PHTN702

Advanced Photonics

S2 Day 2016

Dept of Physics and Astronomy

Contents

General Information

Unit convenor and teaching staff
Lecturer
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By appointment

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Credit points
4

Prerequisites
Admission to MRes

Corequisites

Co-badged status

Unit description
We explore the origin of nonlinear optical effects, and how they are used in modern optics to convert and control light. We derive the hierarchy of nonlinear effects, such as simple frequency doubling and mixing and enhancement using periodic materials; the Kerr effect and its applications in ultrafast lasers; Raman scattering and Brillouin scattering and their relevance to all-optical switching; and high-harmonic generation for generating XUV light and attosecond pulses. Advanced topics may include using the nonlinear Schrodinger equation to investigate nonlinear effects in fibres, such as soliton formation, super continuum generation. We establish how to use light-matter interactions to detect and study atoms and molecules. We determine the form of their excitation spectra, the factors that determine the shape and width of the spectral features, and how to measure them using infrared to ultraviolet excitation wavelengths. We will study more complex techniques that may include enhancements such as cavity ring down and Doppler-free methods; Raman spectroscopy and techniques such as CARS; and enhancement of Raman scattering using nanostructures and the quest for single molecule detection.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.
Understand and describe the principles and methods for advanced photonics topics such as laser structuring of materials and applications.
Demonstrate an advanced knowledge of research principles and methods in photonics.
Demonstrate a comprehensive knowledge of optical materials and their use in linear optics.
Understand how ethics and responsible conduct in research achieve best practice research outcomes, including with respect to collaboration.
Demonstrating high accuracy, high precision photonic measurement, its recording, analysis and communication.
Understanding how to learn how to use a sophisticated piece of photonic instrumentation.

General Assessment Information

Photonic Experimental Research Skills - Assessment task

The photonic experimental research skills will be learned in a collaborative environment between staff and the students in the class. However, all assessment will be on an individual basis. Everyone will attain a high level of awareness and knowledge of all skills. Everyone will work with staff to plan an experiment with the OSP. Everyone will learn to use the OSP to complete their measurement. Everyone will keep their own individual lab record (logbook with associated electronic record keeping) that will be assessed. Everyone will report the analysis, with a sophisticated treatment of uncertainties and errors, and interpretation of their measurements. Everyone will critically appraise their results and suggest how they might be improved in a subsequent, re-planned experiment. All of this should be carried out making positive use of opportunities to collaborate which should be duly acknowledged in record keeping. The assessment will be made from a portfolio which includes the following components.

Original record keeping – 15% Logbook plus a well organised folder of associated e-files that represent a long-term archival record of the experiment completed. Acknowledgement of the inputs of others is strongly encouraged in the record.

Error and Uncertainty Analysis – 5% This report on the error and uncertainty analysis of your experiment, including a discussion of measurement artifacts as relevant, should explicitly reference the literature sources used to inform a best practice analysis of the specific results.

Communication – 2 x 5% (10% total) For assessment choose two of the following: a preliminary partial draft of a letter or note on your results for the scientific literature; a 10 minute scientific presentation with powerpoint slides; a 10 minute public talk with powerpoint slides; a 250-350 word media release for a magazine or journal such as Laser Focus World or Nature News.

Assessment Tasks

Name	Weighting	Due
Assignments	30%	Biweekly during lecture weeks
Experimental Research Skills	30%	Week 9
Exam	40%	Exam week

Assignments

Due: **Biweekly during lecture weeks**
Weighting: **30%**

There are 4 assignments in total: 2 each assigned by the 2 unit lecturers. The assignments will comprise of questions and / or tasks designed to engage the students with the material as it's covered. The difficulty of the questions /tasks will be set so that the assignment would take on

average around 5 hours to complete.

On successful completion you will be able to:

- Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.
- Understand and describe the principles and methods for advanced photonics topics such as laser structuring of materials and applications.
- Demonstrate an advanced knowledge of research principles and methods in photonics.
- Demonstrate a comprehensive knowledge of optical materials and their use in linear optics.

Experimental Research Skills

Due: **Week 9**
Weighting: **30%**

General Approach to Experimental Research Skills Section of PHTN 702

Much experimental research, including in photonics, uses sophisticated, high-tech, high-cost equipment and facilities. The Microscopy Unit http://science.mq.edu.au/macquarie-university-microscopy-unit/ and the Australian Nanofabrication Facility (ANFF) Opto Fab Node http://www.anff.org.au/optofab-node.html are examples of such facilities at Macquarie University. The experimental research skills component of PHTN 702 will involve completing, analysing and reporting experimental studies using such a sophisticated instrument, an optical surface profiler.

On successful completion you will be able to:

- Understand how ethics and responsible conduct in research achieve best practice research outcomes, including with respect to collaboration.
- Demonstrating high accuracy, high precision photonic measurement, its recording, analysis and communication.
- Understanding how to learn how to use a sophisticated piece of photonic instrumentation.

Exam

Due: **Exam week**
Weighting: **40%**

An exam covering the lecture material (~30%) and the experimental skills component (~10%).

On successful completion you will be able to:

- Demonstrate an advanced knowledge of research principles and methods in photonics.
- Demonstrate a comprehensive knowledge of optical materials and their use in linear

optics.

Delivery and Resources

Classes

9 weeks of mixed lectures, tutorials and discussion, with 4 timetabled hours per week.

4 weeks of hands-on experimental research skills, with 4 timetabled hours per week.

The timetable for classes can be found on the University web site at: http://www.timetables.mq.edu.au/

Required and Recommended Texts and/or Materials

Recommended Text

As advised by lecturers.

Unit Web Page

Lecture notes will be available online at iLearn.

Teaching and Learning Strategy

The theoretical and applied aspects of this unit are taught in lectures and tutorials with fortnightly assignments to strengthen the understanding of the material. The material is both mathematical and applied in nature and true understanding can only be achieved through testing and refining understanding through problem solving. This is complemented by hands-on exposure to related systems (eg lasers, spectrometers etc) in a research lab environment. An additional strategy is to increase awareness regarding the open access facilities that support postgraduate research projects. This will be implemented by exposing the students to relevant fabrication and diagnostic facilities both within and outside the University.

Schedule of topics

A plan of topics is under Unit Schedule. Lecturers for each part of the course will provide an outline of that part.

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Unit Schedule

Week 1: Introduction to Photonics at Macqaurie

Week 1-2: Optical Materials

Week 3-4: Laser material interactions

Week 5-8: Experimental Research Skills

Week 9-13: Nonlinear optics

Learning and Teaching Activities

Experimental Research Skills

From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach and steps in becoming a user of the OSP to other instruments you may need to learn to use in the future. 2) That it is necessary to have a reasonable understanding of how an instrument works to be able to use it, and interpret the results generated from it, correctly and responsibly. 3) How to improve your experimental record keeping to a standard expected of a professional researcher. 4) How to maximise the precision and accuracy of experimental measurements so that they are the best that can be achieved with the instrument capability. 5) How to interpret and analyse your experimental data to generate the best possible science from your study and to quantify errors and uncertainty. 6) How to report and communicate your experimental research in different modes. Written: as a primary record of research completed, for the science community, for the public, and as an executive summary. Oral presentation for a specialist or more generalist audience. 7) How a focus on ethics and responsible conduct in research informs best practice and best outcomes from research.

Optical Materials / Laser Material Interactions

The lectures will review linear optics and offer insights into how optical materials behave when used in high power laser systems. The learning outcomes include insights into how to construct a beam delivery system,controlling aberrations and losses. Students will demonstrate knowledge of the physics of intense laser / material interactions. The lecture material will be complemented by hand-on tasks characterising novel optical materials and designing a beam delivery system.

Nonlinear Optics

Students will understand nonlinear optical effects, such as the Kerr effect, frequency doubling and mixing, and how they are used in modern optics to convert and control light. Lecture material will be complemented with lab based activities demonstrating nonlinear optical effects and control in laser research laboratories.

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central. Students should be aware of the following policies in particular with regard to Learning and Teaching:

Academic Honesty Policy http://mq.edu.au/policy/docs/academic_honesty/policy.html

New Assessment Policy in effect from Session 2 2016 http://mq.edu.au/policy/docs/assessment/policy_2016.html. For more information visit http://students.mq.edu.au/events/2016/07/19/new_assessment_policy_in_place_from_session_2/

Assessment Policy prior to Session 2 2016 http://mq.edu.au/policy/docs/assessment/policy.html

Grading Policy prior to Session 2 2016 http://mq.edu.au/policy/docs/grading/policy.html

Grade Appeal Policy http://mq.edu.au/policy/docs/gradeappeal/policy.html

Complaint Management Procedure for Students and Members of the Public http://www.mq.edu.au/policy/docs/complaint_management/procedure.html

Disruption to Studies Policy http://www.mq.edu.au/policy/docs/disruption_studies/policy.html *The Disruption to Studies Policy is effective from March 3 2014 and replaces the Special Consideration Policy.*

In addition, a number of other policies can be found in the Learning and Teaching Category of Policy Central.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/support/student_conduct/

Results

Results shown in *iLearn*, or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au.

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/

offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Graduate Capabilities

PG - Capable of Professional and Personal Judgment and Initiative

Our postgraduates will demonstrate a high standard of discernment and common sense in their professional and personal judgment. They will have the ability to make informed choices and decisions that reflect both the nature of their professional work and their personal perspectives.

This graduate capability is supported by:

Assessment task

- Assignments

Learning and teaching activity

- From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach and steps in becoming a user of the OSP to other instruments you may need to learn to use in the future. 2) That it is necessary to have a reasonable understanding of how an instrument works to be able to use it, and interpret the results generated from it, correctly and responsibly. 3) How to improve your experimental record keeping to a standard expected of a professional researcher. 4) How to maximise the precision and accuracy of experimental measurements so that they are the best that can be achieved with the instrument capability. 5) How to interpret and analyse your experimental data to generate the best possible science from your study and to quantify errors and uncertainty. 6) How to report and communicate your experimental research in different modes. Written: as a primary record of research completed, for the science community, for the public, and as an executive summary. Oral presentation for a specialist or more generalist audience. 7) How a focus on ethics and responsible conduct in research informs best practice and best outcomes from research.

PG - Discipline Knowledge and Skills

Our postgraduates will be able to demonstrate a significantly enhanced depth and breadth of knowledge, scholarly understanding, and specific subject content knowledge in their chosen fields.

This graduate capability is supported by:

Learning outcomes

- Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.
- Understand and describe the principles and methods for advanced photonics topics such as laser structuring of materials and applications.
- Demonstrate an advanced knowledge of research principles and methods in photonics.
- Demonstrate a comprehensive knowledge of optical materials and their use in linear optics.
- Demonstrating high accuracy, high precision photonic measurement, its recording, analysis and communication.
- Understanding how to learn how to use a sophisticated piece of photonic instrumentation.

Assessment tasks

- Assignments
- Experimental Research Skills
- Exam

Learning and teaching activities

- From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach and steps in becoming a user of the OSP to other instruments you may need to learn to use in the future. 2) That it is necessary to have a reasonable understanding of how an instrument works to be able to use it, and interpret the results generated from it, correctly and responsibly. 3) How to improve your experimental record keeping to a standard expected of a professional researcher. 4) How to maximise the precision and accuracy of experimental measurements so that they are the best that can be achieved with the instrument capability. 5) How to interpret and analyse your experimental data to generate the best possible science from your study and to quantify errors and uncertainty. 6) How to report and communicate your experimental research in different modes. Written: as a primary record of research completed, for the science community, for the public, and as an executive summary. Oral presentation for a specialist or more generalist audience. 7) How a focus on ethics and responsible conduct in research informs best practice and best outcomes from research.
- The lectures will review linear optics and offer insights into how optical materials behave

when used in high power laser systems. The learning outcomes include insights into how to construct a beam delivery system,controlling aberrations and losses. Students will demonstrate knowledge of the physics of intense laser / material interactions. The lecture material will be complemented by hand-on tasks characterising novel optical materials and designing a beam delivery system.

- Students will understand nonlinear optical effects, such as the Kerr effect, frequency doubling and mixing, and how they are used in modern optics to convert and control light. Lecture material will be complemented with lab based activities demonstrating nonlinear optical effects and control in laser research laboratories.

PG - Critical, Analytical and Integrative Thinking

Our postgraduates will be capable of utilising and reflecting on prior knowledge and experience, of applying higher level critical thinking skills, and of integrating and synthesising learning and knowledge from a range of sources and environments. A characteristic of this form of thinking is the generation of new, professionally oriented knowledge through personal or group-based critique of practice and theory.

This graduate capability is supported by:

Learning outcome

- Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.

Assessment tasks

- Assignments
- Experimental Research Skills
- Exam

Learning and teaching activities

- From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach and steps in becoming a user of the OSP to other instruments you may need to learn to use in the future. 2) That it is necessary to have a reasonable understanding of how an instrument works to be able to use it, and interpret the results generated from it, correctly and responsibly. 3) How to improve your experimental record keeping to a standard expected of a professional researcher. 4) How to maximise the precision and accuracy of experimental measurements so that they are the best that can be achieved with the instrument capability. 5) How to interpret and analyse your experimental data to generate

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- Students will understand nonlinear optical effects, such as the Kerr effect, frequency doubling and mixing, and how they are used in modern optics to convert and control light. Lecture material will be complemented with lab based activities demonstrating nonlinear optical effects and control in laser research laboratories.

PG - Research and Problem Solving Capability

Our postgraduates will be capable of systematic enquiry; able to use research skills to create new knowledge that can be applied to real world issues, or contribute to a field of study or practice to enhance society. They will be capable of creative questioning, problem finding and problem solving.

This graduate capability is supported by:

Learning outcomes

- Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.
- Demonstrate a comprehensive knowledge of optical materials and their use in linear optics.
- Demonstrating high accuracy, high precision photonic measurement, its recording, analysis and communication.

Assessment tasks

- Assignments
- Experimental Research Skills
- Exam

Learning and teaching activities

- From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach and steps in becoming a user of the OSP to other instruments you may need to learn to use in the future. 2) That it is necessary to have a reasonable understanding of how an instrument works to be able to use it, and interpret the results generated from it, correctly and responsibly. 3) How to improve your experimental record keeping to a standard expected of a professional researcher. 4) How to maximise the precision and accuracy of experimental measurements so that they are the best that can be achieved with the instrument capability. 5) How to interpret and analyse your experimental data to generate the best possible science from your study and to quantify errors and uncertainty. 6) How to report and communicate your experimental research in different modes. Written: as a primary record of research completed, for the science community, for the public, and as an executive summary. Oral presentation for a specialist or more generalist audience. 7) How a focus on ethics and responsible conduct in research informs best practice and best outcomes from research.
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PG - Effective Communication

Our postgraduates will be able to communicate effectively and convey their views to different social, cultural, and professional audiences. They will be able to use a variety of technologically supported media to communicate with empathy using a range of written, spoken or visual formats.

This graduate capability is supported by:

Learning outcomes

- Explain the origin of optical nonlinearities and be able manipulate and interpret the mathematical descriptions of nonlinear phenomena.
- Understand and describe the principles and methods for advanced photonics topics such as laser structuring of materials and applications.

Assessment tasks

- Experimental Research Skills
- Exam

Learning and teaching activities

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PG - Engaged and Responsible, Active and Ethical Citizens

Our postgraduates will be ethically aware and capable of confident transformative action in relation to their professional responsibilities and the wider community. They will have a sense of connectedness with others and country and have a sense of mutual obligation. They will be able to appreciate the impact of their professional roles for social justice and inclusion related to national and global issues

This graduate capability is supported by:

Learning outcome

- Understand how ethics and responsible conduct in research achieve best practice research outcomes, including with respect to collaboration.

Learning and teaching activities

- From this activity you will learn: 1) How an optical surface profiler (OSP) works and how to use it intelligently and creatively to complete planned experi1ments. The OSP is an exemplar of similar scaled instruments and you should be able to translate the approach

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Changes from Previous Offering

This unit was previously based on 13 weeks of lectures delivered by 3 lecturers, each lecturers assigning 2 assignments each totaling 60% of the unit assessment. Those assignments are often based on experimental tasks relevant to the lecture material. This year we are replacing 4 weeks of lectures with a comprehensive Experimental Research Skills component aimed at providing the students with a solid grounding in advanced experiment design, resourcing, data analysis, reporting and presenting outcomes.