PHY6255: INTRODUCTION TO QUANTUM OPTICS

Effective Term

Semester A 2025/26

Part I Course Overview

Course Title

Introduction to Quantum Optics

Subject Code

PHY - Physics

Course Number

6255

Academic Unit

Physics (PHY)

College/School

College of Science (SI)

Course Duration

One Semester

Credit Units

3

Level

P5, P6 - Postgraduate Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

(1) PHY3205 Electrodynamics or equivalent AND
(2) PHY3251 Quantum Mechanics or equivalent

Precursors

Nil

Equivalent Courses

Nil

Exclusive Courses

PHY8255 Introduction to Quantum Optics

Part II Course Details

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.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Recognizing and use appropriately important technical terms and definitions in quantum descriptions of light fields and in interaction between light and matters		x	x	
2	Use appropriate mathematical notations and apply in concise form the laws of quantum optics to understand modern physics problems		x	x	
3	Understand measurement techniques of quantum optics and apply them to the study of modern physics problems		x	x	
4	Solve real and hypothetical problems in quantum physics and optics by identifying the underlying physics and analysing the problems		x	x	x

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.

Learning and Teaching Activities (LTAs)

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

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Assignments	1, 2, 3, 4	30	-	Yes
2	Test	1, 2, 3, 4	30	-	No

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Minimum Continuous Assessment Passing Requirement (%)

50

Minimum Examination Passing Requirement (%)

30

Assessment Rubrics (AR)

Assessment Task

Assignment (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

The student completes all assessment tasks/activities including answers to questions and the work demonstrates excellent understanding of the scientific principles and the working mechanisms

Excellent

(A+, A, A-) high (excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) significant (good accomplishment with mostly correct understanding)

Fair

(C+, C, C-) moderate (fair accomplishment with some correct understanding)

Marginal

(D) basic (essential accomplishment with basic understanding

Failure

(F) Not given enough efforts or unable to grasp the basic concept.

Assessment Task

Test (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

He/she can thoroughly identify and explain how the principles are applied to science and technology for solving multidisciplinary sciences problems

Excellent

(A+, A, A-) high (excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) significant (good accomplishment with mostly correct understanding)

Fair

(C+, C, C-) moderate (fair accomplishment with some correct understanding

Marginal

(D) basic (essential accomplishment with basic understanding)

Failure

(F) Not given enough efforts or unable to grasp the basic concept.

Assessment Task

Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Ability to grasp the concept of the taught materials and to solve common quantum optics problems.

Excellent

(A+, A, A-) high (excellent accomplishment with creativity and correct understanding)

Good

(B+, B, B-) significant (good accomplishment with mostly correct understanding

Fair

(C+, C, C-) moderate (fair accomplishment with some correct understanding)

Marginal

(D) basic (fair accomplishment with some correct understanding)

Failure

(F) Not given enough efforts or unable to grasp the basic concept.

Assessment Task

Assignment (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

The student completes all assessment tasks/activities including answers to questions and the work demonstrates excellent understanding of the scientific principles and the working mechanisms.

Excellent

(A+, A, A-) high (excellent accomplishment with creativity and correct understanding)

Good

(B+, B) significant (good accomplishment with mostly correct understanding)

Marginal

(B-, C+, C) Basic (essential accomplishment with basic understanding)

Failure

(F) Not given enough efforts or unable to grasp the basic concept.

Assessment Task

Test (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

He/she can thoroughly identify and explain how the principles are applied to science and technology for solving multidisciplinary sciences problems.

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Assessment Task

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Part III Other Information

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

Reading List

Additional Readings

	Title
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)