrödinger equation, self-focusing and solitons<br>5. Be familiar with optical resonators, the mean-field limit and Maxwell-Bloch equations<br>6. Be familiar with optical bistability, pattern formation, and cavity solitons<br>7. Be familiar with parametric down conversion and optical parametric oscillators |
| **Web-site** | http://my.supa.ac.uk/course/view.php?id=300 |
| **Suggested Reading** | *Introduction to Quantum Optics*, G Grynberg, A Aspect, C Fabre, Cambridge (2010)<br>*Quantum Optics,* M Scully and M Zubairy, Cambridge (1997) |
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