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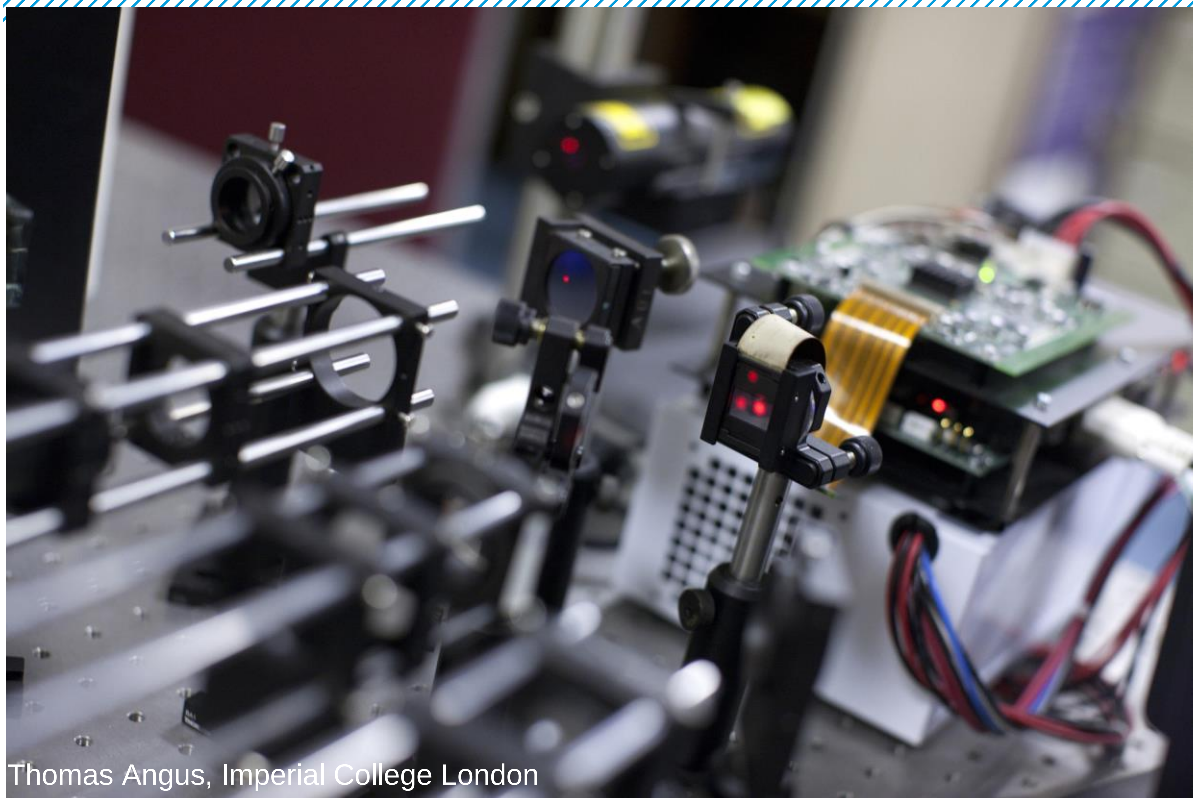
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DEPARTMENT OF PHYSICS

Faculty of Natural Science

MSc in Optics and Photonics

Programme Information 2024-25

Contents

1. Programme information

Introduction

The information provided in this document covers the main points of what makes up this programme and is drawn from the full Programme Specification and Module Specification documents. The Programme Specification can be found here and details of the Modules can be found in the appendix.

This booklet, and the Specifications, should be read in conjunction with the MSc Optics and Photonics Handbook, which may be found here.

Overview

Optics is of key importance as a scientific discipline in its own right, with applications in many industrial sectors including engineering, life sciences, medicine, ICT and high-tech manufacturing.

Imperial College has offered an advanced programme in optics for over 90 years and the current MSc in Optics and Photonics draws on our experience as one of the largest centres for optics-based research and application in the UK.

The main taught elements (i.e. lectures and laboratory work) take place in the first two terms. The first term consists of practical laboratory work and three compulsory lecture-based modules that together provide a key grounding in some of the essential knowledge and skills underpinning optics. Elective lecture-based modules allow you to choose from a range of advanced topics at the forefront of current optical research and practice; these are mostly in the second term with a couple taking place in the first term. In the second term, you will carry out a laboratory-based project to design and build a working optical system. You will also undertake a self-study project in an area of your choice. Your studies finish with a four-month, full-time Master's research project which is usually carried out in one of our academic research communities but may be with one of our industrial partners or, where appropriate arrangements can be made, abroad.

Graduates of this course are well qualified to apply their knowledge in a wide range of industrial contexts, as well as in a research environment. They find employment with a variety of careers in industry and many move on to doctoral studies at leading universities in the UK and around the world.

Aims and Objectives

The formal aim of the MSc in Optics and Photonics Course is:

"To provide a high-quality education in optics that prepares students for research or technical work in industry or an academic environment."

This aim is fulfilled via the following formal objectives. MSc graduates will be able to:

- Use theoretical knowledge of the fundamental laws and principles of optics and photonics, and appropriate mathematical techniques applied to the physical world to solve real-world problems in optics.
- Organise as part of a team the design, and execute safely, a series of experiments or computations, including the identification and use of appropriate specialist equipment
- Evaluate and select appropriate theoretical knowledge of optical principles and mathematical techniques to support practical work
- Model and simulate complete optical experiments and systems using appropriate specialist software
- Determine the strength and validity of results obtained from experiments, models or simulations, include appropriate consideration of errors, and draw conclusions
- Report the results of experimental work in writing
- Evaluate the inter-relationships between a range of complex/advanced topics in optics and photonics, and explain their application
- Critically examine the scientific literature to design an experimental, theoretical and/or computational investigation that extends current knowledge in the field
- Execute an extended research project, analyse the results and formulate new knowledge that can be applied to real-world situations
- Present the details of the research project, the work carried out, results and conclusions to a specialist audience orally and in writing

Part time studies

As the part-time programme requires the student to gain some practical experience in optics and to complete an optics-related project outside College, the part-time programme is only available to students currently employed in an organisation in the optics community.

The MSc in Optics and Photonics is available as a part-time programme over two years. In the first year, students complete two of compulsory lecture modules, approximately half of their elective modules, a selection of laboratory experiments and their self-study project. In the second year, students complete the remaining modules and their project.

Description of the Programme

The modules available to make up this programme are summarised in the following table:

Module Name	Module Type	Module Credits	Term
Lasers	Compulsory	5	1
Imaging	Compulsory	5	1
Optical Measurements and Devices	Compulsory	5	1
Laboratory	Core	15	1 & 2
Self-Study project	Core	5	2
Master's Project	Core	30	Summer[1]
Quantum Optics	Elective	7.5	1
Laser Technology	Elective	7.5	2
Optical Communications Physics	Elective	5	1
Biomedical Optics	Elective	5	2
Fibre and Ultrafast Lasers	Elective	5	2
Optical Design	Elective	5	2
Opto-Electronic Devices	Elective	5	2

1. The Master’s Project is undertaken in the summer over a four-month period from May to September.

Modules described as “Core” must be passed. “Compulsory” modules must be taken.

Students have a free choice of elective modules apart from Quantum Optics. Quantum Optics requires sufficient prior background in quantum mechanics at undergraduate level and can only be selected after discussion with one of the course co-directors. There are no prerequisites for the other electives. Students should consider the balance of the workload in each term.

You must choose Elective Modules with Credits totalling 25 to 27.5 Credits in order to have a total of 90 to 92.5 Credits (including laboratory and projects).

Module Descriptions

A summary of the Modules is provided as an appendix to this document.

Teaching

The programme is delivered using a range of methods including lectures and classworks, laboratory classes (including computational work) and directed supervision on projects.

Lectures are 50-minute oral presentations. The lecturer provides supporting material that may include notes, problem sheets and solutions and other resources. Learning is guided through classworks (where a timetabled session is used for a group problem solving exercise) and regular problem sheets. Lectures may be ‘flipped’, where recorded material is provided in advance of classwork and group exercises. All of the material that lecturers provide is available online via Blackboard. Lecturers provide office hours as informal drop-in question and answer sessions for students.

Practical/Laboratory is timetabled for a total of 160 hours over Term 1 and Term 2. Your first laboratory work will be short well-scripted experiments so that you can understand the operation of key optical experimental equipment, understand the basic procedures and the protocols of safe working in the laboratory and keep a good laboratory record. As your work develops in the laboratory your experiments will be less scripted and you will be expected to plan the progression of your experiment. Some of these experiments will involve computation, modelling or simulation. The last laboratory exercise will require you to design, build and test an optical system to address a given problem. In the laboratory you will work in a group of 2 or 3 students. You will write up your work individually, and you will be asked to write reports in a range of different formats that are routinely required in reporting scientific work.

Project work is carried out individually and in pairs. You will complete 2 project exercises: a smaller self-study project, which is carried out individually, and the main summer Master’s research project which may be carried out in pairs.

The self-study project requires you to take a topic or subject area (this is selected from a list that is provided) and conduct a review of the scientific literature and provide a written report explaining the background to the topic, its development and its current status. Each topic has a member of staff assigned as the project supervisor and you are encouraged to meet regularly to discuss your progress and plans. The self-study project takes place over Term 2 and in the last week of that term you will submit your report and give a short oral presentation on your work.

Your summer Master’s research project is chosen from a list of projects offered by staff, or you can propose your own (subject to us having appropriate resource to support it). Each project is supervised by a member of staff. Typically you will meet your project supervisor weekly, though it may vary depending on the nature of your project. You will begin your project work towards the end of May when all other activities are complete meaning that you can work full-time on your project for four months. At the end of the project you will submit an individual dissertation and give a short oral presentation.

Project Selection

Self-study projects are selected early in the second term. A list of projects with supervisors is provided, and students can approach the supervisor and both may agree on the project. If the student has their own idea for a project they can approach the self-study project coordinator and, if it is agreed the student may approach potential supervisors (with help from the self-study project coordinator if needed). If a student has difficulty finding a project, they should speak to the self-study project coordinator.

The process is similar for summer projects. A list of project with supervisors is provided later in the second term and students may select a project as above. Several projects may be offered by industrial companies or external research organisations; if a student is interested in these projects then a visit and interview are usually arranged prior to either party agreeing to the project – please note the company is not obliged to accept a student.

If you wish to arrange your own project you must speak to the Programme Director as soon as possible, **and by the end of February at the latest**. The Department needs to ensure that supervisory, health and safety and intellectual property issues are agreed before the project is approved. It is expected that most projects will have been arranged by the end of the second term, and all should be in place by the start of the examinations.

The projects are assessed by a final report which must be submitted by the date specified, and a final oral presentation (of 15 minutes duration plus 5 minutes for questions). Students must submit an electronic copy of their report (in PDF format) which will be added to the College archive. The report will be submitted via and checked by Turnitin.

Where projects are pursued in industry, it is important that industrial supervisors ensure that confidentiality considerations will not prevent students from adequately reporting their work. If there is concern of commercial sensitivity, this must be raised at the outset of the project, so that the College can consider the issue at an early stage.

Students are also required to make a short oral presentation on their project work approximately six weeks into the project. This is not formally assessed but provides useful comment and advice on the project plan.

2. Assessment

Module Assessment

The pass mark for each of the modules is 50% (they are all Level 7 Modules).

The taught Modules (compulsory and elective) are assessed by a written examination in January or May, though some also include other assessed components, for example assessed coursework or practical work (see details below).

The Laboratory Module is assessed on written reports. You will be asked to write these reports in different styles to reflect the different ways in which scientific work is reported.

Both the self-study project and summer Master’s project are assessed by a written report (self-study a maximum of 6,000 words, Master’s Project a maximum of 30,000 words) and short oral presentations (each of 20 minutes including questions).

The assessment is summarised in the table on the following page.

Module Name	Module Type	Module Credits	Term	Assessment summary	Assessment Timing
Lasers	Compulsory	5	1	2 hour written examination	January
Imaging	Compulsory	5	1	2 hour written examination	January
Optical Measurements and Devices	Compulsory	5	1	2 hour written examination	May
Laboratory	Core	15	1 & 2	Written reports	Throughout the work
Self-Study project	Core	5	2	Project report (approx. 3,000 words) and 20 minute oral presentation	End of Term 2
Master's Project	Core	30	Summer	Project report (approx. 30,000 words) and 20 minute oral presentation	End of September
Laser Technology	Elective	7.5	2	2 hour written examination	May
Quantum Optics	Elective	7.5	1	2 hour written examination	May
Optical Communications Physics	Elective	5	1	1 hour written examination (70%) and coursework (30%)	May
Biomedical Optics	Elective	5	2	1.5 hour written examination (80%) and coursework (20%)	May
Fibre and Ultrafast Lasers	Elective	5	2	2 hour written examination	May
Optical Design	Elective	5	2	2 hour examination (67%) and report on practical optical design problem (33%)	May
Opto-Electronic Devices	Elective	5	2	2 hour written examination	May

Formal feedback on each activity is by way of a letter grade indicating the percentage band of their attainment. The definition of the letter grades are

A*	80.0 - 100%
A	70.0 – 79.9%
B	60.0 – 69.9%
C	50.0 – 59.9%
D	40.0 – 49.9%
F	0 – 39.9%

With these definitions a "D" corresponds to a mark which may be considered for Compensation.

Written Examinations

Assessment of the lecture modules includes written examinations, though some include other forms of assessment. The examination questions are set by the lecturers delivering the module. The rubric for the examinations may be different for different examinations (for example the examinations shared with the undergraduate programmes). We will highlight the rubric to you, but it is your responsibility to read the rubric and complete the exam accordingly.

For the examinations, each examination question is marked by the module lecturer, the mark being moderated by a second marker. The total mark for each paper is converted to a percentage, the corresponding letter grade being fed back to the student approximately two months after the examination.

The examination marks are reviewed by meetings of the internal Examiners' meeting (staff involved in the modules). The College requires that individual students cannot be identified by staff present at the Examiners meeting.

The marks are then forwarded to the External Examiner for information. The External Examiner will also see a selection of the project reports in advance of the final Examiners' meeting.

A separate independent meeting will consider any claims for mitigating circumstances and their recommendations will be reviewed by the appropriate Examiners meeting.

The Board of Examiners (including the External Examiner) meets soon after the completion of the course for the final Examiners' meeting to review all the marks and make final recommendations to the College.

After this meeting the results are communicated to Registry and Registry then releases the marks to the students.

Deadlines

Deadlines are absolute. The Board of Examiners reserve the right not to mark reports submitted late. Computer difficulties will not be accepted as excuses for late submission.

Any extenuating circumstances (e.g. illness) should be discussed with the Programme Director immediately.

Overall Mark

The overall mark for the MSc is based on assessment results from each of the modules you complete and the project marks. These results are then combined, weighted by Credits relative to the total Credits taken (either 90 or 92.5 Credits), to produce the overall weighted average which is used for the purpose of degree classification.

Award of the MSc Degree

To qualify for the award of the MSc in Optics and Photonics degree a student must have:

1. accumulated Credit to the value of no fewer than 90 Credits at level 7 or above;
2. and no more than 15 Credits as a Compensated Pass;

A Compensated Pass may, at the discretion of the Board of Examiners, be awarded for a compulsory or elective module assessment where the overall module result is 40.00-49.99 inclusive. Core modules cannot be compensated.

Classification of Postgraduate Taught Awards

The MSc in Optics and Photonics degree may be awarded with the following classification:

1. Distinction:

   The student has achieved an overall weighted average of 70.00% or above across the programme.

2. Merit:

   The student has achieved an overall weighted average of above 60.00%.

3. Pass:

   The student has achieved an overall weighted average of 50.00% but less than 60.00%.

Anyone who has a failed module that cannot be compensated, or failed more than 15 Credits, will be required to resit the assessment of the corresponding modules.

Resits for the written examinations are normally offered or at the next available opportunity, usually the following academic year. College regulations allow only one resit, otherwise the student is deemed to have failed the course. Students will retake the examinations for the specific subjects they have failed. You cannot resit modules that have been passed or Compensated.

3. Appendix - Module Information

Imaging

Term: 1
Credits: 5
A Compulsory Module

Brief Description
The Imaging module is split into two parts: geometrical optics and wave optics. Geometrical optics introduces you to the ray model for light propagation through optical systems and methods to model aberrations. The wave optics part introduces methods to model the propagation of scalar waves through optical systems and how this can be used to describe image formation for both coherent and incoherent illumination.

Learning Outcomes
On completion of this module students will be able to

- apply the refraction invariant, aperture and field stops and the Lagrange invariant in calculations of imaging systems
- evaluate wave and transverse ray aberrations, use the aberration polynomial and characterise aberrations in terms of the primary aberrations
- calculate wavefront aberrations in optical systems using Seidel sums and perform associated calculations
- derive and describe the field distribution in the vicinity of the back focal plane of a perfect lens under coherent illumination and its relationship to the Fourier transform
- use the point spread function and coherent transfer function analyse to calculate the performance of coherent imaging systems
- use the point spread function and optical/modulation transfer function to analyse and calculate the performance of incoherent imaging systems

Module content
Geometrical optics:
Ideal optical systems, cardinal points, lateral and longitudinal magnification, paraxial approximation, Gaussian lens formula, single refracting surface, refraction invariant, aperture and field stops, Lagrange invariant, afocal systems, Gaussian properties of two systems, ABCD ray tracing matrices, wave and transverse ray aberrations, the aberration polynomial, primary aberrations, Seidel sums and Seidel sums for thin lenses.
Wave optics:
Scalar diffraction theory, angular spectrum of plane waves, first Rayleigh-Sommerfeld integral, Fresnel and Fraunhofer diffraction integrals, transmission function and field distribution in back focal plane region of a thin lens, application of Fourier transform to diffraction calculations, weak aberration and the Strehl ratio, coherent imaging of point and extended object, coherent transfer function and coherent point spread function, transition from coherent to incoherent imaging, optical/modulation transfer function and incoherent point spread function.

Lasers

Term: 1
Credits: 5
A Compulsory Module

Brief Description

Lasers underpin much of commercial and research optics and photonics. This module provides a basic introduction to the physics of lasers including 3 and 4-level lasers, the conditions required for gain and laser operation, control of the spectral properties of laser emission, Q-switching, modelocking and the different types of laser gain media, spatial laser modes, Gaussian beam propagation and includes an introduction to the topic of nonlinear optics.

Learning Outcomes

On completion of this module students will be able to:

- calculate the conditions for laser action using laser and material rate equations
- describe the implementation of the techniques of q-switched and modelocked laser operation to create laser pulses
- calculate the characteristic parameters of a Gaussian beam and its propagation
- design laser resonators to achieve a given spatial mode size, and describe the form of higher order spatial modes
- solve key equations of nonlinear optics including second harmonic generation, phase matching and intensity-dependent refractive index

Module content

- Overview of the key light-matter interactions involved in laser action
- Two, three and four level laser systems and the development of corresponding rate equations
- The operation of laser cavities and laser output power
- Methods used to control and adjust the spectral characteristics of the laser output
- Methods for q-switched and modelocked laser operation
- Overview of different classes of laser gain media and the different hosts used in solid-state lasers
- The equations for Gaussian laser beam propagation
- Laser stability condition
- The use of ABCD matrix law for transformation of a Gaussian beam through a lens system
- Design of laser resonators to achieve a given minimum mode size and its location
- Higher-order Hermite-Gaussian and Laguerre-Gaussian modes
- Description of nonlinear polarisation and its use in deriving nonlinear wave equation
- Second harmonic generation, solution of nonlinear equation, and the concept of phase matching.
- Intensity-dependent refractive index and its consequences for self-focussing and self-phase modulation

Optical Measurement & Devices

Term: 1
Credits: 5
A Compulsory Module

Brief Description
Optical measurement techniques are important to manufacturers and users of optical equipment and in a wide range of applications. Polarisation, interference and coherence are aspects of light that can be exploited for a broad range of measurement techniques and form the foundation of many optical devices. This module introduces these phenomena and provides frameworks for describing, understanding and exploiting them. The module gives details of the underlying generic optical concepts, their mathematical representation and their practical applications.

Learning Outcomes
On completion of this module you will be able to:

- determine the mathematical representation of polarisation state of light as a vector expression, as a Jones Vector or via Stokes parameters and relate these to the azimuth and ellipticity of the light;
- explain the concept of interference of light and use mathematical representations to describe interference, analyse results and use it in optical measurements
- determine the relationship between the temporal and spectral coherence of light and the light's properties, explain their interpretation and their implications for interference measurements;
- critically assess the performance of a range of interferometry methods and their applications in optical testing and measurements, select appropriate methods and analyse the corresponding results
- develop a framework for the design and analysis of the performance of thin-film coatings for different real-world applications.

Module content
Light as a wave; definition of the polarisation state of light; vector, Stokes' parameters and Jones vector representation of polarisation; devices for the manipulation of polarisation and their Jones matrices and Mueller matrices; measurement of polarisation.
Principles of interferometry; division of wavefront and division of amplitude; two-beam and multiple beam interferometry; coherence including spatial and temporal coherence; practical interferometers.
Interferometric and non-interferometric techniques for testing the quality of optical surfaces, optical components and wavefront measurement.
Optical properties of thin films; design of thin film antireflection coatings, and high reflection coatings; narrow band optical interference filters; practical techniques for the manufacture of thin film devices.

Laser Technology

Term: 2
Credits: 7.5
An Elective Module

Brief Description

An introduction to principles and practice of laser devices and nonlinear optical technology. The module will provide an understanding of the key physical concepts underlying laser and nonlinear optics and their contemporary applications. Students will be equipped with sufficient knowledge to be able to use and understand lasers and nonlinear processes in the subsequent research or commercial careers.

Learning Outcomes

On completing the Laser Technology module, students will:

- know key laser applications and commercially important lasers;
- be able to match laser properties and laser systems to best meet applications' needs;
- know how to control (and in some cases design) key laser parameters;
- be able to quantify some laser applications (e.g. laser cutting speed);
- have rigorous but not overly mathematical understanding of nonlinear optical phenomena and contemporary applications;
- have an understanding of phase matching, second-order nonlinear processes and the key physical processes underlying nonlinear optics;
- be able to use third-order nonlinearity to illustrate the process of intensity-dependent refractive index and its effects (e.g. self-focusing, self-guiding, self phase modulation).

Module content

- Overview of commercially important lasers, laser market and laser applications.
- Characterising lasers for real-world applications, spatial mode and M^2 values.
- Details of key laser technologies (Diode, Fibre, Solid State, Gas).
- Solid-State Laser Design.
- Thermal effects in lasers.
- Laser material processing.
- Guided self-study covering laser induced damage and scaling of laser systems to high energy.
- Polarisation, refractive index and dispersion
- Second harmonic generation, phase matching (types I and II and non-critical)
- Real sources in NLO, phase matching acceptance angle, pulse walk-off and phase-matching bandwidth
- Three-wave mixing and second-order nonlinearity, sum frequency generation, difference frequency generation, optical parametric amplifier and oscillator
- Third-order nonlinearity, intensity-dependent refractive index, self-focusing, self-guiding, self-phase modulation, chirped pulses and pulse compression

Quantum Optics

Term: 1
Credits: 7.5
An Elective Module

This module requires sufficient prior background in quantum mechanics at undergraduate level and can only be selected after discussion with one of the course co-directors.

Brief Description

This module covers the interaction of quantum mechanical objects with light, including at the single-photon level. A description of the quantised electromagnetic field will be introduced, and the physics of atoms' and mechanical oscillators' interaction with the electromagnetic field will be discussed.

Learning Outcomes

On completing the Quantum Optics module, students will have a detailed understanding of the quantisation of the electromagnetic field, correlation functions and photon statistics. Students will be familiar with the interaction of light with quantum-mechanical objects and the Jaynes-Cummings model.

Module content

- Semi-classical atom-field interaction (optical Bloch equations, Ramsey interferometry)
- Field quantisation (Fock states, coherent states)
- Fluctuations and correlations (Mach-Zahnder interferometry, Hanbury-Brown-Twiss experiment, Hong-Ou-Mandel effect)
- Quasi-Probabilities (Wigner function, Husimi function)
- Atom-field interaction (dipole interaction, Jaynes-Cumming model)

Optical Communications Physics

Term: 1
Credits: 5
An Elective Module

Brief Description
This module builds on the Oscillations and Waves, E&M and Solid State Physics core modules, and develops understanding of how modern optical communications technologies operate. The module considers optical fibres and the surrounding optoelectronic and photonic technology, classical information theory and data encoding, and network infrastructure.

Learning Outcomes
On completion of this modules, students will be able to:

- Explain the operation principles and technology of optical fibre networks
- Explain the factors that limit light transmission and the information it carries over optical fibres and the methods commonly used to mitigate them.
- Explain the operation of semiconductor light sources and detectors used in optical communications systems.
- Explain the implementation of optical fibre communications systems and the factors that affect wavelengths of operation, information capacity and likely future developments.
- Describe the factors that limit bit-rates in optical fibre communications

Module content
- Ray picture of light propagation in optical fibres: Fresnel's Equations/Total Internal Reflection
- Guided-mode solutions of cylinder from Maxwell's equation: optical fibre modes
- Light propagation in optical fibres: dispersion, attenuation
- Fibre Amplifiers (Erbium doped and Raman)
- Dispersion compensation in optical fibres
- Revision of semiconductor physics
- Revision of light emission from semiconductor materials (LEDs)
- Principles of laser action and introduction to semiconductor lasers
- Laser modulation (direct and indirect): Laser ringing and chirp, Electro-Absorption (Franz-Keldysh, Quantum-Confined Stark Effects, Electro-Refraction and Mach Zehnder Interferometers)
- Photodiodes: efficiency, speed and noise
- Noise in optical communications systems, bit error rates and eye diagrams
- Data-encoding strategies to maximize data capacity over optical linkstations. Consideration of future developments in nanophotonics.

Biomedical Imaging

Term: 2
Credits: 5
An Elective Module

Brief Description

An introduction to principles and practice of biomedical imaging technologies, including microscopes, fluorescence and tomography. The module will provide an understanding of the challenges presented by tissue samples, in vivo and ex vivo systems. You will be equipped with sufficient knowledge to be able to use and understand a biomedical imaging system in subsequent research or industry settings and will gain knowledge of latest research frontiers.

Learning Outcomes

On completion of the module you will be able to:

- demonstrate awareness of the key techniques in imaging biological samples, and select and apply appropriate mathematical methods to the analysis of the technique,
- critically analyse key and current problems/ frontiers in biomedical imaging,
- design from first principles a biomedical imaging system, analyse its performance and assess its relative merits
- analyse complex biomedical imaging systems using appropriate mathematical descriptions and simulation tools,
- describe the detail, and assess the performance characteristics and relative merits, of advanced, state-of-the-art biomedical imaging techniques.

Module content

- The mechanisms for creating contrast for imaging
- The principles of microscopy
- Properties of tissue and challenges for imaging in a biological content
- Design consideration and elements of a biomedical imaging system
- Using fluorescence as contrast, techniques and research examples
- Using phase as contrast, techniques and research examples
- Computational techniques for superresolution
- Advanced techniques for biomedical imaging

Fibre and Ultrafast Lasers

Term: 2
Credits: 5
An Elective Module

Brief Description

This module is an introduction to fibre lasers and ultrafast lasers. It will cover the fundamentals of optical fibres and how they can be used as laser gain media, the generation and characterisation of ultrafast optical pulses and relevant examples of ultrafast pulsed lasers. You will gain an understanding of how fibre and ultrafast lasers work and gain insight into why they are such useful tools in a wide variety of scientific and industrial applications.

Learning Outcomes

On completing this module you will be able to:

- determine, and calculate where appropriate, the transmission characteristics of different types of optical fibre
- interpret the spectroscopic properties of the main rare-earth-doped fibre gain media and their associated optical pumping schemes for applications in optical amplifiers and/or fibre lasers
- critically analyse the main state-of-the-art continuous-wave and pulsed fibre laser architectures and the key characteristics of the components used to build them
- calculate the key characteristics of ultrafast laser pulses, and explain the fundamental physics behind their formation
- determine the details of the unique properties of fibre and ultrafast lasers which are useful in applications such as materials processing and nonlinear optics.

Module content

- Waveguiding properties and transmission characteristics of single-mode and multimode optical fibres
- Rare-earth-doping of optical fibres, the spectroscopic properties of key laser-active ions and optical pumping schemes
- Continuous-wave and pulsed fibre laser architectures
- The physics of ultrafast optical pulses and characterisation techniques
- Exemplar fibre and solid-state ultrafast pulsed lasers
- Example applications of fibre and ultrafast lasers: materials processing and nonlinear optics

Optical Design

Term: 2
Credits: 5
An Elective Module

Brief Description

The module introduces Seidel aberration theory to describe and enumerate the aberrations that arise in optical imaging systems such as compound lenses and mirrors. It studies arrangements of optical surfaces that are able to control or minimise aberrations and investigates both theoretical and practical design processes using an industry standard computer aided design package.

Learning Outcomes

On completion of this modules students will be able to:

- evaluate the aberrations arising in optical systems and characterise those present in terms of the primary aberrations
- demonstrate and evaluate how refractive and reflective elements can be combined to minimise certain aberrations
- identify the fundamental limitations to the performance of certain design combinations
- critically analyse and refine the performance of optical systems using industry standard techniques based on ray-tracing and optimisation

Module content

- Seidel aberration theory and the effect on Seidel aberrations of shifting the stop
- Refractive index and dispersion in real glasses
- Controlling aberrations in thin singlet and doublet lenses
- Optimising lens designs on a computer using finite raytracing
- More complex compound lens designs including Petzval, Telephotos, Triplets and Double Gauss
- Aberrations in mirror systems

Opto-electronic Devices

Term: 2
Credits: 5
An Elective Module

Brief Description

An introduction to the most important device components from the worlds of optical telecommunication, space lighting, optical displays and sustainable energy production. You will acquire advanced mastery of the principles of diode laser action and design, and you will explore how quantum theory can be harnessed to improve performance in nano-scale devices. You will also consider the key factors affecting the use of photovoltaics and LED lighting as part of a sustainable energy future. You will examine the operation of optical displays, how the human visual system works and the way in which it perceives light and colour, and the operating principles behind many displays and their development.

Learning Outcomes

On completion of this module students will be able to:

- compute the effect of band structure and carrier statistics in determining the characteristics of p-n junctions, and the operation of associated lasers, LEDs and detectors
- model the way light interacts with electrons in crystalline materials
- use photometric units and chromaticity diagrams to characterise the human visual perception of light and colour
- critique the key performance characteristics of optical displays and their impact on displays' applications

Module content

Semiconductor Crystals, doping, law of Mass Action. P-N junctions. LEDs. LEDs for space lighting. Diode Lasers. Diode Lasers for telecommunications, data and research. Photovoltaics, 1st, 2nd and 3rd generation ideas and key performance limits. Low dimensional systems, basic quantum theory and how it impacts on device performance in Quantum Well lasers. Intersubband devices for emission and detection in the mid-infrared. Optical Display Characteristics (Brightness, Colour hue and saturation, Contrast, Viewing angle, Efficiency, Response time, Memory, Resolution, Durability); Visual perception; Colour charts; Display Devices: Emissive (Thin film electroluminescence, Field emission, Organic LED, Inorganic LED, Fluorescent liquid crystal) and Non-emissive (Liquid crystal, Micromirror, Electrochromic, Electrophoretic)

Laboratory

Term: 1 and 2
Credits: 15
A Core Module

Brief Description

You will follow a set of experiments ranging from short introductory experiments, through longer experiments and finally an extended self-design project. You will be exposed to a wide variety of optical techniques and phenomena that you will also see in taught lecture modules.

Learning Outcomes

On completion of this module students will be able to:

- recognise a range of optical phenomena and their fundamental origins, and understand their significance in the operation of, and/or the limitations they impose in, optical instrumentation
- use state of the art optical measurement techniques, optical instruments and components
- construct detailed optical instrumentation from simpler components to address specific optical measurements
- critically analyse the results of measurements made during experiments, taking account of errors.
- model extended optical experiments using your own computer programmes or through dedicated software
- Keep a laboratory record in a lab-book
- Produce written reports in a variety of scientific formats

Module content

The module will contain practical work related to:

- a range of optical phenomena including: refraction, diffraction, interference, dispersion, polarisation, imaging;
- making use of optical components including: lasers, optical fibres, detectors, cameras, lenses, mirrors, diffraction gratings;
- using optical methods: spectrometers, interferometers, computer modelling.

Self-study Project

Term: 2
Credits: 5
A Core Module

Brief Description

This module lets you develop your ability to distil information from the scientific literature using methods appropriate to the chosen topic. You will develop skills for analysing and critiquing the literature. You will produce a report outlining the background to the chosen topic and the key steps in its development from conception through to the current state-of-the-art. Typically the topic chosen will be a research area or technique.

Learning Outcomes

On completion of this module you will be able to:

- appraise and interpret the scientific literature to extract information on a particular topic
- critically review material extracted from the scientific literature and be able to explain the development of the topic to the current state-of-the-art
- produce a written report on the literature review and give an associated oral presentation

Module content

An independent literature review of a research topic or technique in optics and photonics. Using the scientific literature students develop an understanding of the basic principles behind their selected topic, and the research and/or development that has been applied around that topic to bring it to its current day standing.

Master's Project

Term: May to September
Credits: 30
A Core Module

Brief Description

A 4-month research project on a state-of-the-art problem within the area of optics and photonics. The project will encompass either a laboratory-based practical project, computational project or theoretical project, either within one of our research groups or with an industrial partner and under the guidance of research-active staff. You will be able to choose from a range of projects based on your interests and the background you have developed through your prior studies on the MSc.

Learning Outcomes

On completion of this module you will be able to:

- design a research plan for addressing the problem being pursued
- critically assess techniques appropriate to meeting the project's aims
- carry out laboratory/computational/theoretical work at the state-of-the-art
- evaluate the performance of different methods and their suitability for the problem studied
- present, by both a written thesis and an oral presentation, on the research problem and work conducted for addressing the problem

Module content

A research-led project in a chosen area of optics and photonics. This is a substantial, open-ended project which tackles an open problem in optics and photonics, or may make a significant, stand-alone contribute to a major research project within the department. It may be theoretical, laboratory based or computational in nature. The project is selected from topics offered by research staff, and is supervised by a member of research staff.