City University of Hong Kong
Course Syllabus

offered by Department of Physics
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	**Introduction to Quantum Optics**
Course Code:	**PHY6255**
Course Duration:	**One semester**
Credit Units:	**3 credits**
Level:	**P6**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**(1) PHY3205 Electrodynamics or equivalent AND** **(2) PHY3251 Quantum Mechanics or equivalent**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**PHY8255 Introduction to Quantum Optics**

Part II Course Details

1. Abstract

This is a graduate course on quantum optics, aiming to equipping students with advanced knowledge of quantum aspects of light and light-matter interactions that are necessary to conduct research and to understand literatures. The course will start with classical theory of electromagnetic fields and make a transition to quantum theory. It then discusses classical and quantum description of optical systems and introduces two basic techniques for quantum measurement of light. Second half deals with interaction between optical fields and between light and matters. It will cover nonlinear optical interactions for the generation of quantum states of light, the semiclassical and quantum theories of atom-field interaction, open quantum systems. Afterward students will learn about Casmir effect, Purcell effect, polaritons, and other advanced applications.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Recognizing and use appropriately important technical terms and definitions in quantum descriptions of light fields and in interaction between light and matters		✓	✓	
2.	Use appropriate mathematical notations and apply in concise form the laws of quantum optics to understand modern physics problems		✓	✓	
3.	Understand measurement techniques of quantum optics and apply them to the study of modern physics problems		✓	✓	
4.	Solve real and hypothetical problems in quantum physics and optics by identifying the underlying physics and analysing the problems		✓	✓	✓
		100%			

A1: *Attitude*
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: *Ability*
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: *Accomplishments*
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

3. Learning and Teaching Activities (LTAs)

(LTAs designed to facilitate students' achievement of the CILOs.)

LTA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4			
Lectures/Student Centred Activities	Explain key concepts, build mathematic foundation and analytical skills, provide examples and solutions of advanced problems in quantum optics	✓	✓	✓	✓			3 hours/week

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.						Weighting	Remarks
	1	2	3	4				
Continuous Assessment: 60%								
Assignments	✓	✓	✓	✓			30%	
Test	✓	✓	✓	✓			30%	
Examination: 40% (duration: 2 hours)								
							100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignment	Capable to show a good understanding of the taught materials from solving the given problems.	high	significant	moderate	basic	Not given enough efforts or unable to grasp the basic concept.
2. Test	Ability to solve common quantum optics problems.	high	significant	moderate	basic	Not given enough efforts or unable to grasp the basic concept.
3. Examination	Ability to grasp the concept of the taught materials and to solve common quantum optics problems.	high	significant	moderate	basic	Not given enough efforts or unable to grasp the basic concept.

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Assignment	Capable to show a good understanding of the taught materials from solving the given problems.	high	significant	moderate	Not given enough efforts or unable to grasp the basic concept.
2. Test	Ability to solve common quantum optics problems.	high	significant	moderate	Not given enough efforts or unable to grasp the basic concept.
3. Examination	Ability to grasp the concept of the taught materials and to solve common quantum optics problems.	high	significant	moderate	Not given enough efforts or unable to grasp the basic concept.

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

1.1 Classical wave description of optical fields
1.2 Maxwell equations for electromagnetic fields – first quantization
1.3 Second quantization for quantum theory of light
1.4 Quantum states for optical fields – squeezed states, entangled states, and more Glauber-Sudarshan P-representation
1.5 Photon counting for discrete variables – multi-photon interference
1.6 Homodyne detection for continuous variables – quantum noise
1.7 Nonlinear interaction for generation of quantum states
1.8 Atom-light interaction, Gauge invariance
1.9 Liouville equation for density matrix
1.10 Canonical transformation
1.11 Open quantum systems
1.12 Macroscopic quantum phenomena

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

1.	Zheyu Jeff Ou, *Quantum Optics for Experimentalists*, 1st Edition (WSPC, 2017)
2	R. Loudon, *Quantum Theory of Light*, 3rd Edition (Oxford University Press, 2000)
3.	Marlan O. Scully & M. Suhail Zubairy, *Quantum Optics*, 1st Edition (Cambridge University Press, 1997)
4.	D. F. Walls & Gerard J. Milburn, *Quantum Optics*, 2nd Edition (Springer, 2007)
5.	Heinz P. Breuer & Francesco Petruccione, *The Theory of Open Quantum Systems* (Oxford University Press, 2007)
6.	Girish S. Agarwal, *Quantum Optics*, 1st Edition (Cambridge University Press, 2012)
7.	William H. Louisell, *Quantum Statistical Properties of Radiation* (Wiley-VCH, 1990)