Lahore University of Management Sciences

PHY 411 / PHY 5312 / EE 533 – Quantum Optics

Fall 2023-24

Instructor	Faheel Ather Hashmi
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Course URL (if any)	

Course Basics				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	1:15
Recitation (per week)	Nbr of Rec (s) Per Week		Duration	
Lab (if any) per week	Nbr of Session(s) Per Week		Duration	
Tutorial (per week)	Nbr of Tut(s) Per Week	1	Duration	1 hour

Course Distribution	
Core	
Elective	Yes
Open for Student Category	
Closed for Student Category	

COURSE DESCRIPTION
Electromagnetic radiation is inherently quantum in nature, a fact thrust upon everyone in the guise of photons. Yet this quantum character is surprisingly subtle and clear-cut signatures of the quantum nature of the electromagnetic radiation itself are relatively hard to come by. In this course, we will rigorously quantize the electromagnetic field (thereby serving as a first example of a quantum field theory), after which we will look at definite signatures of the quantum properties of light. The light-matter interaction will also be treated quantum mechanically, and features will be found that have no classical interpretation. Such quantum features of light will be shown to have great importance in metrology and quantum information.

COURSE PREREQUISITE(S)	
•	• Quantum Mechanics I (PHY212)

COURSE OBJECTIVES	
• •	Quantization of the EM field and some typical quantum states Light-matter interaction treated fully quantum-mechanically

Learning Outcomes	
• • •	CLO 1: Learn how to quantize the electromagnetic field. Realize (roughly) what is a photon. CLO 2: Analyze the common quantum states of light and how to generate them. CLO 3: Manipulate the quantum states of light CLO 4: Analyze matter-light interaction semi-classically as well as quantum mechanically.

Grading Breakup and Policy
Assignment(s): Home Work: 20 (5 in total) Quiz(s): 20 (2 in total) Class Participation: Attendance: Midterm Examination: 25 Project: Final Examination: 35

Examination Detail	
Midterm Exam	Yes/No: Yes Combine Separate: Duration: 2 hours Preferred Date: Exam Specifications: Written, closed book
Final Exam	Yes/No: Yes Combine Separate: Duration: 3 hours Exam Specifications: Written, closed book

COURSE OVERVIEW

Week/ Lecture/ Module	Topics	Recommended Readings	Course learning objective
1	Maxwell's equations; Time-dependent perturbation theory, photoelectric effect	**Fox, Chapter 1 and 2.1; notes on time-dependent perturbation theory; Beck Chapter 15**	**CLO 1**
2 and 3a	Quantization of the EM field	**Tannoudji, Chapter 1; Grynberg, Chapter 4**	**CLO 1**
3b and 4	Quantum states of light I (number states, coherent states). Poissonian statistics. Quadratures.	**Fox, 5.1, 5.2, 5.3, 5.4; Fox 8.1, 8.2, 8.3 Tannoudji, Pages 192 to 196; Fox, 8.4 Grynberg, 5.3, 5.3.1, 5.3.2; Fox, 7.2.**	**CLO 2**
5	Density matrices, thermal states. Super-Poissonian statistics.	**Mark Fox, 5.5; Knight, 2.5**	**CLO 2**
6a	Photodetection	**Haroche, 3.1.4; Grynberg, 5.1.1; Les Houches lectures by Roy Glauber**	**CLO 3**
6b	Beam splitters	**Haroche, 3.2; Grynberg, 5.1.2**	**CLO 3**
7a	Homodyne detection	**Grynberg, 5.1.3**	**CLO 3**
8a	Mach-Zehnder interferometer	**Grynberg, 5.5; Loudon, 3.3**	**CLO 3**
8b and 9a	Coherence functions: classical and quantum	**Loudon, 3.3; Fox, 2.3 and Chapter 6 (for classical) Loudon, 4.12; Knight, 5.2; Fox, 8.5 (for quantum)**	**CLO 2**
9b and 10a	Squeezed states and their generation	**Fox, Chapter 7; Knight, Chapter 7**	**CLO 2**
10b, 11 and 12a	Introduction to matter-light interaction. Rabi oscillations. Spontaneous emission	**Grynberg, Chapter 6; Fox, Chapter 9; Steck, 5.1 and 5.2; Scully and Zubairy, 6.1 and 6.3**	**CLO 4**
12b and 13	Jaynes-Cummings model	**Fox, Chapter 10; Scully and Zubairy, 6.2; Grynberg, 6B, Haroche 3.4; Knight, 4.5 and 4.6**	**CLO 4**
14	Application of quantum optics to quantum information – an overview	**Grynberg, 5D and 5E**	**CLO 4**

Textbook(s)/Supplementary Readings
There will be no required textbook. A few of the more useful books (referenced above) are: Quantum Optics by Mark Fox; Introduction to Quantum Optics by Grynberg, Aspect and Fabre; Introduction to Quantum Optics by Gerry and Knight; Quantum and Atom Optics by Steck (online lecture notes); Exploring the Quantum by Haroche.; Quantum Optics by Scully and Zubairy; Quantum Mechanics by Mark Beck Many other readings will be given during the course as appropriate.