School of Physics & Astronomy

Head of School

Professor Andrew Cameron

Taught Programmes

MSc:

European Master of Science in Photonics (EMSP)
Photonics and Optoelectronic Devices
Physics

EngD:

Photonics

For all Masters degrees there are exit awards available that allow suitably-qualified candidates to receive a Postgraduate Certificate or Postgraduate Diploma.

Programme Requirements

European Master of Science in Photonics (EMSP) MSc

This is an international two-year Masters programme in Photonics. Students spend their first semester at the University of Ghent, the second semester at Vrije Universiteit Brussels, and then attend a short summer school at one of the partner institutions. The rest of that summer may be used for vacation and/or a relevant internship. At the start of the following academic year (i.e. third semester of the programme) the students all study at St Andrews. The fourth semester is spent entirely on a research project, which may be at St Andrews, Ghent, KTH Stockholm, Vrije Universiteit Brussels, or associated institutions.

The semester in St Andrews consists of a research skills module, an advanced photonics lab module, and a number of optional advanced modules on aspects of photonics. There are strong links between our research activities and the teaching of this MSc.

St Andrews Taught Element:	28 credits (14 ECTS): PH5260 and PH5262
	32 credits: (16 ECTS): from PH5263 - PH5269
	60 credits (30 ECTS): PH5261

Photonics and Optoelectronic Devices MSc

www.st-andrews.ac.uk/physics/msc

The primary aim of this twelve-month, full-time programme 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. There are strong links between our research activities and the teaching of this MSc .

Graduates from the programme 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 lead organisation for the course. In 2014-15 the course will be led by St Andrews, and in 2015-16 by Heriot-Watt. Regardless of which institution leads the course, the first semester is spent at St Andrews, and the second semester at Heriot-Watt. For the MSc degree a project is undertaken during the summer months, usually in industry, and is assessed in September.

Taught Element: 120 credits: PH5180 - PH5187

MSc: 120 credits: PH5180 - PH5187

60 credits: PH5177

(www.st-andrews.ac.uk/physics/msc)

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

Photonics EngD

http://www.idcphotonics.hw.ac.uk/

The EngD 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 programme 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.

The course is organised jointly by Heriot-Watt, Glasgow, St Andrews, and Strathclyde universities. St Andrews will normally be the location for the start of the course and will provide full time teaching in photonics during the first semester of the first year of the course. Students then have a semester of electronic engineering theory and practice at Glasgow and Strathclyde Universities as additional preparation before embarking on their research. Details at http://www.idcphotonics.hw.ac.uk/sites/www.idcphotonics.hw.ac.uk/files/news/CDT%20Applied%20Photonics%20leaflet.pdf

EngD PH5181 Photonics Laboratory is a compulsory module, and students then normally choose 45 credits from PH5180, PH5182, PH5183, and PH5016. Students also take later in their programme modules amongst those taught by Heriot-Watt, Strathclyde, and Glasgow Universities,and PH5209 and PH5208 which are distance learning courses that may be taken from St Andrews

Physics MSc

Taught Element: 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.

MSc: 120 credits as for Taught Element together with a dissertation (PH5301) comprising 3 months full-time study and worth 60 credits.

Modules

AS5001 Advanced Data Analysis

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	9.00 am Tue, Thu, 10.00 am Mon, 12.00 noon Thu and 3.00 pm - 5.00 pm Tue (Lab)			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Entry to a taught postgraduate programme in the School. Familiarity with scientific programming language essential,
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials and some supervised computer lab sessions
Assessment pattern:	Coursework = 100%
Module Co-ordinator:	Prof A C Cameron
Lecturer(s)/Tutor(s):	Prof A C Cameron

AS5002 Magnetofluids and Space Plasmas

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	11.00 am Mon, Tue, Thu			

This module is aimed at both physics and astrophysics students with interests in the physics of plasmas. The interaction of a magnetic field with an ionized gas (or plasma) is fundamental to many problems in astrophysics, solar- terrestrial physics and efforts to harness fusion power using tokamaks. 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.

Programme module type:	Optional for Postgraduate programmes within the School.
Pre-requisite(s):	Entry to a taught postgraduate programme in the School.
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Prof M M Jardine
Lecturer(s)/Tutor(s):	Prof M M Jardine

AS5003 Contemporary Astrophysics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	12.00 noon Wed, Fri and 3.00 pm Mon			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Substantial astronomy knowledge and skills
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures and some tutorials
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Dr C Helling
Lecturer(s)/Tutor(s):	Dr C Helling and others

PH5002 Foundations of Quantum Mechanics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Mon, Tue, Fri			

This module consists of seven parts: (i) classical and quantum systems; (ii) vector spaces, Hilbert spaces, operators and probability; (iii) basic postulates of quantum mechanics for observables with discrete spectra; (iv) illustrative examples; (v) treatment of continuous observables in terms of probability distribution functions and the spectral functions; (vi) quantum theory of orbital and spin angular momenta, Pauli-Schrodinger equation and its applications; (vii) introduction to relativistic quantum mechanics.

Programme module type:	Optional for some Postgraduate programmes in the School.
Pre-requisite(s):	Relevant Quantum Mechanics
Required for:	Recommended, but not required, for PH5004
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Dr K Wan
Lecturer(s)/Tutor(s):	Dr K Wan

PH5003 Group Theory

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	12.00 noon Wed, Fri, 3.00 pm Mon			

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 homorphisms, 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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant undergraduate mathematics and physics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Prof J Cornwell
Lecturer(s)/Tutor(s):	Prof J Cornwell

PH5004 Quantum Field Theory

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Thu, 3.00 pm Tue, Fri			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant undergraduate mathematics and physics
Co-requisite(s):	At least one of PH5002 and PH5012 is recommended but not compulsory.
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 90%, Coursework = 10%
Module Co-ordinator:	Dr J Keeling
Lecturer(s)/Tutor(s):	Dr J Keeling

PH5005 Laser Physics 2

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	10.00 am Mon, Tue, Wed, Thu			

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.

Programme module type:	Optional for Postgraduate programmes in the School.		
Pre-requisite(s):	Relevant mathematics and physics	**Anti-requisite(s):**	PH5018, PH5180
Learning and teaching methods and delivery:	**Weekly contact**: 4 lectures or tutorials.		
Assessment pattern:	2.5-hour (open notes) Examination = 100%		
Module Co-ordinator:	Dr B Sinclair		
Lecturer(s)/Tutor(s):	Prof M Dunn, Dr L O'Faolain, Dr B Sinclair		

PH5011 General Relativity

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	9.00 am Wed, Fri, 3.00 pm Thu			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant mathematics and physics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Dr H Zhao
Lecturer(s)/Tutor(s):	Dr H Zhao

PH5012 Quantum Optics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	11.00 am Mon, Tue, Thu			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant quantum mechanics and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures or tutorials.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Dr F Koenig
Lecturer(s)/Tutor(s):	Dr F Koenig, Dr N Korolkova

PH5014 The Interacting Electron Problem in Solids

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	4.00 pm Mon, Tue, Thu			

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.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant solid state physics, quantum mechanics, and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and some tutorials.
Assessment pattern:	Coursework = 50%, Presentation plus Oral Examination = 50%
Module Co-ordinator:	Dr C Hooley
Lecturer(s)/Tutor(s):	Dr C Hooley

PH5015 Applications of Quantum Physics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	12.00 noon Mon, Tue, Thu			

Quantum physics is one of the most powerful theories in physics yet is at odds with our understanding of reality. In this module 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 module includes studies of laser cooling, Bose-Einstein condensation, quantum dots and quantum computing. An emphasis throughout will be on how such quantum systems may actually turn into practical devices in the future. The module will include assessment based on tutorial work and a short presentation on a research topic.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant physics and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures (x 11 weeks) and a further 2 x 1-hour tutorials, 1 x 3-hour research lab visit, 3 hours student presentations during the semester.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Prof K Dholakia
Lecturer(s)/Tutor(s):	Prof K Dholakia, Dr M Mazilu

PH5016 Biophotonics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	9.00 am Mon, Wed, Fri			

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 writing a specific news piece on a research paper, assessed tutorial sheets and a presentation. A visit to a biomedical research laboratory using various photonics methods will also be arranged.

Programme module type:	Optional for Postgraduate programmes in the School. Optional for EngD Programme
Pre-requisite(s):	Relevant physics and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and some tutorials.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Prof K Dholakia
Lecturer(s)/Tutor(s):	Prof K Dholakia, Prof M C Gather, Dr Penedo

PH5023 Monte Carlo Radiation Transport Techniques

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm Mon, Tue, Fri			

This module introduces the theory and practice behind Monte Carlo radiation transport codes for use in physics, astrophysics, atmospheric physics, and medical physics. Included in the module: recap of basic radiation transfer; techniques for sampling from probability distribution functions; a simple isotropic scattering code; computing the radiation field, pressure, temperature, and ionisation structure; programming skills required to write Monte Carlo codes; code speed-up techniques and parallel computing; three-dimensional codes. The module assessment will be 100% continuous assessment comprising homework questions and small projects where students will write their own and modify existing Monte Carlo codes.

Programme module type:	Optional for Postgraduate programmes in the School.
Pre-requisite(s):	Relevant physics, mathematics, and computing
Learning and teaching methods and delivery:	**Weekly contact**: 3 hours of lectures (x 5 weeks), 1-hour tutorials (x 5 weeks)
Assessment pattern:	Coursework = 100%
Module Co-ordinator:	Dr K Wood
Lecturer(s)/Tutor(s):	Dr K Wood

PH5177 Research Project (POED MSc)

SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	Summer
Availability restrictions:	This project module is organised and assessed with St Andrews as the lead institution in 2014/15 and alternate years thereafter.It is available only to those in the POED MSc programme.			
Planned timetable:	Placement, full time.			

All POED MSc 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.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programme.
Pre-requisite(s):	Satisfactory completion of the taught element of Photonics and Optoelectronic Devices MSc programme.
Learning and teaching methods and delivery:	**Weekly contact**: About 40 hours a week working on the project, with appropriate levels of supervision
Assessment pattern:	Dissertation and Oral Examination = 100%
Module Co-ordinator:	Dr B D Sinclair
Lecturer(s)/Tutor(s):	Dr B D Sinclair

PH5180 Laser Physics

SCOTCAT Credits:	20	SCQF Level 11	**Semester:**	1
Planned timetable:	10.00 am Mon, Tue, Wed, Thu			

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.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programmes. Optional for EngD Programme
Pre-requisite(s):	Admission to a Taught Postgraduate programme in the School.
Learning and teaching methods and delivery:	**Weekly contact**: 4 lectures/tutorials each week and occasional tutorials.
Assessment pattern:	2.5-hour open-notes Examination = 80%, Coursework = 20%
Module Co-ordinator:	Dr B D Sinclair
Lecturer(s)/Tutor(s):	Dr B D Sinclair, Prof M H Dunn, Dr L O'Faholain

PH5181 Photonics Laboratory 1

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Planned timetable:	2.00 pm - 5.30 pm Mon, Tue and Thu			

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, Brag reflectors, and holography. A formal lab report is included.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programmes and EngD Programme
Pre-requisite(s):	Admission to a Taught Postgraduate programme in the School.
Learning and teaching methods and delivery:	**Weekly contact**: 3 x 2.5-hour practicals.
Assessment pattern:	Coursework = 100%
Module Co-ordinator:	Dr B D Sinclair
Lecturer(s)/Tutor(s):	Dr B D Sinclair and others

PH5182 Displays and Nonlinear Optics

SCOTCAT Credits:	10	SCQF Level 11	**Semester:**	1
Planned timetable:	To be arranged.			

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.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programmes. Optional for EngD Programme
Pre-requisite(s):	Admission to a Taught Postgraduate programme in the School.
Learning and teaching methods and delivery:	**Weekly contact**: 2 lectures and occasional tutorials.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Prof I D W Samuel
Lecturer(s)/Tutor(s):	Prof I D W Samuel, Prof M H Dunn, Dr C F Rae

PH5183 Photonics Applications

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	This module is intended for students in the MSc in Photonics and Optoelectonic Devices MSc, and for those on the EngD degree in Photonics.			
Planned timetable:	9.00 am Mon, Wed, Fri, 11.00 am Wed, Fri, 12.00 noon Mon, Tue, Thu Depending on options taken			

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 electronics 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.

Students must not cover Biophotonics in both this module and PH5016/PH5264, and must not cover Optical Trapping and Atom Optics in both this module and PH5015/PH5267.

Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Taught Programme. Optional for EngD Programme
Pre-requisite(s):	Relevant physics and mathematics
Learning and teaching methods and delivery:	**Weekly contact**: 3 lectures and occasional tutorials.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Prof K Dholakia
Lecturer(s)/Tutor(s):	Prof K Dholakia, Dr M Mazilu, Dr A Di Falco, Dr L O'Faolain, Dr Penedo

PH5208 Semiconductor Physics and Devices - Distance Learning

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Distance Learning			
Planned timetable:	To be arranged.			
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.				
Programme module type:	Optional for Engineering Doctorate in Photonics Postgraduate Taught Programme. Postgraduate level module available on-line			
Learning and teaching methods and delivery:	**Weekly contact**: Material, tutorial support, and continuous assessment delivered at a distance by means of Moodle. Students are responsible for ensuring they have internet access. The course covers material equivalent to that covered in 30 conventional lectures.			
Assessment pattern:	2-hour Written Examination = 60%, Coursework = 40%			
Module Co-ordinator:	Dr G A Turnbull			
Lecturer(s)/Tutor(s):	Dr G A Turnbull			

PH5260 EMSP Research Skills

SCOTCAT Credits:	8	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	To be arranged.			
This module is conducted in self-study and supported by informal tutorial sessions. The module consists of 3 parts, a) Research into a specific topic in semiconductor photonics, which builds on previously learned material by recognising how the corresponding concepts are applied in advanced devices. b) Conduct a literature search in the field of study related to the project which you will conduct in the fourth semester. Establish the state-of-the-art in the field and put your project into context. Critically assess the relevant literature and write a report. c) give a presentation on the content of the literature search and outline the project strategy.				
Programme module type:	Compulsory for the European Master of Science in Photonics			
Pre-requisite(s):	Admission to the European Master of Science in Photonics programme.			
Learning and teaching methods and delivery:	**Weekly contact**: 3 tutorials over 6 weeks.			
Assessment pattern:	Coursework = 100%			
Module Co-ordinator:	Dr A Di Falco			
Lecturer(s)/Tutor(s):	Dr A Di Falco and others			

PH5261 EMSP Research Project

SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	2
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	5-month long project.			

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.

Programme module type:	Compulsory for the European Master of Science in Photonics
Pre-requisite(s):	Admission to the European Master of Science in Photonics programme.
Learning and teaching methods and delivery:	**Weekly contact**: 40 hours research work
Assessment pattern:	Coursework = 100%
Module Co-ordinator:	Dr A Di Falco
Lecturer(s)/Tutor(s):	Photonics staff

PH5262 EMSP Advanced Photonics Laboratory

SCOTCAT Credits:	20	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	2.00 pm - 5.30 pm Mon, Tue, Thu			

This module allows students to explore the science and engineering of photonics through experimentation in an advanced teaching laboratory. The module is a medium for self-driven learning and discovery through usually open-ended practical work and associated reading and computation, and aims to give practice in relevant experimental techniques. Furthermore, it will give experience in data handling, including estimates of uncertainty and give experience of some aspects of experimental design. It should stimulate and maintain an interest in laser physics and optoelectronics, and should develop the practical skills required to conduct independent research in a photonics laboratory.

Investigations may include work using cw and pulsed lasers, interferometry, holography, optical trapping, semiconductor optoelectronics, biophotonics, spectroscopy, clean-room techniques, etc.

Programme module type:	Compulsory for the European Master of Science in Photonics
Pre-requisite(s):	Admission to the second year of the EMSP programme.
Learning and teaching methods and delivery:	**Weekly contact**: 10.5 hours per week for 11 weeks.
Assessment pattern:	Coursework = 100% (marked experiments and related work)
Module Co-ordinator:	Dr B D Sinclair
Lecturer(s)/Tutor(s):	Dr B D Sinclair and others

PH5263 EMSP Nanophotonics

SCOTCAT Credits:	8	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	11.00 am Wed and Fri			

Nanophotonics based on nanostructured materials such as photonic crystals or plasmonic metamaterials is a hot topic in contemporary photonics. The fascination arises from the fact that the properties of these materials can be designed to a significant extent via their structure. While photonic crystals are made of dielectric materials, plasmonic structures are typically made of metals. Many of the properties of these nanostructured materials can be understood from their dispersion diagram or optical bandstructure, which is a core tool that will be explored in the module. Familiar concepts such as multilayer mirrors and interference effects will be used to explain the more complex features such as slow light propagation, high Q cavities in photonic crystal waveguides and supercontinuum generation in photonic crystal fibres. Similarly, the concepts of propagating and localised plasmons and their properties will be explained and expanded to include the novel effects of superlensing and optical cloaking in metamaterials. This advanced module capitalises on current research in the School.

Programme module type:	Optional for the European Master of Science in Photonics
Pre-requisite(s):	Admission to the second year of the EMSP programme.
Learning and teaching methods and delivery:	**Weekly contact**: 2 hours of lectures per week for 8 weeks.
Assessment pattern:	1-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Dr A di Falco
Lecturer(s)/Tutor(s):	Dr A di Falco and Dr L O'Faolain

PH5264 EMSP Biophotonics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	9.00 am Mon, Wed, Fri			

The module will expose students to the exciting opportunities offered by applying photonics methods and technology to biomedical sensing, therapy and detection. A rudimentary biological background will be provided where needed. Topics include different microscopy techniques employed in biophotonics research, such as fluorescence microscopy and confocal microscopy, as well as related techniques such as optical coherence tomography (OCT) and two-photon effects. The module covers a number of optical detection methods, based e.g. on fluorescence and interferometry, as well as the basics of biochemical sensitisation and tagging, which leads to topics such a lab-on-a-chip, microarrays and microfluidics incl. optical trapping. The module includes guest lectures by specialists e.g. cell biology and DNA, as well as problem-solving exercises, including a short critique of a contemporary biophotonics research paper and a presentation by students on a research topic related to the content of the module.

Programme module type:	Optional for the European Master of Science in Photonics
Pre-requisite(s):	Admission to the second year of the EMSP programme.
Learning and teaching methods and delivery:	**Weekly contact**: 2 - 3 hours of lectures per week for 11 weeks.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20%
Module Co-ordinator:	Prof K Dholakia
Lecturer(s)/Tutor(s):	Prof K Dholakia, Prof M C Gather, Dr Penedo

PH5265 EMSP Solar Power

SCOTCAT Credits:	6	SCQF Level 11	**Semester:**	1
Planned timetable:	Full time 23 and 24 October			

This module will introduce students to the societal need and the economics of solar power, then enter into the fundamental limitations of solar cells, such as the Shockley limit for a single junction solar cell and how it is addressed using multifunction cells. This is followed by methods of characterising solar cells. The light-trapping problem will be discussed next and how it is addressed using photonic nanostructures (random scatterer, diffractive, plasmonic structures) and "black silicon". Finally, the students will be introduced to different solar cell materials and their specific requirements, e.g. organic semiconductors, organic/inorganic hybrids, dye-sensitised cells and more "exotic" materials such as CdTe and CIGS. The module includes 3 off 2h laboratory sessions reinforcing key solar cell concepts. Overall, the students will gain insight into key aspects of solar cell operation and be exposed to some of the current research trends.

Programme module type:	Optional for European Master of Science in Photonics
Pre-requisite(s):	Admission to a Taught Postgraduate programme within the School
Learning and teaching methods and delivery:	**Weekly contact**: 2-day residential workshop + 1 afternoon of presentation.
Assessment pattern:	Coursework = 100% (tutorial sheets = 50%, project presentation = 50%)
Module Co-ordinator:	Prof I Samuel
Lecturer(s)/Tutor(s):	Prof I Samuel and others

PH5266 EMSP Quantum Optics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	11.00 am Mon, Tue, Thu			

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. In detail, the content covers the quantum version of Maxwell's equations, the quantisation of light modes, single quantum states of light, different single-mode states (quadrature states, Fock states, coherent states), zero-point energy and the Casimir force. Quasiprobability distributions in phase space include the Wigner representation and other quasiprobability distributions (Glauber P-function, Husimi Q-function, s-parametrised quasi-probability distributions) Simple optical instruments, such as beam splitters, amplitude and quadrature detection and quantum-state tomography are considered in this framework.

Irreversible processes include a discussion of Lindblad's theorem, loss and gain and continuous quantum measurements. Finally, the module covers entanglement, parametric amplifiers and polarisation correlations. Homework problems and questions are provided for student's individual study to improve module understanding. They are then discussed during the whole class tutorial sessions (at least 3).

Programme module type:	Optional for European Master of Science in Photonics Postgraduate Programme.
Pre-requisite(s):	Admission to the EMSP programme and previous training in quantum mechanics equivalent to PH3061, PH3062, PH4028
Learning and teaching methods and delivery:	**Weekly contact**: 3 hours of lectures per week for 11 weeks.
Assessment pattern:	2-hour Written Examination = 100%
Module Co-ordinator:	Dr F Koenig
Lecturer(s)/Tutor(s):	Dr F Koenig, Dr N Korolkova

PH5267 EMSP Applications of Quantum Physics

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	1
Academic year:	2014/5			
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme.			
Planned timetable:	12.00 noon Mon, Tue, Thu			

The module begins with the Statistics of light: coherence; First and second order correlation functions; Chaotic light; coherent light; Photon statistics; Sub and super Poissonian light; Photon bunching and antibunching. Quantum cryptography. Entangled states. Single photon sources. Then follows a discussion of laser cooling and Bose-Einstein condensation (BEC) explaining basic laser cooling, Doppler theory, sub Doppler cooling, magneto-optical traps. Quantum mechanical complementarity (which-way experiments). Evaporative cooling, magnetic trapping. Signatures of BEC and Fermi gases. Matter wave interference. Wave-particle duality studies. Charged ion trapping. Studies of laser cooled ions in traps. Quantum jumps. Atom lasers.

Programme module type:	Optional for the European Master of Science in Photonics Postgraduate Programme.
Pre-requisite(s):	Admission to the EMSP programme and previous training in quantum mechanics equivalent to PH3061, PH3062
Learning and teaching methods and delivery:	**Weekly contact**: 3 hours of lectures.
Assessment pattern:	2-hour Written Examination = 80%, Coursework = 20% (tutorials and 15-minute presentation)
Module Co-ordinator:	Prof K Dholakia
Lecturer(s)/Tutor(s):	Prof K Dholakia, Dr M Mazilu

PH5268 EMSP Nonlinear Optics

SCOTCAT Credits:	~~10~~8	SCQF Level 11	**Semester:**	1
Availability restrictions:	Admission to the second year of the European Master of Science in Photonics programme			
Planned timetable:	12.00 noon - 3.00 pm some Wed			
This module comprises an introduction, and the following topics: Origin of optical non-linearity: microscopic model, resonant and non-resonant nonlinearity. Polarisation and susceptibility: general description of macroscopic polarisation, symmetry properties of non-linear susceptibility, non-linear wave equation (slowly varying envelope approximation). Second order effects: Coupled wave equations, phase matching methods, Manley-Rowe, sum frequency and second harmonic generation, difference frequency generation and parametric amplification. Third order effects: four-wave mixing, Intensity dependent refractive index, self-focusing, self-phase modulation, bistability, supercontinuum and comb generation. Non-linear scattering: spontaneous and stimulated scattering, phonons, Brillouin scattering, Raman scattering. Resonant (or indirect) optical non-linearities: non-linearities induced by plasma effect, and filling effects, thermo-optic effect, optical forces etc. Non-linear optical materials: glasses, semiconductors, ferroelectrics, polymers. High harmonic generation; generation of extreme UV light. The lectures are video-conferenced from Ghent, with tutorial support provided locally.				
Programme module type:	Optional for the European Master of Science in Photonics Postgraduate Programme.			
Pre-requisite(s):	Admission to the second year of the European Master of Science in Photonics programme			
Learning and teaching methods and delivery:	**Weekly contact**: 2.5 hour lectures and some tutorials.			
Assessment pattern:	2-hour Written Examination = 50%, Coursework = 50%			
Module Co-ordinator:	Dr A di Falco			
Lecturer(s)/Tutor(s):	Dr A di Falco, staff Frm Ghent			

PH5301 Dissertation for MSc Programme

SCOTCAT Credits:	60	SCQF Level 11	**Semester:**	2
Availability restrictions:	Only available to students on the Physics MSc Programme			
Planned timetable:	To be arranged.			
This dissertation will be supervised by a member of the academic 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 stated date in August.				
Programme module type:	Compulsory for MSc Physics Postgraduate Programme.			
Pre-requisite(s):	Successful completion of the first two semesters of the Physics MSc programme in the School.			
Learning and teaching methods and delivery:	**Weekly contact**: Weekly meetings with supervisor			
Assessment pattern:	Dissertation and Oral Examination = 100%			
Module Co-ordinator:	TBC			
Lecturer(s)/Tutor(s):	TBC			

PH5184 Photonics Experimental Laboratory 2 (B21HL)

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	2
Availability restrictions:	Available only to students on the Photonics and Optoelectronics programme			
Planned timetable:	To be arranged.			
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.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programmes.			
Pre-requisite(s):	Admission to the Photonics and Optoelectronics MSc			
Learning and teaching methods and delivery:	**Weekly contact**: At Heriot-Watt University			
Assessment pattern:	Coursework = 100%			
Module Co-ordinator:	at Heriot-Watt University			

PH5185 Semiconductor Optoelectronic Devices (B21OD)

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	2
Availability restrictions:	Available only to students on the Photonics and Optoelectronics programme			
Planned timetable:	To be arranged.			
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.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices Programme			
Pre-requisite(s):	Admission to the Photonics and Optoelectronics MSc			
Learning and teaching methods and delivery:	**Weekly contact**: At Heriot-Watt University			
Assessment pattern:	3-hour Examination = 100%			
Module Co-ordinator:	at Heriot-Watt University			

PH5186 Modern Optics (B21FM)

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	2
Availability restrictions:	Available only to students on the Photonics and Optioelectronics programme			
Planned timetable:	To be arranged.			
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.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programme.			
Pre-requisite(s):	Admission to the Photonics and Optoelectronics MSc			
Learning and teaching methods and delivery:	**Weekly contact**: At Heriot-Watt University			
Assessment pattern:	3-hour Examination = 100%			
Module Co-ordinator:	at Heriot-Watt University			

PH5187 Fibre Optic Communications (B21FC)

SCOTCAT Credits:	15	SCQF Level 11	**Semester:**	2
Availability restrictions:	Available only to students on the Photonics and Optioelectronics programme			
Planned timetable:	To be arranged.			
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.				
Programme module type:	Compulsory for Photonics and Optoelectronic Devices Postgraduate Programme.			
Pre-requisite(s):	Admission to the Photonics and Optoelectronics MSc.			
Learning and teaching methods and delivery:	**Weekly contact**: At Heriot-Watt University			
Assessment pattern:	3-hour Examination = 100%			
Module Co-ordinator:	at Heriot-Watt University			