Phys 3102 (31802) Special Topics – Quantum Optics and Quantum Information, Spring 2019

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Office hours: by appointment, after class.

Lectures T, Th 11:00-12:15 pm 103 Allen **G. Dutt**

E-mail: We frequently use e-mail for announcements and distributing course material. Please, read your e-mail regularly, and make sure that your account is not over quota!

INTRODUCTION

Quantum optics describes the manipulation and coupling of quantum systems to their environment, and is key to understanding quantum computation, precision measurements, fundamentals of QM like entanglement and decoherence. Fundamental concepts and applications in a wide range of systems such as atoms, ions, photons, spin qubits, superconducting qubits, condensates, and optical lattices will be considered. See course outline in Section II below.

TEXTBOOK:
The class lectures will not follow any particular textbook, however the following textbooks are useful supplements to the lecture notes. Where appropriate, the relevant chapters from a particular textbook will be referenced in the lecture notes,

- *Elements of Quantum optics* by P. Meystre and M. Sargent III
- *Quantum Optics* by M. Scully and M. Suhail Zubairy
- *Quantum optics* by Mark Fox
- *Quantum Computer Science* by David Mermin
- *Fundamentals of Quantum Optics and Quantum Information* by Lambropoulos and Petrosyan
- *Quantum Computation and Quantum Information* by Nielsen and Chuang

COURSEWEB:
There is a CourseWeb site associated with this course. It can be accessed through your http://my.pitt.edu account. The site has:

- Important announcements
- hand-outs, reading assignments, homeworks, and additional course materials
- Grade information
- Discussion board (good for comments and suggestions)

GRADING

- Homework (75%): HWs will be assigned regularly, and students will grade each others work in teams of 2-3 using the solutions provided.

- Final Project (25%): The last 3 periods of semester will be reserved for a 30 minute presentation on a topic/paper **and** a written report on a topic of current research. The instructor will assign potential lists of topics and papers ranging over different physical implementations of qbits to fundamental quantum optics experiments and theory.

Cautions

If you have the flu, please notify me by phone or e-mail and stay home for 24 hours after the fever has gone. I will meet with you when you return and you will not be penalized for missing class.

If I have the flu and have to cancel class, I will send an email from the Blackboard account to your email account.

SPECIAL ACCOMMODATIONS FOR DISABILITY

If you have a disability that requires special testing or other accommodations, you need to notify both the instructor and the Office of Disability Resources and Services no later than the 2nd week of the term. You may be asked to provide documentation of your disability to determine the appropriateness of accommodations. The Office of Disability Resources and Services is located in the William Pitt Union, Room 216. Call 648-7890 (Voice or TDD) to schedule an appointment.

STATEMENT OF ACADEMIC HONESTY

Plagiarism is a serious transgression. All work submitted for a grade is to be written by the student. Each time a quote is used from another source, it must be properly cited in the text (a short citation in the text and a listing in the reference section at the end of the document). An automatic failing grade for the assignment will be issued for submitted work not written by the student or referenced in the text. Tendering work (giving work to another student to be copied) is not permitted. Copying graded assignments from another student is not allowed. All written assignments must be the student's own work.

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

II. Tentative Course Outline

Week	Dates	Notes
1	Jan 8,10	Introduction and background of QO and QI
2	Jan 15,17	Review of classical optics and QM
3	Jan 22, 24	Atom-light interactions – semiclassical
4.	Jan 29, 31	Quantized electromagnetic fields – photons and photodetection
5	Feb 5, 7	photon statistics, coherent states, squeezed states, number states
6	Feb 12, 14	Quantized atom-light interactions – Purcell effect, strong coupling
7	Feb 19, 21	Open quantum systems- master equation, Heisenberg-langevin
8	Feb 26, 28	Open quantum systems – stochastic wavefunction, continuous measurement
9	Mar 5,7	Quantum information processing – introduction, qbits, circuits, gates
10	Mar 12,14	SPRING RECESS – no class
11	Mar 19, 21	Deutsch-Josza algorithm, Simon's problem, Quantum fourier transform
12	Mar 26, 28	Breaking RSA encryption – Shor's algorithm
13	Apr 2, 4	, Quantum search – Grovers algorithm , Quantum error correction
14	Apr 9, 11	Quantum cryptography, Bell and GHZ states, Dense coding, teleportation
15	Apr 16, 18	Project presentations
16	Apr 23, 25	Project presentation, final report due.

III. Final project report

The format to be followed is roughly that required for manuscripts submitted to scientific journals. Typically you can look at review articles in leading journals such as Rev. Mod. Phys. or Nature Physics if you are reviewing an entire field, or for technical reviews of some papers.

Textbook

The following textbook is highly recommended:

"The craft of scientific writing", 3rd edition, by Michael Alley

Procedure

Please, write your paper on a computer, and upload PDFs (only!) to the assignment area provided on courseweb. Note that converting from Word to PDF sometimes results in missing symbols and messy equations, so you must check your PDF before uploading. I recommend learning LaTeX for preparing your lab reports, and can provide additional resources for this if requested. In addition, a hard copy must be turned in to the instructor.

If you have never read a paper in a scientific journal, go the library and find a recent issue of "American Journal of Physics". Pick an article that you find interesting, read it carefully and pay attention to style of writing and format of presentation. BUT: Do not try to duplicate the print layout of the published article (like two columns, inserted figures etc). Some students have wasted far too much time on making MS WORD or Latex do tricks! This is a writing exercise, not a printing exercise.

The preamble of your report should contain:

1. Title: Your report should have a title. Guidelines on good titles will be given in the lecture.

2. Abstract: The report should be preceded by an "Abstract". The abstract states in a few concise sentences (less than about 200 words) what you have done and what you concluded from your work.

The body of the report typically contains several sections:

I. Introduction

An introduction gives the reader a preview and a "road map" of your report. It should inform the reader about the background of your work, the scope of your investigations, and point to the sections where specific details are to be found. The introduction should briefly present the basic theory of your experiment and give the equations that you used. Equations must be incorporated into the text, i.e., they must be part of a grammatically correct sentence. It is not permissible to simply write "dangling" equations.

II. Experimental Methods OR Theory

This section contains the details of the experiments, the experimental equipment and apparatus, and the methods that used to analyze the data. If the paper is more theoretical, you would use this section to elaborate on the theoretical methods that are being explored.

A figure of the experimental setup is much better than long verbal descriptions. It is not necessary to restate in the body of the text what is obvious from the figure, but each figure should have a "caption". The caption appears below the figure and contains only brief information required to understand the figure. Figures are numbered and referred to in the text as Fig. X. Place figures at the end of the paper.

III. Results and Analysis

In this section you will present the data that was obtained and give the results of the analysis. If you use tables to display the data, the tables must have a "table heading" which identifies the quantities in that table (including units, of course). Place tables at the end of the document, not in the body of the text.

It is often better to present your results in the form of graphs rather than tables. You might plot, for instance, the Rabi oscillations or gate fidelity as a function of some parameter. This is usually much more informative than tables of numbers. Place figures at the end of the document, not in the body of the text.

All data graphs count as figures and are numbered in sequence (Fig. 1, 2 ...). Provide captions which clearly say what is shown. Label the axes in all graphs. For data points use circles, squares or other symbols to distinguish different sets of points. Error bars on data points are usually required.

IV. Conclusions, Summary

This last section of the text contains the conclusions of your work. The introduction stated your goals; here you draw the bottom line and judge if you achieved those goals. If you did not quite succeed in all respects, discuss the problem and suggest improvements for future work.

V. References:

If you refer to published source material (textbooks, journal articles) in the text of your report, number the references in sequence as they appear in the text (in square brackets, [ ], for instance). A list of published work (Title: References) should appear at the end of your report. You can use WORDs INSERT/ FOOTNOTE/ENDNOTE feature for this. But Latex has a special package that does a better job, known as Bibtex.

Additional formatting tips and guidelines:

- Use double line spacing.
- Insert all figures and tables (with captions) at the end of the text (one figure per page), after the list of references! Inserting figures into the text creates problems with page breaks etc.! Use the equation editor in Word for equations. In Latex, this is much easier, and gives professional looking results.
- Write the text in a single column. Your file will be returned to you with comments. Always make a back-up copy of your work and keep it in a safe place. If you wish to discuss your report in person with your instructor, please make an appointment.
- The style of writing should be clear and concise. Do not say the same thing over and over in different ways. Avoid excessive use of the passive voice. It is acceptable to write "We varied distance x ....." rather than "The distance x was varied ....".
- Do not copy or rewrite chapters of textbooks; you are not likely to improve on the original. There are no bonus points for "overweight" reports. More likely you will be asked to get rid of the excess bulk through strenuous exercise.
- Even though this is writing exercise, the physics should be correct and should be explained correctly.
- It may be a good idea to ask one of your fellow students to read and criticize your report before you hand it in. If he or she gets frustrated reading your report, your instructor probably feels the same way. It sometimes helps to put your paper aside for a day or so and then read it.

IV. Final project presentation

Each student will prepare one brief oral project presentation at the end of the semester (see posted schedule for the dates). The 20 min presentation (plus 5 minutes for questions) will be made to the entire class. The presentation need not follow precisely writeup; it should be engaging and educational. Your instructors and peers will evaluate your presentation and give you feedback. The instructor will NOT take the peer feedback into account for the grade, so it is fine to give constructive criticism of your friends.

Twenty minutes is a short time, so it is essential that you rehearse your presentation as you would if you were giving an invited presentation at a meeting of the American Physical Society. Please review the Society guidelines at http://www.aps.org/meet/guidelines.cfm. We suggest a maximum of 12 - 14 slides and strongly suggest preparing your presentation electronically (e.g.LaTeX or MS Power Point) and using the LCD projector for the cleanest most professional presentation possible. I will also make available templates and give tips on making good presentations.