PHYS306

Optical Physics

S2 Day 2015

Dept of Physics and Astronomy

Contents

General Information

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Credit points
3

Prerequisites
MATH235 and PHYS301

Corequisites

Co-badged status
Phys799 MRes Shell Unit

Unit description

Optics touches on many branches of physics and technology in the world today. The theme is physical optics, taught in the contexts of physics, electromagnetic fields, optical engineering and technology, and photonics. This unit illuminates electromagnetic waves in media, Fresnel reflection coefficients, multilayer dielectric filters, Gaussian beams, anisotropic media, nonlinear optics, interference, the Fabry-Perot interferometer, Fourier theory, Fraunhofer (far-field) and Fresnel (near-field) diffraction, spatial coherence, temporal coherence, optical transfer functions, the Abbe theory of image formation, holography, and modern aspects of near-field optics and their applications in measuring nanoscale phenomena. Key optical measurement techniques are studied in the regular laboratory program together with advanced data analysis techniques and report writing providing a strong foundation for future research project work.

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:

Interference, Diffraction and High Precision Optical Spectral Measurement: Understanding the relevance of interference and diffraction as the enabling concepts in current optics research; the method of solving two beam and multi-beam interference problems using complex exponential wave descriptions; the practical implementations of two beam and multi-beam interference in optical instrumentation; the fundamental trade-off between resolution and free spectral range in optical instruments used to chaaracterise the spectral content of light; the contrast of prism spectrometers, grating spectrometers and Fabry Perot interferometers; Fourier theory in optics, the far field (Fraunhofer) diffraction pattern as the Fourier transform of an “object”/aperture; recognition of the generalised diffraction integral; how to solve near field (Fresnel) diffraction cases in rectangular and circular symmetry; the Fresnel integrals, the cornu spiral, Fresnel zones; the Abbe theory of image formation and related topics in optical data processing

Spatial and Temporal Coherence of Light: Understanding experiments which demonstrate the coherence properties od light; temporal coherence and its fundamental limitation by the natural linewidth of a light source; the concepts of coherence: degree of coherence, partial coherence, coherence length, coherence time; the methods for measuring the degree of coherence: using a Michelson interferometer, using the

normalised Fourier transform of the power spectrum.
Further optical instruments and their physical optics concepts and principles: Understand the Michelson Stellar Interferometer; the correlation interferometer; the Fourier transform spectrometer.
Holography and Holographic Interferometry: Understand the point source (Gabor) hologram and its description from interference of complex exponential waves; the off-axis (Leith Upatnieks) hologram and its description from interference of complex exponential waves; thin and volume holograms, reflection holograms; practical, experimental issues of high diffraction efficiency holograms and their reconstruction; real-time holographic interferometry as a quantitative measurement technique for objects under deformation; time averaged holographic interferometry as a quantitative measurement technique for vibrating objects.
Waves, Media and Boundaries: Understand the modifications to Maxwell’s equations in a vacuum required to give Maxwell’s equations in media; the continuity conditions for E, D, B and H across a boundary between two media; how the continuity conditions can be used to derive the familiar laws of geometrical optics; metamaterials with negative refractive index and implications; how the continuity conditions can be used to derive the Fresnel equations for (amplitude) reflection and transmission coefficients for EM waves at a boundary between two media;
Polarisation: Understand the mathematical representation of polarization states by Jones vectors and Stokes parameters; the representation of polarization states on the Poincare sphere; the representation of polarization operations by Jones matrices and their representation on the Poincare sphere; the design and operation of basic polarization elements: wave plates, polarizers; basic concepts of the Pancharatnam phase
Gaussian Beams: Understand the progression from Maxwell’s equations to the general wave equation to the Helmholtz equation to the paraxial wave equation; the solution of the paraxial wave equation for the lowest-order Gaussian beam; the existence of higher-order beams with Cartesian symmetry; why Gaussian beams are produced by lasers.
Anisotropic Crystals and Nonlinear Optics: Understanding the optical properties of anisotropic materials and the associated terminology; the consequences of anisotropy for the propagation of EM waves; the method for finding allowed polarisations and appropriate refractive indices for waves in anisotropic media, especially as applied to polarising prisms; the origin of nonlinear polarisation in anisotropic materials; second harmonic generation, Type I and Type II phase matching.

Assessment Tasks

Name	Weighting	Due
Assignments	15%	various
Laboratory Reports	20%	various
Laboratory Logbook	10%	6 Nov
Presentation	5%	Week 13
Final Exam	50%	End of Unit

Assignments

Due: **various**
Weighting: **15%**

There will be 6 assignments with equal weight, three from each part of the course. Assignments will be issued on approximately the following dates and will be due 12 days later.

Thu Jul 30, Thu Aug 13, Thu Aug 27, Thu Sep 10, Thu Oct 8, Thu Oct 22

Extension Requests

Given the importance we place on assignments as a key aid to learning we expect assignments to be submitted on time. In turn, we undertake to return your assignments (provided they were submitted on time), marked and with feedback within two weeks of their due date. This will allow us to provide you feedback in time to aid your ongoing learning through the course. Extensions will only be considered if requested with valid reasons prior to the due date. Work submitted after the due date without an approved extension will accrue a penalty of 10% per additional day for the first week. Work submitted more than one week late will be marked at the lecturer's discretion.

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recognition of the generalised diffraction integral; how to solve near field (Fresnel) diffraction cases in rectangular and circular symmetry; the Fresnel integrals, the cornu spiral, Fresnel zones; the Abbe theory of image formation and related topics in optical data processing

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- Polarisation: Understand the mathematical representation of polarization states by Jones vectors and Stokes parameters; the representation of polarization states on the Poincare sphere; the representation of polarization operations by Jones matrices and their representation on the Poincare sphere; the design and operation of basic polarization elements: wave plates, polarizers; basic concepts of the Pancharatnam phase
- Gaussian Beams: Understand the progression from Maxwell’s equations to the general wave equation to the Helmholtz equation to the paraxial wave equation; the solution of

the paraxial wave equation for the lowest-order Gaussian beam; the existence of higher-order beams with Cartesian symmetry; why Gaussian beams are produced by lasers.

- Anisotropic Crystals and Nonlinear Optics: Understanding the optical properties of anisotropic materials and the associated terminology; the consequences of anisotropy for the propagation of EM waves; the method for finding allowed polarisations and appropriate refractive indices for waves in anisotropic media, especially as applied to polarising prisms; the origin of nonlinear polarisation in anisotropic materials; second harmonic generation, Type I and Type II phase matching.

Laboratory Reports

Due: **various**
Weighting: **20%**

Students must complete 4 experiments and submit two full reports and associated drafts together with their log book and calculations for the other two experiments. Submission of the 2 reports, and a logbook with a record of 4 experiments completed, and the associated calculations and analysis for the two experiments not the subject of a formal report, is mandatory.

Reports

- You should refer to the document “Recommendations for Laboratory Report Writing” when preparing reports.
- A draft report or report can only be submitted once a satisfactory sign off on your laboratory book record of the experiment has been obtained.
- Draft reports are optional but they represent an important opportunity to improve your report writing by gaining feedback during the writing stage. They will not be formally assessed. They will be returned to you annotated with suggestions for improvement which you should act on in your final report submitted for assessment.
- Any report submitted after a draft phase must submit the original draft with the report.
- Draft reports will be returned no later than one week after submission. Reports for assessment will be returned no later than two weeks after submission.
- Photocopies of all relevant pages for the experiment from your log-book should be submitted with your draft and/or report.
- Submissions should be to Dr Gina Dunford in the third year laboratory by 4pm on the due date.

Submission Dates

1. Draft first report – Thursday, Week 5
2. First report – Thursday Week 7

3. Draft second report – Thursday Week 10
4. Second report –Thursday Week 12

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Laboratory Logbook

Due: **6 Nov**
Weighting: **10%**

Log-books with the record of experimental data are to be kept. These will be assessed in the laboratory sessions for being a satisfactory or unsatisfactory. The criteria are readability, layout, completeness and clarity. A student must gain a satisfactory sign-off in their experimental log-book before any draft or report submission can be made.

Students must complete 4 experiments and submit two full reports and associated drafts together with their log book and calculations for the other two experiments. Submission of the 2 reports, and a logbook with a record of 4 experiments completed, and the associated calculations and analysis for the two experiments not the subject of a formal report, is mandatory.

Your laboratory log book including the write-up of two experiments additional to those in the formal reports, with graphs, analysis and calculations, is to be handed in by 5pm Friday 6 November. The log book should not have the formal background and polished presentation of a formal report. It should contain all recorded data and your analysis of measurements, as well as your conclusions. It should provide sufficient information for a reader to assess the validity of your experimental procedure and conclusions.

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Presentation

Due: **Week 13**
Weighting: **5%**

In week 13, students will provide a short in-class presentation on the topic of their choice from the contemporary optics literature. Lecturers will provide a list of suggested topics and starting points for reading, but students are free to pick their own topics and in any case, will need to read more broadly than the suggestions provided. Example topics might be metamaterials, lasers in new wavelength ranges, biophotonics or sub diffraction-limited resolution optics. We will also have a computer lab class devoted to accessing new research articles on your chosen topic.

Students may work alone or in pairs and will have seven minutes per student for the presentation. Assessment will be based on the clarity and effectiveness of presentation, your explanation of the essential physics in your chosen area, and your discussion of why this area is significant.

You may use aids such as PowerPoint or overhead transparencies but this is not required. Some of the most effective presentations use nothing more than the whiteboard. We are more interested in seeing how you can be creative and effective in your communication, than the degree to which you have mastered fancy software tricks. Further details on requirements and assessment will be provided during the semester.

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Final Exam

Due: **End of Unit**
Weighting: **50%**

The examination lasts 2 hours 30 minutes and consists of thirteen questions worth 4 marks each and six questions worth 8 marks each. All questions are to be answered. The exam questions are based closely on the assessment criteria that you have received.

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Delivery and Resources

Required Text

Introduction to Optics (3rd Edition) by FL Pedrotti and LS Pedrotti (Prentice-Hall, 2007)

Recommended Reading

- Optics by E Hecht (Addison-Wesley)
- Optical Physics (3rd Edition) by SG Lipson and H Lipson and DS Tannhauser (Cambridge University Press)
- The Fabry-Perot Interferometer by JM Vaughan (Adam Hilger)
- Interferometry by WH Steel (Cambridge University Press)
- Optical Holography by P Hariharan (Cambridge University Press)
- Optical Waves in Crystals by A Yariv and P Yeh (Wiley)

Teaching Strategy

This unit is taught through lectures and tutorials and through undertaking laboratory experiments. We strongly encourage students to attend lectures because they provide a much more interactive and effective learning experience than studying a text book. Questions during and outside lectures are strongly encouraged in this unit – please do not be afraid to ask as it is likely that your classmates will also want to know the answer. You should aim to read the relevant sections of the textbook before and after lectures and discuss the content with classmates and lecturers.

This unit includes a compulsory experimental component. The experiments are stand alone investigations and may include topics not covered by the lecture content of this course – They are an important part of the learning for this unit and the skills learned are essential for a well rounded physics graduate.

You should aim to spend 3 hours per week working on the assignments. You may wish to discuss your assignment problems with other students and the lecturers, but you are required to hand in your own work (see the note on plagiarism below). Assignments are provided as one of the key learning activities for this unit, they are not there just for assessment. It is by applying knowledge learned from lectures and textbooks to solve problems that you are best able to test and develop your skills and understanding of the material.

Unit Schedule

Part I: Coherent optics and interference

- Interference,
- Fabry-Perot interferometer,
- Fourier theory,
- diffraction theory,
- Fourier optics,
- Fraunhofer (far-field) diffraction,
- Fresnel (near-field) diffraction,
- near field optics,
- spatial coherence,
- temporal coherence,
- holography.

Part II: Optics of thin films and beams

- Electromagnetic waves in media,
- descriptions of polarisation states and control,
- Fresnel reflection coefficients,
- Gaussian beams,
- anisotropic media,
- non-linear optics.

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

Assessment Policy http://mq.edu.au/policy/docs/assessment/policy.html

Grading Policy http://mq.edu.au/policy/docs/grading/policy.html

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

Grievance Management Policy http://mq.edu.au/policy/docs/grievance_management/policy.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.

W.H."Beattie" Steel PRIZE

As a result of a generous donation to the University, the W H "Beattie" Steel Prize for Optical Physics may be awarded to the strongest student in the unit. We expect the value of the prize to be in the vicinity of $400.

Beattie Steel gained the highest French doctorate for his work on Fourier Transform methods at L'Institut d'Optique in Paris. He was President of the International Commission of Optics, author of "Interferometry" and a winner of the Mees Medal, given by the Optical Society of America. He led Optics research at CSIRO, Lindfield for 30 years and he continued this as an Honorary Professor at Macquarie University.

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://informatics.mq.edu.au/help/.

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

Graduate Capabilities

Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

Learning outcomes

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Assessment tasks

- Assignments
- Laboratory Reports
- Laboratory Logbook
- Presentation

- Final Exam

Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

Learning outcomes

- Interference, Diffraction and High Precision Optical Spectral Measurement: Understanding the relevance of interference and diffraction as the enabling concepts in current optics research; the method of solving two beam and multi-beam interference problems using complex exponential wave descriptions; the practical implementations of two beam and multi-beam interference in optical instrumentation; the fundamental trade-off between resolution and free spectral range in optical instruments used to chaaracterise the spectral content of light; the contrast of prism spectrometers, grating spectrometers and Fabry Perot interferometers; Fourier theory in optics, the far field (Fraunhofer) diffraction pattern as the Fourier transform of an “object”/aperture; recognition of the generalised diffraction integral; how to solve near field (Fresnel) diffraction cases in rectangular and circular symmetry; the Fresnel integrals, the cornu spiral, Fresnel zones; the Abbe theory of image formation and related topics in optical data processing
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experimental issues of high diffraction efficiency holograms and their reconstruction; real-time holographic interferometry as a quantitative measurement technique for objects under deformation; time averaged holographic interferometry as a quantitative measurement technique for vibrating objects.

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Assessment tasks

- Laboratory Reports
- Presentation

Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

Learning outcomes

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Assessment tasks

- Assignments
- Laboratory Reports
- Laboratory Logbook
- Presentation
- Final Exam

Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

Learning outcomes

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Assessment tasks

- Assignments
- Laboratory Reports
- Laboratory Logbook
- Presentation
- Final Exam

Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

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Learning outcomes

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Assessment tasks

- Assignments
- Laboratory Reports
- Laboratory Logbook
- Presentation
- Final Exam

Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

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Assessment tasks

- Assignments
- Laboratory Reports
- Laboratory Logbook
- Presentation
- Final Exam

Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

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Assessment tasks

- Assignments
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Engaged and Ethical Local and Global citizens

As local citizens our graduates will be aware of indigenous perspectives and of the nation's historical context. They will be engaged with the challenges of contemporary society and with knowledge and ideas. We want our graduates to have respect for diversity, to be open-minded, sensitive to others and inclusive, and to be open to other cultures and perspectives: they should have a level of cultural literacy. Our graduates should be aware of disadvantage and social justice, and be willing to participate to help create a wiser and better society.

This graduate capability is supported by:

Assessment task

- Presentation

Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

Assessment task

- Presentation

Laboratory

Required work

Attendance at laboratories is compulsory. You must attend the scheduled laboratory session each week, on Tuesday 2-5 pm. Access to the laboratory at other times will not normally be possible due to staffing constraints. You are urged to finish one experiment at a time, aiming to take no more than three laboratory sessions.

Students must complete 4 experiments and submit two full reports and associated drafts together with their laboratory log book and calculations for the other two experiments. Submission of the 2 reports, and a logbook with a record of 4 experiments completed, and the associated calculations and analysis for the two experiments not the subject of a formal report, is mandatory. **The logbook must be kept and updated in real time in the laboratory class**. Students writing experimental results onto loose sheets of paper will have these confiscated in the laboratory. Data etc. collected in electronic formats must be reproduced in hardcopy in the logbook. This original record is the logbook that must be submitted for assessment.

We expect to mark and return laboratory reports submitted on time, within two weeks at most.

Available Experiments

- Correlation Interferometer
- Diffraction and Image Formation
- Fabry-Perot Interferometer
- Fourier Transform Spectrometer
- Photon Counting
- Polarised Light and Berry Phase

Safety

A condition of entry to the laboratory is thorough knowledge of the safety requirements in the laboratory, given in the document entitled "Health and Safety Guidelines in the 300 Level Physics Laboratory". Students will be issued with the document in week 1 and will complete a short written quiz to demonstrate their understanding of safety requirements observed during all laboratory sessions. The safety aspects of the laboratory can also be found on posters in the laboratory.

General notes

- The laboratory sessions start in the first week of semester.
- You must sign in and out using the Attendance Book (your name, date and experiment, legibly).
- Students should make a booking for three laboratory afternoons for each experiment they undertake. A booking gives priority provided the students arrive punctually at the start of the laboratory session.
- Log-books with the record of experimental data are to be kept. These will be assessed in the laboratory sessions for being a satisfactory or unsatisfactory. The criteria are readability, layout, completeness and clarity. A student must gain a satisfactory sign-off in their experimental log-book before any draft or report submission can be made.

Changes since First Published

Date	Description
27/07/2015	Updated assignment dates
24/07/2015	Part 1 and Part 2 reordered.