ulm university universität ulm

Fakultät für Naturwissenschaften, Fachbereich Physik

Announcement SS2020

Theoretical Quantum Optics

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Note for SS2020: The circumstances during these times request a change of paradigm and force us towards attempting new ways for progressing. Accordingly, the course will be made on-line and a careful planning must be set in order to successfully bring your knoweledge on quantum optics to a level in which you can endevour on research. Because a personal presentation is missing this time, this announcement also integrates guidelines for the development of the first weeks, as stated in **Guidelines**. Please become familiar with th BigBlueButton application in the uni-ulm Moodle plattform.

Description

The field of quantum optics has served as an important tool to measure and verify the principles of quantum mechanics. This lecture, besides providing an adequate historical context of some of the main developments, it emphasizes the interplay between the theoretical concepts and the experimental achievements that have given shape to the current understanding in this field. This course should be useful for graduate students in physics as well as for research workers who want to become familiar with the ideas of quantum optics.

Content:

		Recommended lecture	Session
		Loudon Scully Garrison Gerry	Date
0	**Test**		**1**
1	**Preliminaries**		
1.1	Ultraviolet catastrophe, Plank's Law	1.1-1.3, 1.1.1	20.4
1.2	Qualitative description of Einstein coefficients, stimulated emission and Basics of lasers	1.5-1.7, 1.2.2	**2**
2	**Semiclassical atom-radiation interaction**		
2.1	Point-dipole approximation	5.1.2	
2.2	Rotating wave-approximation and Semi-classical Rabi model	5.2	27.04
2.2	Scope of semiclassical treatment of radiation: Are photons needed?		**3**
2.2.1	No: photoelectric effect and Einstein B coefficient	2.3, 1.3	
2.2.2	Yes: Photo-indivisibility.	1.4	
3	**The quantum nature of light**		
3.1	Single mode field quantization and Fock states		04.05
3.2	Characterization of the field: quantum fluctuations, quadratures and quantum phase	2.1,2.2,2.3	**4**
3.3	Multi-mode field quantization	2.4	
Add.	Density operator I	2.3.2, A. A.1	
4	**Quantum states of light**		
4.1	Single mode thermal field	2.5	11.05

4.2	Coherent states	3.1,2.2,2.3,2.4, 5.1.3	5
4.2.1	Displacement operator	3.2,5.4.1	
4.2.2	Introduction to quasi-probability distributions	5.4.2,5.4.3	
5	**Quasi-probability distributions**		
5.1	P, Q, W	3.7, 5.6	
5.2	Characteristic functions	3.8, 5.6.3 B	18.05
6	**Quantum mechanical atom-mode field interaction**		6
6.1	Jaynes-Cummings Model	6.1,6.2, 4.5	
6.2	Atom-multi mode interaction		
Add.	Density operator II, General reservoir theory	8.1	
6.3	Microscopics of spontaneous emission	8.2	25.05
6.4	Optical Bloch equations	11.3.3, A. 5B, 2.7.1-2.7.3, A. A2	7
7	**Optical Observables: Absorption, resonance fluorescence photon-photon correlation functions**		
7.1	Absorption spectrum	Lecture notes	
7.2	Quantum regression theorem	10.4	08.06
7.3	Scattered Electric field from an atomic system in the far zone	10-A	8
7.4	Theory of spectrum analyser: single photon-detection probability and First order coherence function	9.1.2, 6.5, Appendix 10.D	
7.4.1	The fluorescence spectrum of a two level system	10.5 5.5	15.06
7.5	Coincidence measurements: Hanbury Brown-Twiss experiment	9.2.4, 6.5	9
7.5.1	Two photon excitation probability and second-order coherence		
7.5.2	Bunching and anti-bunching: quantum signatures		
7.5.3	Fluorescence anti-bunching in a two level system	10.6	
7.5.4	Photon-time traces with quantum jumps	8.5 [1]	22.06
8	**Other non-classical quantum states of light**		10
8.1	Squeezed states: Theory and experimental realisation	2.5,2.6,2.7, 7.1,7.2	
8.2	Quantumness of Fock states		
8.3	Cat states: characterisation upon homodyne detection		29.06
9	**Topics**		11
9.1	Lamb Shift		
9.2	Casimir effect		29.06
9.3	Dynamic Casimir effect		12
9.4	Optical bi-stability		06.07
9.5	Parametric down-conversion as a source of entanglement		13
9.4	Using optics for gravitational waves detection		13.07
9.6	Bunching and Antibunching for position detection with sub-nanometer precision		14
9.7	Zeeman splitting or position detection with sub-nanometer precision		20.06

Literature

- R. Loudon, The *Quantum theory of light* (Oxford University Press, New York, 2000)
- M.O. Scully and M.S. Zubairy, *Quantum Optics* (Cambridge University Press, Cambridge, 1997)
- G.C. Garrison and R. Y. Chiao, *Quantum Optics* (Cambridge University Press, Cambridge, 1997)
- C.C. Gerry and P.L. Knight, *Introductory Quantum Optics* (Oxford University Press, New York, 2008)

[1] J. Dalibard, Y. Castin and K. Mölmer, Phys. Rev. Lett., **68**, 580 (1992)

Prerequisites

A basic knowledge of quantum mechanics, electrodynamics and classical statistics is assumed.

Details

Lectures (3 SWS, Mondays 10-13), exercises (2 SWS Tuesdays 14-16), 6 ECTS credits. Both sessions are taking place via BigBlueButton.

Lecturer

Dr Felipe Caycedo-Soler, Institute for Theoretical Physics, Ulm University

Attention hours: Monday 14-16, use BigBlueButton and the session used for the Morning Lecture.

Tutorial

Mr Andrea Mattioni and Mr Alejandro Somoza-Márquez, Institute for Theoretical Physics, Ulm University

Guidelines

1- Homeworks shall be uploaded in pdf document to avoid large size formats. These can be photos of hand-written material.

2-The Homeworks will be available and shall be handed over via Moodle on the dates below. In this table are also presented the dates on which Solutions will be available and the date of the respective tutorial.

Homework file	Available in Moodle from 10:00 (Mondays)	Hand over using Moodle before 10.00 (Mondays)	Solution Available in Moodle at 18:00 (Wednesdays)	Discussion of solutions at 14:00 via Moodle BigBlueButtom (Tuesdays)
Lecture1_HW.pdf test of Moodle	20th April	27th April	29th April	5th May
Lecture2_HW.pdf Problem Sheet 1	27th April	4th May	6th May	12th May
Lecture3_HW.pdf Problem Sheet 2	4th May	11th May	13th May	19th May
Lecture4_HW.pdf Problem Sheet 3	11th May	18th May	20th May	26th May
Lecture5_HW.pdf Problem Sheet 4	18th May	25th May	27th May	2nd June
Lecture6_HW.pdf Problem Sheet 5	25th May	2nd June (Tuesday)	4th June (Thursday)	9nd June

Lecture7_HW.pdf Problem Sheet 6	8th June	15th June	17th June	23rd June
Lecture8_HW.pdf Problem Sheet 7	15th June	22nd June	24th June	30th June
Lecture9_HW.pdf Problem Sheet 8	22th June	13th July	13th July at 12:00	7th July: Solve questions about programming and issues relating concepts for developing the program 14th July: revision of the program and doubts about the solution program

Example (for the first week we will revise the flow of information through Moodle, no exercises left)

The Homework Lecture1_HW.pdf is available on 20.04 at 10:00 (Monday). Please submit a 'solution.pdf' (void document on this simulation) before one week's time (before next Monday, 27.04, 10.00, the latest at 11:00) using Moodle plattform. A solution will be available two days (Wednesday 29.04 at 18:00) after your submission. This time, there will be a solution (void document) with name Solution1_HW.pdf on 29.04 at 18:00 available. You should review the solution before the tutorial on Tuesday next week (for this case on 05.05 at 14:00). You can discuss this solution via BigBlueButton plattform on the time-slot for the tutorial, with the tutor and your colleagues. Please participate in the session on 05.05 to check the software.

3- The lectures will be available in the same day the Homeworks are made available, so you can access to the external links and material discussed during the lecture.

4- If possible, material regarding the arithmetic details of the lecture will be made available in the same day in which the Homeworks are made available.

5- Homeworks are graded. They correspond to 40% of the final mark. Each homework has a maximum number of points. The final homework‘s grade is the sum of the points won in all homeworks: every homework has a different percentage on the homework‘s grade.

6- A mark of 30% of the final grade will be given for presentations during the Topics section on weeks 11, 12, 13 and 14 (number of presentations depend on the number of students registering the final exam). The topics which stem in the program are only preliminar. A presentation shall be made in which an article of relevance to the quantum optics achievements is developed and explained thoroughly.

7- A final oral exam corresponds to the rest 30% of the final mark and will be conducted via BigBlueButton in a date to be scheduled. It will cover Homework subjects and matters of all the Topics presentations.