QIC 895 (Proposed reading course) Summer 2015

Theory of Quantum Optics

Instructors

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Overview

Quantum optics is becoming increasingly important in fields such as quantum computing and quantum cryptography. Not only can the quantum nature of the electromagnetic field be used to encode and transmit quantum information, but it plays an important role in the decoherence of numerous systems. This reading course will offer an in-depth treatment of quantum optics and its role in decoherence.

Concretely, this course is planned to be based on the MIT graduate course *Quantum Theory of Radiation Interactions* [1], a 12-week course on these subjects offered in 2012 by Prof. Paola Cappellaro. A portion of [1] covers material treated in Phys 434 and Phys 454/AMath 473 (Waterloo), which will be omitted here in order to allow for a more in-depth treatment of the other topics, following the textbooks [2] and [3], on quantum optics and quantum noise respectively.

Description

The course will use [1] as a primary reference, as the full course material for it is available online, including complete lecture notes, assignments, and tests. As time permits, [2] and [3] will be used to supplement the lecture notes, as per the schedule below.

The material will be divided into 8 blocks, each of which will take 1 to 2 weeks. Blocks 1–5 will introduce the central concepts of quantum optics, including quantization of the electromagnetic field, light-matter interactions, and non-classical states of light. Block 4 will cover relativistic effects in light-matter interactions, for which certain common approximations may not be valid. Blocks 6–7 will apply the material from the first five blocks to study noise and damping in quantum systems. Block 8 will briefly cover implementations of quantum optics, including cavity and circuit QED, with an emphasis on applications to quantum information processing.

Students will be expected to present one or several 1-hour seminars on the course material. Depending on the number of students enrolled, a substantial amount of this material may be covered in these seminars, which all students will be expected to attend. Students will complete assignments from [1] every 2-3 weeks on average, which will be graded on a pass/fail basis.

Schedule

Block	Duration	Sources	Topics
1	1 Week	[2] Ch. 5	Semiclassical Light-Matter Interactions
2	2 Weeks	[1] Ch. 10, [2] Ch. 1, [3] Ch. 8.1	Quantizing the Electromagnetic Field
3	1 Week	[1] Ch. 12 [2] Ch. 6	Quantum Light-Matter Interactions
4	1 Week	(E.M.-M.)	Relativistic Considerations in L-M Interactions
5	1 Week	[2] Ch. 2, [3] Ch. 10	Coherent and Squeezed States
6	2 Weeks	[1] Ch. 8, [3] Ch. 5	Open Quantum Dynamics, Markov Processes
7	2 Weeks	[2] Ch. 8–9	Quantum Damping
8	2 Weeks	(A.L. & T.J.)	Implementations and Applications

References

[1] P. Cappellaro, *Quantum Theory of Radiation Interactions*, MIT Open Courseware, Course 22.51 (2012).

[2] M. O. Scully and M. S. Zubairy, *Quantum Optics*, Cambridge University Press (1997).

[3] C. W. Gardiner, P. Zoller, *Quantum Noise: A Handbook of Markovian and Non-Markovian Quantum Stochastic Methods with Applications to Quantum Optics*, Springer (2004).