

## School of Physics & Astronomy

**Head of School** Professor T Krauss

### Degree Programmes

Postgraduate Diploma: Photonics and Optoelectronic Devices  
Physics

M.Sc.: Photonics and Optoelectronic Devices  
Physics

Erasmus Mundus – MSc.: Photonics

Eng.D.: Photonics

### Programme Requirements

#### Photonics and Optoelectronic Devices M.Sc. and Postgraduate Diploma

[www.st-andrews.ac.uk/physics/msc](http://www.st-andrews.ac.uk/physics/msc)

The primary aim of this one-year, full-time course is to provide specialist postgraduate training in modern optics and semiconductor physics, tailored to the needs of the Photonics industrial sector. The secondary aim is to provide the education required for those wishing to continue in academia on Ph.D. research projects in photonics.

Graduates from the course will have gained an in-depth understanding of the fundamental properties of optoelectronic materials and practical experience of the technology and operation of a wide range of laser and semiconductor devices. They will additionally have had experience of research, usually in an industrial environment, and have received training in the transferable skills required in such an environment.

The course is organised jointly by the School of Physics & Astronomy at the University of St Andrews and the School of Engineering and Physical Sciences at Heriot-Watt University. Each organisation will act in turn as host for the course. In 2009-10 the course will be hosted by Heriot-Watt, and in 2010-11 by St Andrews. Regardless of which institution hosts the course, the first semester is spent at St Andrews, and the second semester at Heriot-Watt. For the M.Sc. degree a project is undertaken during the summer months, usually in industry, and is assessed in September.

Postgraduate Diploma: PH5180 – PH5187

M.Sc.: PH5180 – PH5187 and PH5177 ([www.st-andrews.ac.uk/physics/msc](http://www.st-andrews.ac.uk/physics/msc))

[Note that PH5184 - PH5187 are carried out at Heriot-Watt University under their own module numbers.]

#### Photonics Eng.D.

[www.photonics-engd.hw.ac.uk/](http://www.photonics-engd.hw.ac.uk/)

The Eng.D. degree in Photonics is a 4-year course involving a blend of specialist postgraduate training in all aspects of photonics, tailored to the needs of the photonics industrial sector, and a significant, challenging and original research project undertaken as a partnership between industry and academia. Each research project provides experience in project management (including financial management) and teamwork as well as the opportunity to gain greater understanding of photonics and the business context in which the research is conducted. A significant proportion of the student's time (typically around 70%) is spent within the sponsoring company.

Graduates from the course will have gained an in-depth understanding of the fundamental properties of photonic materials and practical experience of the technology and operation of a wide range of photonic devices. They will additionally have had extensive experience of research in an industrial environment and have received training in the transferable skills required in such an environment.

## **Physics & Astronomy – 5000 Level Modules 2009/10 – August 2009**

The course is organised jointly by the School of Physics & Astronomy of the University of St Andrews, the School of Engineering and Physical Sciences at Heriot-Watt University, and the Department of Electronics and Electrical Engineering at the University of Strathclyde. St Andrews will normally be the location for the start of the course and will provide full time teaching during the first semester of the first year of the course. When this initial semester is completed students move to their industrial location and begin their research. They also take during the next five semesters the balance of the taught component of the Eng.D. either by distance learning or via short courses offered by Heriot-Watt and St Andrews.

The course is approved by the Engineering and Physical Sciences Research Council (E.P.S.R.C.) and a number of EPSRC-funded studentships are available.

Eng.D. PH5180 to PH5183 are normally taken, together with modules taught by Heriot-Watt University and the University of Strathclyde [NOTE PH5209 and PH5208 are distance learning courses that may be taken from St Andrews later in the programme]

### **Physics Postgraduate Diploma and M.Sc.**

Postgraduate Diploma: A total of 120 credits from AS and PH modules at 4000 level and above, including at least 90 credits at 5000 level, the course of study to be approved by the Head of School.

M.Sc.: 120 credits as for Postgraduate Diploma together with a dissertation (PH5301) comprising 3 months full-time study and worth 60 credits.

### **Erasmus Mundus Master of Science in Photonics**

<http://www.master-photonics.org>

This two year programme extends the existing twelve-month M.Sc. in Photonics by incorporating an additional year at one of the Erasmus Mundus partner institutions (University of Ghent, Vrije Universiteit Brussels or KTH Stockholm). This increases student exposure to the latest research and methods in Photonics/Optoelectronic Devices. Students may commence their course either at University of St Andrews/Heriot-Watt University or at one of the partner institutions. EU funding is available for a number of suitably qualified students from outside the EU.

Students who spend their first year of study in Scotland spend first semester in St Andrews and the second semester at Heriot-Watt University, Edinburgh. After a short workshop in the summer time, and a summer vacation, students will spend their next year studying outside Scotland at one of the partner universities listed above. Students who spend their first year of study outside Scotland on this programme may spend the second year in Scotland. Depending on their choice/allocation of thesis project, they will spend their entire second year either at St Andrews or at Heriot-Watt. They will start with their project right away and take several, mainly optional, lecture courses either in the first or in the second semester.

Erasmus Mundus Master of Science in Photonics, for those studying in St Andrews in the first semester of their programme: PH5180, PH5181, PH5182, PH5183.

Erasmus Mundus Master of Science in Photonics, for those studying in St Andrews in the second year of their programme: PH5181, PH5261, PH5260 and at least 37 credits chosen from PH4025, PH5005, PH5008, PH5012, PH5015, PH5016, PH5182, PH5183.

## **Modules**

### **AS5001 Astronomical Data Analysis**

Credits: 15 Semester: 1  
Availability: 2009-10  
Prerequisite: AS2001. Highly recommended: AS3013 (Computational Astrophysics) or PH4030 (Computational Physics). Familiarity with a programming language and concepts of computational physics or astrophysics are assumed.

Description: This module develops an understanding of basic concepts and offers practical experience with the techniques of quantitative data analysis. Beginning with fundamental concepts of probability theory and random variables, practical techniques are developed for using quantitative observational data to answer questions and test hypotheses about models of the physical world. The methods are illustrated by applications to the analysis of time series, imaging, spectroscopy, and tomography datasets. Students develop their computer programming skills, acquire a data analysis toolkit, and gain practical experience by analyzing real datasets.

Class hour: To be arranged.  
Teaching: Three lectures or tutorials.  
Assessment: Continuous Assessment = 100%

### **AS5002 Star Formation and Plasma Astrophysics**

Credits: 15 Semester: 1  
Prerequisite: AS2001

Description: The aim is to describe the physics of how a magnetic field interacts with a plasma, and to use this knowledge to explore the role of magnetic fields in the formation of solar-like stars and in compact objects with accretion discs. The syllabus comprises: Solar-like magnetic activity on other stars. The basic equations of magneto-hydrodynamics. Stellar coronae: X-ray properties and energetics of coronal loops. Energetics of magnetic field configurations. MHD waves and propagation of information. Solar and stellar dynamos: mean field models. Star formation: properties of magnetic cloud cores, magnetic support. Physics of accretion discs: transport of mass and angular momentum. Accretion on to compact objects and protostars. Rotation and magnetic fields in protostellar discs. Rotation distributions of young solar-type stars. Magnetic braking via a hot, magnetically channelled stellar wind.

Class hour: To be arranged.  
Teaching: Three lectures or tutorials.  
Assessment: 2 Hour Examination = 100%

### **AS5003 Contemporary Astrophysics**

Credits: 15 Semester: 1

Description: This module will provide an annual survey of the latest, most interesting, developments in astronomy and astrophysics at the research level. Emphasis will be placed upon the application of knowledge and expertise gained by students in their other modules to these current research topics.

Class Hour: To be arranged.  
Teaching: 3 lectures and some tutorials  
Assessment: 2 Hour Examination = 100%

### **PH5002 Foundations of Quantum Mechanics**

Credits: 15 Semester: 1  
Prerequisite: PH3061 and PH3062

Description: This module consists of five parts: (i) Hilbert spaces and operators including a discussion of spectral decomposition of selfadjoint operators; (ii) postulates of quantum mechanics for observables with discrete spectra with illustrative examples including various pictures (Schrodinger, Heisenberg, interaction) of time evolution; (iii) postulates of quantum mechanics for observables with continuous spectra in terms of probability distribution functions and the spectral functions; (iv) quantum theory of orbital, spin angular momenta and their addition, Pauli-Schrodinger equation; (v) introduction to relativistic quantum mechanics.

Class Hour: To be arranged.  
Teaching: Three lectures or tutorials.  
Assessment: 2 Hour Examination = 100%

## Physics & Astronomy – 5000 Level Modules 2009/10 – August 2009

### PH5003 Group Theory

Credits: 15 Semester: 1

Prerequisites: PH3061 and PH3062

Description: This module explores the concept of a group, including groups of coordinate transformations in three-dimensional Euclidean space; the invariance group of the Hamiltonian operator; the structure of groups: subgroups, classes, cosets, factor groups, isomorphisms and homomorphisms, direct product groups; introduction to Lie groups, including notions of connectness, compactness, and invariant integration; representation theory of groups, including similarity transformations, unitary representations, irreducible representations, characters, direct product representations, and the Wigner-Eckart theorem; applications to quantum mechanics, including calculation of energy eigenvalues and selection rules.

Class Hour: To be arranged.

Teaching: Three lectures or tutorials.

Assessment: 2 Hour Examination = 100%

### PH5004 Quantum Field Theory

Credits: 15 Semester: 2

Prerequisites: PH3061, PH3062 and PH3073 or MT4507

Co-requisite: PH5002 is recommended but not compulsory.

Description: This module presents an introductory account of the ideas of quantum field theory and of simple applications thereof, including quantization of classical field theories, second quantization of bosons and fermions, the failure of single particle interpretation of relativistic quantum mechanics, solving simple models using second quantization, Feynman's path integral approach to quantum mechanics and its relation to classical action principles, field integrals for bosons and fermions, the relationship between path integral methods and second quantization, and a descriptive introduction to Green's functions and Feynman diagrams.

Class Hour: To be arranged.

Teaching: Three lectures or tutorials.

Assessment: 2 Hour Examination = 100%

### PH5005 Laser Physics 2

Credits: 15 Semester: 1

Prerequisites: PH4034, PH3061, PH3062, PH3007

Anti-requisite: PH5018

Description: Quantitative treatment of laser physics embracing both classical and semiclassical approaches; transient/dynamic behaviour of laser oscillators including relaxation oscillations, amplitude and phase modulation, frequency switching, Q-switching, cavity dumping and mode locking; design analysis of optically-pumped solid state lasers; laser amplifiers including continuous-wave, pulsed and regenerative amplification; dispersion and gain in a laser oscillator - role of the macroscopic polarisation; unstable optical resonators, geometric and diffraction treatments; quantum mechanical description of the gain medium; coherent processes including Rabi oscillations; semiclassical treatment of the laser; tunable lasers.

Class Hour: To be arranged.

Teaching: Three lectures or tutorials.

Assessment: 2 Hour Examination = 100%

**PH5011 General Relativity**

Credits: 15 Semester: 1

Description: This module covers: inertial frames, gravity, principle of equivalence, curvature of spacetime; basic techniques of tensor analysis; Riemannian spaces, metric tensor, raising and lowering of indices, Christoffel symbols, locally flat coordinates, covariant derivatives, geodesics, curvature tensor, Ricci tensor, Einstein tensor; fundamental postulates of general relativity: spacetime, geodesics, field equations, laws of physics in curved spacetime; distances, time intervals, speeds; reduction of equations of general relativity to Newtonian gravitational equations; Schwarzschild exterior solution, planetary motion, bending of light rays, time delays; observational tests of general relativity; Schwarzschild interior solution, gravitational collapse, black holes.

Class Hour: To be arranged.

Teaching: Three lectures or tutorials.

Assessment: 2 Hour Examination = 100%

**PH5012 Quantum Optics**

Credits: 15 Semester: 1

Prerequisites: PH3061, PH3062, PH4028

Description: Quantum optics is the theory of light that unifies wave and particle optics. Quantum optics describes modern high-precision experiments that often probe the very fundamentals of quantum mechanics. The module introduces the quantisation of light, the concept of single light modes, the various quantum states of light and their description in phase space. The module considers the quantum effects of simple optical instruments and analyses two important fundamental experiments: quantum-state tomography and simultaneous measurements of position and momentum.

Class Hour: To be arranged.

Teaching: Three lectures or tutorials.

Assessment: 2 Hour Examination = 100%

**PH5014 The Interacting Electron Problem in Solids**

Credits: 15 Semester: 1

Prerequisites: PH3002, PH3061, PH3062

Description: The aim of this module is to give an overview of developments in modern condensed matter physics. The difficulties of a full quantum mechanical treatment of electrons with strong interactions will be discussed. Common existing approaches such as the Hubbard and t-J models and Fermi liquid theory will be compared. It will be shown that, although microscopic models can explain aspects of magnetism, they have little chance of capturing many other features of the fascinating low-energy physics of these systems. Instead, we introduce the principle of emergence, and show how it suggests radically new approaches to the problem of complexity in condensed matter physics and beyond. In this module, formal lectures will be combined with reading assignments, and the assessment will be based on marked homework together with an oral presentation followed by questions.

Class Hour: To be arranged.

Teaching: Two lectures and some tutorials.

Assessment: Continuous Assessment = 50%, Presentation plus Oral Examination = 50%

**PH5016 Biophotonics**

Credits: 15 Semester: 1

Prerequisites: PH4034 or PH4035

Description: The module will expose students to the exciting opportunities offered by applying photonics methods and technology to biomedical sensing and detection. A rudimentary biological background will be provided where needed. Topics include fluorescence microscopy and assays including time-resolved applications, optical tweezers for cell sorting and DNA manipulation, photodynamic therapy, lab-on-a-chip concepts and bio-MEMS. Two thirds of the module will be taught as lectures, including guest lectures by specialists, with the remaining third consisting of problem-solving exercises, such as specific literature reviews, design exercises and mini-projects. A visit to a biomedical research laboratory, e.g. at Ninewells hospital, will also be arranged.

Class Hour: To be arranged.

Teaching: Two lectures and some tutorials.

Assessment: Continuous Assessment = 25%, 2 Hour Examination = 75%

## **Physics & Astronomy – 5000 Level Modules 2009/10 – August 2009**

### **PH5018 Laser Physics 2 - Extended**

Credits: 20 Semester: 1  
Prerequisites: PH3007, PH4034  
Anti-requisite: PH5005  
Description: This module consists of the material in PH5005 with the addition of a project involving directed reading on a related advanced topic.  
Class Hour: To be arranged.  
Teaching: Three lectures and some tutorials.  
Assessment: Continuous Assessment = 25%, 2 Hour Examination = 75%

### **PH5177 Research Project**

Credits: 60 Semester: Summer  
Programme(s): Compulsory module for Photonics and Optoelectronic Devices Postgraduate Taught Programme.  
Description: All M.Sc. students carry out a 3-month research project, in most cases carried out at a U.K. company. Part-time students who are industry employees may carry out the project at their own company. Students will have completed a literature survey prior to the project, and write a dissertation on the project which is assessed in September.  
Class Hour: Placement  
Assessment: Dissertation, Continuous Assessment & Oral Examination= 100%

### **PH5180 Laser Physics**

Credits: 20 Semester: 1  
Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.  
Description: This module presents a description of the main physical concepts upon which an understanding of laser materials, operations, and applications can be based. These concepts include a treatment of light-matter interaction, gain, absorption and refractive index, rate-equation theory of lasers, gain and its saturation, frequency selection and tuning in lasers, transient phenomena, resonator and beam optics, and the principles and techniques of ultrashort pulse generation and measurement.  
Class Hour: To be arranged.  
Teaching: Four lectures each week and occasional tutorials.  
Assessment: Continuous Assessment = 20%, Two-and-a-half Hour Examination = 80%

### **PH5181 Photonics Laboratory I**

Credits: 15 Semester: 1  
Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.  
Description: The photonics teaching laboratory gives training in the experimental photonics, and allows students the opportunity to explore photonics practically in a series of chosen open-ended investigations. Students use their knowledge and skills from the lecture modules, supplemented by additional reading, to investigate relevant photonic effects. Phase I involves work in small groups in introductory areas, then phase II allows primarily individual investigation of topics such as the second harmonic generation, optical parametric oscillation, erbium amplifiers, Nd lasers, optical tweezers, spectroscopy, remote sensing of speed, Bragg reflectors, and holography. A poster or a formal lab report is included.  
Class Hour: 2.00 - 5.00 pm Monday, Tuesday and Thursday  
Teaching: Three two-and-a-half hour practicals each week.  
Assessment: Continuous Assessment = 100%

**PH5182 Displays and Nonlinear Optics**

Credits: 10 Semester: 1

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: The physics of polymers and liquid crystals is covered, showing the way to the use of semi-conducting polymers as light emitters, and the use of liquid crystals in displays and spatial light modulators. The nonlinear optics section of this module describes the physical ideas and application of second and third order nonlinear optics, including phenomena such as harmonic generation, parametric gain, saturated absorption, nonlinear refraction, Raman scattering, and optical solitons. The final section looks at second order nonlinear effects being exploited in optical parametric amplifiers and oscillators in the optical and THz regions.

Class Hour: To be arranged.

Teaching: Two lectures and occasional tutorials.

Assessment: Continuous Assessment = 20%, Two-and-a-half Hour Examination = 80%

**PH5183 Photonics Applications**

Credits: 15 Semester: 1

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: Students on this module choose to do two of the following three sections:

Microphotonics and Plasmonics: This covers the Bragg effect, multilayer mirrors, defects causing confined cavity states, periodicity leading to bandstructure, scaling of bandstructure in reduced frequency, Bloch modes and photonic bandgap. It then considers photonic crystal waveguides, photonic crystal fibres, and supercontinuum generation in photonic crystal fibres. Plasmonics is based on oscillations of the free electrons in a metallic material. Resonances of Plasmons are the basis for a new class of materials called 'Metamaterials'. These are compared with photonic crystals. Applications include super-resolution imaging, optical cloaking, sensing, and surface enhanced Raman scattering.

Biophotonics: This will introduce students to the exciting opportunities offered by applying photonics methods and technology to biomedical sensing and detection. A rudimentary biological background will be provided where needed. Topics include fluorescence microscopy and assays including time-resolved applications, optical tweezers for cell sorting and DNA manipulation, photodynamic therapy, lab-on-a-chip concepts and bio-MEMS.

Optical Trapping and Atom Optics: Quantum physics is one of the most powerful theories in physics yet is at odds with our understanding of reality. In this course we show how laboratories around the world can prepare single atomic particles, ensembles of atoms, light and solid state systems in appropriate quantum states and observe their behaviour. The material includes optical cooling and trapping of atoms and ions, Fermi gases, studies of Bose-Einstein condensation, and matter-wave interferometry.

Class Hour: To be arranged.

Teaching: Three lectures and occasional tutorials.

Assessment: Continuous Assessment = 15%, Two Hour Examination = 85%

**PH5184 Photonics Experimental Laboratory 2 (B21HL)**

Credits: 15 Semester: 2

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: This module is taught at Heriot-Watt University, and forms part of certain taught Master's degrees run collaboratively between St Andrews and Heriot-Watt Universities.

Class Hour: To be arranged.

Teaching: at Heriot-Watt University

Assessment: Continuous Assessment = 100%

## **Physics & Astronomy – 5000 Level Modules 2009/10 – August 2009**

### **PH5185 Semiconductor Optoelectronics (B20SO)**

Credits: 15 Semester: 2

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: This module is taught at Heriot-Watt University, and may form part of certain taught Master's degrees run collaboratively between St Andrews and Heriot-Watt Universities.

Class Hour: To be arranged.

Teaching: at Heriot-Watt University

Assessment: Three Hour Examination = 100%

### **PH5186 Modern Optics (B21FM)**

Credits: 15 Semester: 2

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: This module is taught at Heriot-Watt University, and may form part of certain taught Master's degrees run collaboratively between St Andrews and Heriot-Watt Universities.

Class Hour: To be arranged.

Teaching: at Heriot-Watt University

Assessment: Three Hour Examination = 100%

### **PH5187 Fibre Optic Communications (B21FC)**

Credits: 15 Semester: 2

Programme(s): Compulsory module for Photonics and Optoelectronic Devices and Mundus Master Postgraduate Taught Programme.

Description: This module is taught at Heriot-Watt University, and may form part of certain taught Master's degrees run collaboratively between St Andrews and Heriot-Watt Universities.

Class Hour: To be arranged.

Teaching: at Heriot-Watt University

Assessment: Three Hour Examination = 100%

### **PH5208 Semiconductor Physics and Devices**

Credits: 10 Semester: 1

Availability: 2009-10

Programme(s): Compulsory module for Engineering Doctorate in Photonics Postgraduate Taught Programme.  
Graduate level module available on-line

Description: This is a distance learning module covering the basic properties of semiconductor physics including their optical and electronic properties, and the low dimensional structures which may be constructed from them; and semiconductor devices ranging from pn junctions, solar cells, and LEDs to lasers, waveguides, optical amplifiers, optical modulators, and detectors.

Teaching: Material, tutorial support, and continuous assessment delivered at a distance by means of WebCT. Students are responsible for ensuring they have internet access.

Assessment: Continuous Assessment = 40%, Two Hour Examination = 60%



**PH5209 Polymers and Liquid Crystals for Displays – Distance Learning**

Credits: 5 Semester: 1

Programme(s): Optional module for Engineering Doctorate in Photonics Postgraduate Taught Programme.  
Graduate level module available on-line

Description: This is a distance learning module covering the concepts of optoelectronic display devices, including semiconducting polymers, and the properties of liquid crystals.

Teaching: Material, tutorial support, and continuous assessment delivered at a distance by means of WebCT . Students are responsible for ensuring they have internet access. The course covers material equivalent to that covered in 12 conventional lectures.

Assessment: Continuous Assessment = 40%, Two Hour Examination= 60%

**PH5260 Project Preparation**

Credits: 4 ECTS Semester: 1

Programme(s): Compulsory module in the Erasmus Mundus Master of Science in Photonics

Description: This module is conducted in self-study and supported by informal tutorial sessions to guide students through the assignment. It consists of conducting a literature search of the field of study related to the project. Students establish the State-of-the-Art in the field and put their own project into context. They critically assess the relevant literature, write a report and give a presentation outlining their project strategy. Furthermore, they study the requirements for conducting their project and develop a plan of experiments.

Teaching: 3 tutorials over 6 weeks.

Assessment: Continuous Assessment = 100%

**PH5261 Research Project**

Credits: 30 ECTS Semester: 2

Programme(s): Compulsory module in the Erasmus Mundus Master of Science in Photonics

Description: This module comprises a 5 month long research project that is conducted in self-study and supported by a project supervisor (to be determined). It comprises the analysis of a problem provided by the supervisor and builds on the preparation conducted in the first semester (PH5260). The student will conduct a series of experiments to develop and test possible solutions to the problem provided. The methods employed and solutions developed during the project will be described in a report and the findings be presented as an oral presentation at the summer school.

Teaching: 5 month long project.

Assessment: Continuous Assessment = 100%

**PH5301 Dissertation for M.Sc. Programme**

Credits: 60 Semester: Summer

Programme(s): Compulsory module for M.Sc. Physics Postgraduate Taught Programme.

Description: This dissertation will be supervised by a member of the teaching staff who will advise on the choice of subject and provide guidance during the work. The completed dissertation of not more than 15,000 words must be submitted by the end of August.

Teaching: Weekly meetings with supervisor

Assessment: Dissertation and Oral Examination = 100%

