量子光学导论课程教学大纲

课程基本信息（Course Information）					
课程代码（Course Code）	PH260	*学时（Credit Hours）	48	*学分（Credits）	3
*课程名称（Course Name）	量子光学导论 Introduction to Quantum Optics				
课程性质 (Course Type)	选修　Elective				
授课对象（Audience）	大三物理专业学生 Third year undergraduate students in physics				
授课语言 (Language of Instruction)	英语　English				
*开课院系（School）	物理与天文学院　School of Physics and Astronomy				
先修课程（Prerequisite）	Calculus, Algebra, Classical Mechanics, Quantum Mechanics, Electromagnetism, Optics				
授课教师（Instructor）	Carlos Navarrete-Benlloch	课程网址 (Course Webpage)	www.carlosnb.com/quantum-optics-course		
*课程简介					
*Course Description	Quantum optics is the fundamental theory for light-matter interactions, or with more generality, for quantum electrodynamics at low energies. This course thoroughly introduces the basics of this vast field, which is intimately connected to other fields such as quantum information and condensed matter physics. Starting from basic quantum mechanics and optics, key concepts in quantum optics are introduced in a consistent, self-contained fashion. Although the course focuses on the theoretical concepts, these are connected to relevant experimental observations. The course covers a variety of basic topics in the field. In particular, it introduces the quantum theory of the electromagnetic field, including its most important types of states, how to generate them, and how to detect them. Students also learn about the quantum theory of matter (including atoms, dielectric materials, and other modern solid-state systems such as superconducting circuits) and its interactions with the electromagnetic field. One of the distinguishing features of quantum optics is that it deals with systems out of equilibrium (e.g., driven by lasers) that exchange energy and information with their environment (e.g., an optical cavities loosing light through imperfect mirrors). Hence, the course also covers the theory of open quantum systems, which is of fundamental relevance to essentially all branches of (quantum) physics. Overall, this is a course that no one with interest in modern quantum mechanics should miss, since it dives directly into the core of the theory, but builds towards the description of modern quantum technologies linked to computing, communication, and sensing.				

<table>
<tr><th colspan="2">课程目标与内容（Course objectives and contents）</th></tr>
<tr><td>*学习目标
(Learning Outcomes)</td><td>After the course, the student will be able to:
1．Apply the laws of quantum mechanics to practical scenarios
2．Quantize the electromagnetic field subject to different boundary conditions
3．Understand quantum states and visualize them in phase space
4．Use light-matter interactions to create interesting quantum states
5．Derive evolution equations for general open quantum systems and solve them
6．Understand how to detect and use the light coming out of cavities and matter
7．Design effectively desired Hamiltonians by using more fundamental interactions</td></tr>
<tr><td>*毕业要求指标点（见附表）与课程目标的对应关系
（仅要求工科类专业课程填写）</td><td>例：
<table>
<tr><th>课程目标</th><th>毕业要求指标点</th></tr>
<tr><td>课程目标 2
课程目标 3</td><td>1.2 掌握工程基础知识，并能用于机械工程问题的建模与求解。</td></tr>
<tr><td>课程目标 6</td><td>3.2 能够设计满足特定需求的机械工程相关的系统或单元（部件），并体现创新意识。</td></tr>
</table>
Leave blank</td></tr>
<tr><td>*教学内容、进度安排及对应课程目标
(Class Schedule & Course Objectives)</td><td>具体请见附表《教学日历》
Please fill the attached teaching calendar</td></tr>
<tr><td>*考核方式
(Grading)</td><td>说明：分别具体阐明线上和线下考核方式及比例
Clarify the proportion and grading plan of online teaching and classroom instruction

Final grade based on homework given after finishing each chapter (35%) and the final written exam (65%).

[In all cases the instructor will take into account that English is not the first language of the students and value their effort accordingly]</td></tr>
<tr><td>*教材或参考资料
(Textbooks & Other Materials)</td><td>The main material consists on detailed and self-contained lecture notes from the instructor, which will be available in the webpage of the course (to be published as a book by IOP publishing next year).</td></tr>
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	The blackboards will also be available after each lecture, in order for students to know exactly what was introduced in class (material not mentioned in class will not count for the exam). Other textbooks complementary to or extending the material above for interested students: • C. Navarrete-Benlloch, An introduction to the formalism of quantum information with continuous variables (Institute of Physics publishing, 2015). • C. Cohen-Tannoudji, J. Dupont-Roc, and J. Grynberg, Photons and atoms: Introduction to quantum electrodynamics (John Wiley & Sons, 1989). • D. F. Walls and G. J. Milburn, Quantum optics (Springer, 1994). • L. Mandel and E. Wolf, Optical coherence and quantum optics (Cambridge University Press, 1995). • M. O. Scully and M. S. Zubairy, Quantum optics (Cambridge University Press, 1997). • H. J. Carmichael, Statistical methods in quantum optics 1: Master equations and Fokker–Planck equations (Springer Verlag, 1999). • H. J. Carmichael, Statistical methods in quantum optics 2: Non-classical fields (Springer Verlag, 2008).
其它 （More）	
备注 （Notes）	The course content and evaluation methods may be adjusted according to the students preferences and interests. The lecturer is flexible and will try to make a course where students feel comfortable, motivated, and able to pass with just a reasonable amount of work.

备注说明：

1．表格所有内容必须如实。

2．课程简介字数为 300-500 字；课程大纲以表述清楚教学安排为宜，字数不限。

附表：××课程教学日历

Class Schedule

日期 Date	周次 Week	教学内容 Content	学时 Class hour	教学形式 Instructional mode	作业及要求 Homework and requirement	基本要求 Fundamental requirement	考查方式 Examination	对应课程目标 Course objective
	1	Review of quantum mechanics, classical mechanics and linear algebra	1.5	lecture	Homework due a week after the end of chapter	Refresh knowledge, level students, and fix notation	Home work and exam	1, 3, 6.
	1-4	Quantization of the electromagnetic field: states and phase-space visualization	8.5	lecture	Homework due a week after the end of chapter	Learn quantization procedure and states of the field	Home work and exam	1, 2, 3.
	5	Quantum theory of atoms and the two-level approximation	2.5	lecture	Homework due a week after the end of chapter	Learn basic atom-optics in the semiclassical domain	Home work and exam	1, 3, 4.
	6	Light-matter interactions I: single atoms	2.5	lecture	Homework due a week after the end of chapter	Learn quantum effects in atom-light interactions	Home work and exam	1, 4.
	7	Light-matter interactions II: nonlinear media	2.5	lecture	Homework due a week after the end of chapter	Learn quantum effects in light-dielectric interactions	Home work and exam	1, 4, 7.
	8-9	Open quantum optics I: Heisenberg picture	5	lecture	Homework due a week after the end of chapter	Learn quantum Langevin eqs. and applications	Home work and exam	1, 2, 5.
	10-11	Open quantum optics II: Schrödinger picture	5	lecture	Homework due a week after the end of chapter	Learn master equations and applications	Home work and exam	1, 2, 5.
	12	Resolution techniques: phase-space representations and linearization	2.5	lecture	Homework due a week after the end of chapter	Learn phase-space stochastic methods for master eqs.	Home work and exam	1, 3, 5.

	13-14	Detection I: photodetection, bunching and anti-bunching	5	lecture	Homework due a week after the end of chapter	Learn how to use photo-detection to characterize light emitted by cavities and atoms	Home work and exam	1, 2, 3, 6.
	15	Detection II: homodyning and squeezing	2.5	lecture	Homework due a week after the end of chapter	Learn homodyne detection and its use for quantum metrology	Home work and exam	1, 2, 3, 6.
	16	Effective dynamics from fundamental interactions	2.5	lecture	Homework due a week after the end of chapter	Learn how to design desired Hamiltonians from other interactions	Home work and exam	1, 5, 7.