Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2022-23	**Semester**	1
Course Coordinator	Prof Shen Zexiang		
Course Code	PH3602		
Course Title	Photonics		
Pre-requisites	(PH2101 and PH2301) or (PH2301 and CY1303)		
No of AUs	4 AU		
Contact Hours	3 hr – lecture; 1 hr – tutorial		
Proposal Date	07 December 2022		

Course Aims

This course intends to equip you with the fundamental concept and principles of key topics in photonics. You will gain knowledge in the mechanisms of both optoelectronic systems and discrete devices. Based on this knowledge, you will be able to make both predictions and interpretation in important applications such as in optoelectronics and optical communications. In conclusion, after taking this course, your problem-solving skills will be sharpened and you will have the necessary foundation to tackle problems in Photonics research.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you (as a student) would be **able to**:

Optics (OP)

1. use physical optics concepts (such as Fresnel's equation, group velocity) to analyse and solve problems for practical applications (such as beam splitters, optical fibres, TIR microscopy and photonic crystals).
2. design anti-reflection optical thin films, spectral filters and high reflective mirrors (DBRs).
3. apply the basic dispersion principles in optical fibers to design high bit-rate optical communication systems.
4. use the birefringent crystals to design photonic devices (such as polarizers, waveplates, optical switch and modulators).
5. use nonlinear optical crystal to realize optical harmonic generation.

Optoelectronic Devices (OPD)

6. use the basic properties of semiconductors to design and characterize p-n junctions.
7. apply the pn-junction principles to design home-junction LEDs and optimize high power heterojunction LEDs.
8. design and characterize semiconductor laser diodes (LDs), especially optimize heterojuntion LDs based on the concepts of carrier confinement and optical confinement.
9. design and characterize various photodetectors, including, thermal detectors, pn-junction photodiodes, pin-photodiodes, and avalanche-photodiodes.
10. design and characterize high efficiency photovoltaic devices.

Course Content

Light propagation in media
Maxwell Equations
EM wave description of light
Phase velocity and group velocity
Fresnel's equations
Thin film optics
Photonic crystals

Optical Fiber communication
Plane waveguides
Intermodal and intramodal dispersions
Step index optical fibres
Bit-rate, dispersion, and optical bandwidth
Graded index fibres
Attenuation in optical fibers
Fiber manufacture
Photonic crystal optical Fibres
Fiber Bragg grating and application

Polarization and Modulation of Light
Polarization states
Light propagation in an anisotropic medium: birefringence
Birefringent Optical Devices
Optical Activity and Circular Birefringence
Electro-optic effects and Electro-optic modulator
Integrated Optical Modulators
Acousto-Optic Modulators
Magneto-Optic Effects
Non-linear Optics & Second Harmonic Generation

Semiconductor and LEDs
Semiconductor concept & energy bands
Semiconductor statistics
Extrinsic Semiconductors
Direct and Indirect Bandgap Semiconductors: E-k
pn Junction Principles
LEDs

Semiconductor lasers
Stimulated Emission and Photon Amplification
Overview of Laser Operation
Principle of the Laser Diode
Heterostructure Laser Diodes
Steady State Semiconductor Rate Equations
Heterostructure and Quantum well lasers
Laser amplifiers

Photodetectors
Time Response of Thermal Detectors
Principle of the pn Junction Photodiodes
Pin photodiode
Avalanche photodiode
Heterojunction photodiodes
Detector Noise

Photovoltaic Devices
Solar Energy Spectrum
Photovoltaic Device Principles

pn Junction Photovoltaic I-V Characteristics
Series Resistance & Equivalent Circuit
Temperature Effects
Solar Cell Materials, Devices, and Efficiencies

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	Competency (1,3,4)	60%	Individual	Point-based marking (not rubric-based)
2. CA1: Project and presentation	All	Communication (1,2,3) Creativity (1,2) Character (1,2,3)	6%	group	Rubrics marking- Appendix 1
3. CA2: Homework	All	Competency (1,3,4) Character (1,2)	18%	Individual	Point-based marking (not rubric-based)
4. CA3: Mid-term Test	**OP** 1-5	Competency (1,3,4)	16%	Individual	Point-based marking (not rubric-based)
Total			100%		

Formative feedback

Formative feedback is given through discussion within tutorial lessons. Feedback is always provided for your response to each question.

Feedback is also given after each midterm on the common mistakes and level of difficulty of the problems.

Feedback is also given during consultant discussion.

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Use of Learning Catalytics (tutorial and lecture)	This helps to engage you and serves to identify any prior misconceptions that you may have in order to better assist you in your learning journey.
Lectures	Warm-up questions will be raised first, followed by lectures that further explains the physics based on the questions. Then wrap-up questions will also be provided.
Tutorial	You will review main concepts learned in lectures with TAs. This helps you to digest and understand better.

Homework	The homework comprises standard textbook practice questions that are covered during tutorial.

Reading and References

Text book:

1. "Optoelectronics and Photonics: Principles and Practices", S. O. Kasap, Prentice Hall ISBN-13: 978-0201610871

Other references:

1. "Photonics: Optical Electronics in Modern Communication", A. Yariv & P. Yeh, Oxford University Press. ISBN-13: 978-0195179460
2. "Optoelectronic Devices", S. D. Smith, Prentice Hall. ISBN-13: 978-0131437692
3. "Photonics and Lasers: An Introduction", R. S. Quimby, John Wiley and Son. ISBN: 978-0-471-71974-8

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (*subject to availability*) and make-up mid-terms (*subject to availability*).

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Prof Shen Zexiang	SPMS-03-01	63168855	zexiang@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Light propagation in media	**OP** 1	Lecture notes – Chapter 1-I
2	Light propagation in media	**OP** 1	Lecture notes – Chapter 1-II
3	Optical Fiber communication	**OP** 2	Lecture notes – Chapter 2-I
4	Optical Fiber communication	**OP** 3	Lecture notes – Chapter 2-II
5	Polarization and Modulation of Light	**OP** 4	Lecture notes – Chapter 3-I
6	Polarization and Modulation of Light	**OP** 5	Lecture notes – Chapter 3-II
7	Revision and Midterm test	**OP** 1-5	
8	Semiconductor and LEDs	**OPD** 6	Lecture notes – Chapter 4-I
9	Semiconductor and LEDs	**OPD** 7	Lecture notes – Chapter 4-II
10	Semiconductor LDs	**OPD** 8	Lecture notes – Chapter 5-I
11	Semiconductor LDs	**OPD** 8	Lecture notes – Chapter 5-II
12	Photodetectors	**OPD** 9	Lecture notes – Chapter 6
13	Photovoltaic Devices	**OPD** 10	Lecture notes – Chapter 7

Appendix 1: Assessment Rubrics for Project Presentation

	Exceptional (5)	Effective (4)	Acceptable (3)	Developing (2)	Unsatisfactory (1)	Score
Significance of Project	Absolutely significant.	Not totally significant but had made non-trivial improvements on existing ideas.	Not totally significant but had made some minor improvements on existing ideas.	Not totally significant but had made modifications (not necessarily improvements) on existing ideas	The project was a direct copy of existing ideas without the slightest modifications or improvements.	**/ 5**
Content	Provided more than the required information about the project; completely accurate.	Provided required information about the project; mostly accurate.	Provided most of the required information about the project; mostly accurate.	Provided some of the required information about the project; some major errors.	Provided little to none of the required information about the project; major errors.	**/ 5**
Presentation Skills	Ideas were presented very clearly and visuals were very helpful to audience.	Ideas were presented clearly and visuals were helpful to audience.	Ideas were presented somewhat clearly (i.e. generally able to follow but could be more precise, concise) and visuals were somewhat helpful to audience.	Ideas were mostly unclear and visuals were mostly unhelpful to audience.	Ideas were not presented clearly and visuals were not helpful to audience.	**/ 5**
Discussions, Q&A & Contributions	Very productive discussions and deep analyses; critique extends beyond the requirements of the project into new scenarios.	Productive discussions and analyses; critique of how different aspects of the project interact with each other and their impact on the project.	Adequate discussions and analyses; critique of more than one aspect of the project, but unable to connect them.	Little discussions and analyses; critique involved only a single aspect of the project.	No discussions, analyses or critique.	**/ 5**
					Total:	**/ 20**

Graduate Attributes
What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY, PHME, PHMP and PHMS programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics [PHMS only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.