School of Electrical Engineering and Telecommunications

Term 1, 2021
Course Outline

PHTN 4661
Optical Circuits and Fibres

COURSE STAFF

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Consultation

You are encouraged to ask questions on the course material, after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the tutor or laboratory demonstrator, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with PHTN4661 in the subject line, otherwise they will not be answered.

Keeping Informed

Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Microsoft Teams (https://student.unsw.edu.au/teams-students). Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

COURSE SUMMARY

Contact Hours

The course consists of 2 hours of lecture per week, 2 hours of laboratory every *second week* and 1 hour tutorial per week:

	Day	Time	Location
Lectures	Tuesday	13:00 – 15:00	online
Tutorials	Tuesday	15:00 – 16:00	online
Labs	Wednesday	15:00 – 17:00	online
	Tuesday	11:00 – 13:00	online

Context and Aims

Optical circuits are miniaturised and integrated optical paths and devices on a single planar substrate. They are commonly used in traditional optical telecommunications but are now finding new application fields in sensing, MEMs, astronomy and data transfer (chip-to-chip, board-to-board). The course aims to make students familiar with standard silica-on-silicon planar waveguide technology and its interface with standard telecom optical fibres. In that process, the student will be introduced to the modelling and design of optical circuits.

Indicative Lecture Schedule

Period	Summary of Lecture Program
Week 1	Intro + Waveguides + Silica
Week 2	Guidance + Definitions + Wave equations
Week 3	Modes + Slab waveguide + Modedness
Week 4	Optical fibres I
Week 5	optical fibres II + Gaussian approximation + *Mid-term quiz*
Week 6	Review
Week 7	Mode beating + Supermodes + Scattering + Bend loss
Week 8	Perturbation theory + Mode coupling + Splice loss + Transition loss
Week 9	Propagation + BPM + path design
Week 10	Circuit design

Indicative Laboratory Schedule

Period *	Summary of Laboratory Program
Week 1	
Week 2	Lab 1: Modes of rectangular waveguides
Week 3	Lab 2: Modes excitation
Week 4	
Week 5	Lab 3: Phase shifter
Week 6	
Week 7	Lab 4: Beam propagation method
Week 8	
Week 9	Lab 5: Multimode interferometer
Week 10	

* The class will be divided in two or three laboratory groups determined at registration time depending on registration numbers. Flexibility will be allowed depending on availability.

Assessment

Laboratory Practical Experiments (5 experiments)	25%
Mid-Trimester Quiz	25%
Final Exam (2 hours)	50%

COVID19 - Important Health Related Notice

Your health and the health of those in your class is critically important. You must stay at home if you are sick or have been advised to self-isolate by NSW health or government authorities. Current alerts and a list of hotspots can be found here. **You will not be penalised for missing a face-to-face activity due to illness or a requirement to self-isolate**. We will work with you to ensure continuity of learning during your isolation and have plans in place for you to catch up on any content or learning activities you may miss. Where this might not be possible, an application for fee remission may be discussed.

If you are required to self-isolate and/or need emotional or financial support, please contact the Nucleus: Student Hub. If you are unable to complete an assessment, or attend a class with an attendance or participation requirement, please let your teacher know and apply for special consideration through the Special Consideration portal. To advise the University of a positive COVID-19 test result or if you suspect you have COVID-19 and are being tested, please fill in this form.

UNSW requires all staff and students to follow NSW Health advice. Any failure to act in accordance with that advice may amount to a breach of the Student Code of Conduct. Please refer to the Safe Return to Campus guide for students for more information on safe practices.

COURSE DETAILS

Credits

This is a 6 UoC course and the expected workload is 15 hours per week throughout the 10-week trimester including both face-to-face classes and *independent, self-directed study*.

Relationship to Other Courses

This is a 4th year elective course in the School of Electrical Engineering and Telecommunications. For those with a special interest, this course builds on the fundamental formalism associated with electromagnetic waveguides by exploring how they can be used to build functional optical circuits.

Pre-requisites and Assumed Knowledge

The pre-requisite for this course is ELEC3115, Electromagnetic Engineering. It is assumed that the students possess a good understanding of electromagnetism (e.g. Maxwell's equations), and have good computer literacy, in particular familiarity with MATLAB.

Following Courses

The course is a pre-requisite for PHTN4662 Photonics Networks.

Learning Outcomes

After successful completion of this course, you should be able to:

1. Recognise and describe typical applications and benefits of optical circuits;
2. Use waveguide modal analysis to explain coupling mechanisms in optical waveguides;
3. Model performance of optical circuits using various techniques;
4. Design optical circuits for simple applications (paths, phase shifters, interferometers, *etc.*)
5. Explain the limitations imposed on optical circuits by fabrication, losses and integration requirements;

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Skill Development

The course puts its emphasis on developing the necessary skills to properly define problems related to optical circuits and it provides the most efficient and current tools to solve them. Through the compulsory reporting of laboratory outcomes, the course also tries to develop written skills that engineer need as part of the professional future requirements.

Syllabus

The course covers the basic theoretical concepts enabling the design of integrated optics circuits. Doing so, it also reviews several platforms enabling such devices, although focussing on silica-on-silicon technology.

Starting from Maxwell's wave equation, the course moves to the weak guidance approximation as a way to remove unhelpful complexity and to clarify the concepts require to describe the behaviour and limitations of optical circuits: guidance (single- and multi-modal), modes, mode-coupling, super-modes, mode superposition and loss mechanisms.

This theoretical knowledge is strengthened by introducing simulation software. Starting from simple mode calculation, this guides students towards the design of a fully functional optical chip while highlighting the importance of design optimisation and practical limitations.

TEACHING STRATEGIES

Delivery Mode

Lectures

During the lectures, integrated optics and related design issues are discussed and the appropriate theoretical framework is introduced. The lectures provide the students with a focus on the core material in the course and stresses the important conceptual advances. Numerous examples of optical integrated circuits are discussed in order to convey a qualitative understanding of their operations. Students are expected to attend the lectures and prepare themselves for them.

Virtual laboratories

The laboratory work will involve simulations only, using in-house software library. The student will be asked to use this library, in the form on MATLAB scripts/programs, to study various aspects of light propagation in optical circuits. You are not required to attend laboratory as they can be done at home for your convenience.

Learning in this course

You are expected to attend all lectures, tutorials, labs, and mid-trimester exams in order to maximise learning. You must prepare well for your laboratory classes and your lab work will be assessed. In addition to the lecture notes/video, you should read relevant sections of the recommended text. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial classes

You should attempt all of your problem sheet questions in advance of attending the tutorial classes. The importance of adequate preparation prior to each tutorial cannot be overemphasized, as the effectiveness and usefulness of the tutorial depends to a large extent on this preparation. Group learning is encouraged. Answers for these questions will be discussed during the tutorial class and the tutor will cover the more complex questions in the tutorial class. In addition, during the tutorial class, 1-2 new questions that are not in your notes may be provided by the tutor, for you to try in class. These questions and solutions may not be made available on the web, so it is worthwhile for you to attend your tutorial classes to gain maximum benefit from this course.

Laboratory Exemption

There is no laboratory exemption for this course. Regardless of whether equivalent labs have been completed in previous courses, all students enrolled in this course must take the labs. If, for medical reasons, (note that a valid medical certificate must be provided) you are unable to attend a lab, you will need to apply for a catch-up lab during another lab time, as agreed by the laboratory coordinator. Students are required to attempt all laboratory exercises.

ASSESSMENT

The assessment scheme in this course reflects the intention to assess your learning progress through the trimester. Ongoing assessment occurs through 5 laboratory reports and the mid-trimester exam.

Laboratory Reports

Laboratories are primarily about learning, and the laboratory assessment is designed mainly to check your knowledge as you progress through each stage of the laboratory tasks. Each assessment consists in a lab report to be submitted to your lecturer 2 weeks after the completion of the lab. It is essential that you complete the laboratory preparation before coming to the lab.

Mid-Trimester Quiz

The mid-session quiz tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course

material up to the end of week 6. It may contain questions requiring some (not extensive) knowledge of laboratory material and will definitely contain numerical and analytical questions. Marks will be assigned according to the correctness of the responses.

Final Exam

The exam in this course is a standard closed-book 2 hour written examination. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course*.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes				
Assessment	**1**	**2**	**3**	**4**	**5**
Laboratory assessments	✓	✓	-	✓	-
Mid-trimester quiz	✓	✓	✓	✓	✓
Final exam	✓	✓	✓	✓	✓

COURSE RESOURCES

Textbooks

Prescribed textbook

F. Ladouceur and J.D. Love, Silica Based Buried Channel Waveguides and Devices, Kluver.

Reference books

R. März, Integrated Optics, Artech House, Boston.

A.W. Snyder and J.D. Love, Optical Waveguide Theory, Kluver.

Cambridge Illustrated Handbook of Optoelectronics and Photonics, Cambridge University Press.

On-line resources

Microsoft Teams

As a part of the teaching component, Microsoft Teams will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Teams.

Mailing list

Announcements concerning course information will primarily be given via Microsoft Teams or occasionally via email (which will be sent to your student email address).

OTHER MATTERS

Dates to note

Important Dates available at: https://student.unsw.edu.au/dates

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people's work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see https://student.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://student.unsw.edu.au/guide), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **15 hours per week** (including class time) studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others Ergonomic risks are particularly relevant to this course.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. As of Term 1 2019, assessment of applications for Special Consideration will be managed centrally and the University has introduced a "fit to sit/submit" rule. You will no longer be required to take your original documentation to The Nucleus for verification. Instead, UNSW will conduct source checks on documentation for verification purposes. You can apply for special consideration when illness or other circumstances beyond your control interfere with an assessment performance. If you need to submit an application for special consideration for an exam or assessment, you must submit the application prior to the start of the exam or before the assessment is submitted, except where illness or misadventure prevent you from doing so. If you sit an exam or submit an assignment, you are declaring yourself well enough to do so.

Continuing Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the online student survey myExperience. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and

meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods. The virtual laboratories have been completely revamped and have moved from C++ to MATLAB. This is in an effort to better leverage acquired knowledge from students who should have had wide exposure to MATLAB in the previous years of their degree.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:

https://student.unsw.edu.au/guide

https://www.engineering.unsw.edu.au/electrical-engineering/resources

APPENDICES

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows

- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing digital and information literacy and lifelong learning skills through assignment work.
- Developing ethical practitioners who are collaborative and effective team workers, through group activities, seminars and tutorials.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	2,5
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	2,3
	PE1.3 In-depth understanding of specialist bodies of knowledge	1,2,3,5
	PE1.4 Discernment of knowledge development and research directions	4
	PE1.5 Knowledge of engineering design practice	1,4
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	1,3,5
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	1,5
	PE2.2 Fluent application of engineering techniques, tools and resources	1,2,3,4
	PE2.3 Application of systematic engineering synthesis and design processes	1,4
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	4
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	4
	PE3.3 Creative, innovative and pro-active demeanour	1,4
	PE3.4 Professional use and management of information	1
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	4