PH5180 - Laser Physics

Credits: 15.0  Semester: 1
Number of Lectures: 27  Lecturer: Dr Bruce Sinclair (co-ordinator), Dr Tom Brown and Dr Liam O’Faolain
Academic Year: 2016-17

Overview
The course is designed to introduce the student to the classical treatment of laser physics providing the necessary quantitative techniques to permit design and prediction. A rate-equation model is used to model the laser system. In this course a number of variations are explored with regard to their applicability and limitations. Learning is assisted through the incorporation into the course of animations and numerical modelling material. (The latter is the ‘Psst’ software, which may be downloaded free for personal use.)

Aims & Objectives
The course aims to develop a working knowledge and conceptual understanding of important topics in contemporary laser physics at a quantitative level. A key objective is to enable the student to undertake quantitative problem-solving relating to the design, performance and applications of lasers through thereby acquiring an ability to put such knowledge into practice by way of numerical calculations. The aim throughout is to provide a thorough grounding in basic principles and their application, so that by the end of the course the student will have acquired a range of essential skills and knowledge required by a practitioner of laser physics and engineering. Such knowledge of the basics will be of enduring value and relevance. It will enable the student to innovate, design and analyse laser devices and systems at a quantitative level. As well as developing the conceptual framework the course also aims to give a sound perspective of contemporary trends and developments in laser physics, particularly with regard to new schemes for the generation of coherent electromagnetic radiation and the associated devices.

Learning Outcomes
You will have acquired:
- A conceptual understanding of the classical approach to laser physics, and a perspective of areas of applicability.
- An ability through a thorough grounding in the rate equation and strong signal approaches to analyse quantitatively the steady-state and dynamical performance of important contemporary laser devices.
- A comprehensive knowledge, including of recent developments, concerning: solid-state lasers (including diode-laser pumped devices), semiconductor lasers, fibre lasers, vibronic and other tuneable lasers, organic lasers, laser amplifiers, and newly emerging gain media.
- An ability to both analyse quantitatively and to design such lasers.
- A conceptual understanding of such important aspects of laser active media as linewidth determining processes, dispersive/gain properties, spatial and frequency hole-burning.
- An ability to both describe quantitatively and analyse such effects.
- A thorough grounding in the principles and design of laser resonators, particularly stable cavities. - An ability to analyse quantitatively and design such cavities by using matrix techniques.
- Access to and familiarity with numerical modelling tools (including 'Psst') relating to many aspects of laser design and performance.

Synopsis
- Rate Equation Approach to Laser - Steady-State behaviour
- Transient effects
- Relaxation Oscillations
- Q-switching
- Cavity Dumping Modelling of Solid-State Lasers
- Diode-laser-pumped solid-state lasers Optical Amplifier
- Linear Gain Regime
- Power Extraction
- Pulsed amplifiers Dispersion & Gain in Laser
- Electron Oscillator Model
Dispersion Relations
Mode Effects Review of Stable Optical Resonators
Matrix Techniques
Applications
Fibre Lasers Vibronic Lasers
Tuning Techniques
Linewidth Control
Frequency Stabilisation
Organic Lasers Semiconductor Lasers
Ultrafast lasers and diagnostic techniques
VCSEL's
Optical Pumping
Quantum Cascade Lasers
Quantum Dot Lasers Novel & Emergent Gain Media

Pre-requisites
For postgraduate students, entry to the MSc in Photonics and Optoelectronic Devices MSc programme or to the Engineering Doctorate in Applied Photonics.

Anti-requisites
PH5005

Assessment
2.5-hour (open notes) Examination = 80%  Continuous assessment = 20%

Additional information on continuous assessment etc
Please note that the definitive comments on continuous assessment will be communicated within the module. This section is intended to give an indication of the likely breakdown and timing of the continuous assessment.

The first part of the module is taught by Drs Tom Brown Dr Bruce Sinclair, and looks at the key underlying ideas of laser physics. After an introductory pair of lectures we look at laser gain. We then turn our attention to laser modes, both longitudinal and transverse. There follows a treatment of time dependence in lasers, based on coupled rate equations, and taking in relaxation oscillations and Q-switching. This first section is then completed by looking at susceptibilities, finishing about half way through the semester. The remainder of the module looks at how all these ideas can be applied to understand and design various laser systems. Dr Sinclair, and postgraduate students, and hopefully an industrial speaker look at a number of case studies. The group-based laser studies and presentations contribute to the assessment. Dr Tom Brown covers ultrashort pulse lasers, and Dr O’Faolain looks at semiconductor diode lasers. Students in small groups undertake a laser design case study that is summatively assessed. The examination is an open-notes examination where students may take in paper that fits inside one A4 ring binder.

Recommended Books
Please view University online record: http://resourcelists.st-andrews.ac.uk/modules/ph5180.html

General Information
Please also read the general information in the School’s handbook for POED and EngD students.