UNIT GUIDE
PHTN321 - Optical and Photonic Devices and Systems 1
3 Credit Points

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You should read this unit outline carefully. It contains important information about the unit. If anything in it is unclear, please consult the Unit Convenor.

UNIT WEB PAGE
The web page for this unit can be found at: http://www.physics.mq.edu.au/current/undergraduate/units/PHTN321
Please check this web page regularly for material available for downloading.

DESCRIPTION
Lasers and optical waveguides are the most fundamental components of optical and photonic systems. Good examples are optical telecommunication networks where information is encoded on laser pulses that are transmitted via optical fibres. In this unit, practical and theoretical aspects of lasers and of light propagation in waveguide structures are developed.

In the first half of the unit, fundamental aspects of laser-gain materials are discussed. Knowledge about optical transitions and line broadening mechanisms, as well as about properties of passive optical resonators will form the basis for a study of laser performance in terms of threshold, modes and pulsed operation. Laser safety is also discussed.

In the second half of the unit, the principles of electromagnetic theory are applied to dielectric waveguides including optical fibres, 3dB couplers and graded-index structures. Particular emphasis is placed on determining the modes of such systems and the resonance conditions for waveguide modes.

The practical component of the unit provides a valuable preparation for working in the field of optoelectronics, using modern laboratory equipment. Proficiency in practical work is regarded as important, and laboratory experiments involving modulators, laser modes, detectors and detection systems are offered.

CLASSES
The timetable can be found on: http://www.timetables.mq.edu.au/
Lecture 1 Monday, 11am – 12noon, E7B 161
Lecture 2 Thursday, 10am – 11am, E7B 161
Lecture 3 Friday, 10am – 11am, E7B 161
Laboratory Monday, 2pm – 5pm, E7B 248
NB Laboratories will commence in the first week of semester.
PRE-REQUISITES

PHYS201(P) and PHYS202(P)

Students are expected to be familiar with electromagnetic field theory including Maxwell’s equations. Basic knowledge of atomic physics, in particular of atomic orbitals will also be assumed.

EXPECTED LEARNING OUTCOMES

This unit aims to develop and deepen your understanding of the physical principles and major phenomena associated with two key devices in optoelectronic systems: lasers and waveguides. Both the fundamental physical phenomena concerned, and the engineering approaches to these topics are considered in the unit. The laboratory component of the unit is aimed at giving you operational capability using optical detectors, diagnostics and measurement instruments, and an understanding of the physics of various optoelectronic phenomena.

You will be able to quantitatively predict the output and the behaviour of a laser as a function of relevant system parameters, and will have insight into the physical processes that govern a wide range of laser systems. You will understand how the unique properties of lasers are exploited for different applications.

You will be able to model quantitatively the propagation of light in various waveguide geometries and will have insight into the properties of a range of different waveguides. You will understand how waveguides are used to modify the propagation of light through linear and nonlinear optical effects, and how these may be exploited in practical applications.

You will have confidence and capability to use and operate key optical diagnostic equipment.

Graduate Capabilities Developed

In addition to the discipline-based learning objectives, all academic programs at Macquarie seek to develop your generic skills in a range of areas. One of the aims of this unit is that you develop the following skills:

Problem solving is a key component of the unit, requiring an understanding of how to calculate the relevant operating parameters for lasers and waveguides. Written communication skills and collaborative learning are encouraged by working in the laboratory in pairs and by writing regular laboratory reports. Safe laboratory practice and operational familiarity with laboratory equipment is fostered in the unit via 11 laboratory sessions in which new experiments are completed each week.

<table>
<thead>
<tr>
<th>Generic Capabilities of a Physicist</th>
<th>How this unit addresses its development</th>
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<tbody>
<tr>
<td>Demonstrate knowledge of fundamental physics concepts, principles and theories</td>
<td>Knowledge of the fundamental aspects of light–matter interaction, of the principle operation of lasers as well as of the theory of guided wave propagation will be developed.</td>
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<tr>
<td>Apply physics principles to understand the causes of problems, devise strategies to solve them and test possible solutions</td>
<td>Regular assignments and laboratory session are aimed to develop problem solving skills and analytical thinking.</td>
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<tr>
<td>Use a range of measurement and data analysis tools to collect data with appropriate precision and carry out subsequent analysis with due regard to the uncertainties</td>
<td>During the laboratory sessions, particular attention will be paid to a high accuracy and diligence in all measurements as well as to a proper uncertainty analysis.</td>
</tr>
<tr>
<td>Use the tools, methodologies, language, conventions of physics to test and communicate ideas and explanations</td>
<td>The lectures and the laboratory session will be highly interactive, giving the students ample opportunity to test and communicate ideas and explanations.</td>
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<tr>
<td>Work effectively and ethically in a multifaceted scientific environment</td>
<td>The laboratory sessions are aimed to prepare the students to working in a professional scientific environment.</td>
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<tr>
<td>Be responsible, critically reflective, self-directed and motivated learners</td>
<td>Critical reflection and questioning will be highly encouraged during the lectures as well as in the laboratory.</td>
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STUDY GUIDE

Required Text

Handouts will regularly be distributed during the lectures and will also be available for downloading from the unit web-page.

Recommended Readings and Reference Material


**Other Library Resources**


**Teaching Strategy**

The unit is taught through a combination of lectures and tutorial style classes, with weekly or fortnightly problem-based assignments. Practical and report writing experience is provided through the laboratory sessions.

You are expected to submit assignments and lab reports on separate sheets, weekly, or as required. You are also expected to read reference texts or lab resource material for each experiment, as requested by the lecturer or demonstrator.

**Laboratory (Lab) Sessions**

You should have a scientific calculator for use during the laboratory sessions.

It is very important to submit each week’s laboratory report at the next scheduled lab session. The report will then be marked and returned to you during the following lab session. That way your skills with writing laboratory reports can rapidly develop.

The laboratory will operate on Monday afternoons (2.15 - 5 pm) commencing week 1. Access to the laboratory at other times may be possible by arrangement. You must finish one experiment at a time, and each experiment is expected to require one 3-hour laboratory session. Laboratory work is an extremely important part of the unit.

The following optoelectronics experiments will be available:

- Diode-pumped Nd:YAG laser
- Acousto-optic effect
- Laser Doppler velocimetry
- Scanning confocal interferometer
- Second-Harmonic Generation
- Tunable diode laser spectroscopy
- Single mode optical fibres: Gaussian mode, fibre coupling
- Polarisation maintaining optical fibres
- Single mode fibre sensors and interferometers
- Fibre amplifiers
- Fibre lasers

**ASSESSMENT**

**Summary of Assessment Tasks**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Assignments (total)</td>
<td>25%</td>
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<tr>
<td>Laboratory Reports</td>
<td>25%</td>
</tr>
<tr>
<td>Final Examination (3 hours)</td>
<td>50%</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100%</strong></td>
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**Requirements in order to complete the unit satisfactorily**

Satisfactory performance must be achieved in all components of the unit, for a passing grade.

**Assignments**

Assignments consisting of problems will be set weekly or fortnightly. Assignments should be submitted to the lecturer.

**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.
Lab Reports
You must record your experimental data and deliberations in a laboratory exercise book. A brief laboratory report summarising the aims, results, analysis and discussion of the experiment and prepared in loose leaf form is to be handed in for each experiment within one week of completion of the experiment. Penalties for late submission may be imposed. Your lab book must be available for checking each week and at the end of semester. Attendance at Laboratories is compulsory, and all lab reports must be submitted.

Final Examination
You should have a scientific calculator for use during the final examination. Note that calculators with text retrieval are not permitted for the final examination.

The examination will be in two parts, A and B, and will be of three hours duration plus ten minutes reading time. Parts A and B will consist of four questions each. One question in each section will be compulsory, and you can choose two of the remaining three in each section. Part A questions refer to the first half of the unit, and Part B questions refer to the second half of the unit.

You are expected to present yourself for the final examination at the time and place designated in the University examination timetable (http://www.timetables.mq.edu.au/exam/). The timetable will be available in draft form approximately eight weeks before the commencement of examinations and in final form approximately four weeks before the commencement of examinations.

The only exception to not sitting the examination at the designated time is because of documented illness or unavoidable disruption. In these circumstances you may wish to apply for Special Consideration (see ‘Special Consideration’ in this Guide). If a supplementary examination is granted as a result of the special consideration process the examination will be scheduled after the conclusion of the official examination period. You are advised that it is the policy of the University not to set early examinations for individuals or groups of students. All students are expected to ensure that they are available until the end of the teaching semester, i.e. the final day of the examination period.

Prize
Students studying this unit are eligible to be considered for the JC Ward Prize awarded for overall excellence in four 300-level units in Physics.

Relationship between Assessment and Learning Outcomes
The assessment tasks include weekly or fortnightly problem-based assignments to aid you in learning to apply and consolidate your understanding of the subject material, and weekly lab reports, to develop your technical writing skills. Feedback for the problem-based assignments will be provided in lectures, and the lab demonstrators will provide weekly feedback to develop students’ lab report writing skills.

You are strongly encouraged to submit your assessment tasks on time. Penalties may be imposed for assignments or lab reports that are submitted late without an approved request for extension.

Standards Expectations
Academic Senate has deemed that the grades correspond to the following broad performance expectations (http://www.mq.edu.au/policy/docs/grading/policy.html):

<table>
<thead>
<tr>
<th>Grade</th>
<th>Mark %</th>
<th>Description</th>
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<tbody>
<tr>
<td>HD</td>
<td>85-100%</td>
<td>Denotes performance that meets all unit objectives in such an exceptional way and with such marked excellence that it deserves the highest level of recognition.</td>
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<tr>
<td>D</td>
<td>75-84%</td>
<td>Denotes performance that clearly deserves a very high level of recognition as an excellent achievement in the unit.</td>
</tr>
<tr>
<td>Cr</td>
<td>65-74%</td>
<td>Denotes performance that is substantially better than would normally be expected of competent students in the unit.</td>
</tr>
<tr>
<td>P</td>
<td>50-64%</td>
<td>Denotes performance that satisfies unit objectives.</td>
</tr>
<tr>
<td>F</td>
<td>0-49%</td>
<td>Denotes that a candidate has failed to complete a unit satisfactorily.</td>
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High Distinction
Problems are completed with correct solutions and appropriate working and clear relevant diagrams. The student is able to apply standard theory to solve novel problems.

Distinction
Problems are completed with occasional numerical error or incomplete working. The student shows some ability to apply taught material to novel problems or situations.

Credit
Most problems completed correctly. The student shows a limited ability to apply taught material to novel problems or situations.
Some problems completed correctly, and others show a lack of understanding of the taught material.

Inadequate demonstration of knowledge and ability to apply knowledge to solving problems.

The University’s policy for applying for special consideration may be found at:
http://www.student.mq.edu.au/ses/Special%20Consideration.html

The University defines plagiarism in its rules: “Using the work or ideas of another person and presenting this as your own without clear acknowledgement of the source of the work or ideas.” Plagiarism is a serious breach of the University’s rules and carries significant penalties. You must read the University’s policies and procedures on plagiarism. The University’s policy for academic honesty may be found at:
http://www.mq.edu.au/policy/docs/academic_honesty/policy.html

The policies and procedures explain what plagiarism is, how to avoid it, the procedures that will be taken in cases of suspected plagiarism, and the penalties if you are found guilty. Penalties may include a deduction of marks, failure in the unit, and/or referral to the University Discipline Committee.

The Department of Physics and Astronomy values quality teaching and engages in periodic student evaluations of its units, external reviews of its programs and course units, and seeks feedback from students via focus groups and the Student Liaison Committee (SLC). Please consider being a member of the SLC, which meets once during the semester with the purpose of improving teaching via student feedback. Meetings are open and friendly, and invite honest feedback. Student representatives receive a list of outcomes from the preceding meeting. At the beginning of each meeting, an update on responses to feedback is provided by the Head of Department. Feedback is acted upon in a number of ways, mostly initiated via department meetings where decisions on actions are taken.

Macquarie University provides a range of academic student support services. Details of these services can accessed at: http://www.mq.edu.au/currentstudents/

https://my.mq.edu.au/

First Half (Dr Alex Fuerbach)

Lasers

Week 1:
Fundamental properties of light; Laser safety

Week 2:
Light-Matter interaction; Lineshape function; 2-level systems; Saturation of absorption

Week 3:
3-level and 4-level systems; Gain coefficient; Optical amplifiers

Week 4:
Resonator losses; Laser characteristics; Slope efficiency; Longitudinal resonator modes

Week 5:
Pulsed lasers, Relaxation oscillations, Q-switching, Mode-locking

Week 6:
Optical Resonators, Transversal resonator modes, Gaussian beams
Second Half (Dr Gabriel Molina-Terriza)

Optical Waveguides

Review of Maxwell's equations and the wave equation, TE and TM modes, transverse resonance condition and universal curves, graded refractive index, optical fibres, coupled modes, nonlinear optics in waveguides and applications of waveguides.