Quantum Optics

A course for NCU and NTU /Academia Sinica TIGP program

Lecturer: Ying-Cheng Chen、Ming-Shien Chang and Yu-Ju Lin (陳應誠、張銘顯、林育如)

Time(時間): Wednesday(9:10~12:00)

Room(教室): R311 IAMS 中研院原分所 R311(台大校園)

Date		lecturer	Date		lecturer
9/18	9:10~12:00	Prof. Ying-Cheng Chen	11/20	9:10~12:00	Prof. Ming-Shien Chang
9/25	9:10~12:00	Prof. Ying-Cheng Chen	11/27	9:10~12:00	Prof. Ming-Shien Chang
10/2	9:10~12:00	Prof. Ying-Cheng Chen	12/4	9:10~12:00	Prof. Ming-Shien Chang
10/9	9:10~12:00	Prof. Ying-Cheng Chen	12/11	9:10~12:00	Prof. Yu-Ju Lin
10/16	9:10~12:00	Prof. Ying-Cheng Chen	12/18	9:10~12:00	Prof. Yu-Ju Lin
10/23	9:10~12:00	Prof. Ying-Cheng Chen	12/25	9:10~12:00	Prof. Yu-Ju Lin
10/30	9:10~12:00	Prof. Ming-Shien Chang	1/8/2014	9:10~12:00	Prof. Yu-Ju Lin
11/6	9:10~12:00	Prof. Ming-Shien Chang	1/15/2014	9:10~12:00	Prof. Yu-Ju Lin
11/13	9:10~12:00	Prof. Ming-Shien Chang			

- **Course Description**

This class is an introduction to quantum optics. We want to provide an in-depth introduction to fundamental concepts of quantum optics. Parts I and II are devoted for this purpose. In part I, we want to introduce the necessary background knowledge for this course. In part II, we will introduce essential topics of quantum optics. The field of quantum optics becomes a diverse one. We will provide in-depth introduction on some selected special topics of quantum optics in part III to grasp the general interests. In part IV, we shift the topics to atom optics, including laser cooling, Bose-Einstein condensation and applications of matter wave.

- **Syllabus**

Part I: Introduction and Review of Quantum Mechanics

– Semi-classical Treatment on Photon-Atom Interaction

I-1: Density Matrix [1]

I-2 Time-dependent Perturbation Solution to Schordinger's Equation [5]

I-3 Interaction Picture and multi-photon Transition by Density Matrix Formalism [5]

I-4 Optical Bloch Equations for a Two-level Atom [1, 2, 5, 11, 12]

I-5 The Hyperfine Structure of IA Atoms. [1, 10]

Part II: Quantization of EM Field [4, 6, 7, 10, 12]

II-1 Quantization of Harmonic Oscillator [10]

II-2 Quantization of EM Field [4]
II-3 Photon number state of Photon (Fock state) [4]
II-4 Coherent State of Photon [4]
II-5 Squeeze State of Photon [4]
II-6 Lamb shift [4]
II-7 Quantum beat [4]
II-8 Coherence and Correlation Function

Part III: Selected Topics in Quantum Optics

III-1 Dressed State[13]
III-2 Resonance Fluorescence[3,4]
III-3 Coherent Population Trapping and Electromagnetic Induced Transparency[4]
III-4 Photon Echo and Free Induction Decay[4,12]
III-5 Cavity Quantum Electrodynamics

Part IV: Atom Optics
IV-1 Light-force on a Two-level Atom[11,14]
IV-2 Doppler Cooling and the Magneto-optical Trap[11]
IV-3 Various Laser Cooling Schemes[11]
IV-4 Bose-Einstein Condensation[15]
IV-5 Properties and Applications of Matter Wave[15]

- **References**

[1] J. Weiner, P. –T. Ho, “Light-Matter Interaction” volume 1, John Wiley & Sons, 2003. ISBN: 0-471-25377-4
[2] M. Weissbluth, “Photon-Atom Interactions”, Academic Press, 1989. ISBN: 0-12-743660-x
[3] R. Loudon, “The Quantum Theory of Light”, Clarendon Press, second edition, 1983.
[4] M. O. Scully and M. S. Zubairy, “Quantum Optics”, Cambridge University Press, 1997, ISBN: 0-521-43595-1
[5] R. W. Boyd, “Nonlinear Optics”, Academic Press, 1992, ISBN: 0-12-121680-2
[6] Y. Yamamoto and A. Imamoglu, “Mesoscopic Quantum Optics”, John Wiley & Sons, 1999. ISBN: 0-471-14874-1
[7] U. Leonhardt, “Measuring the Quantum State of Light”, Cambridge University Press, 1997, ISBN: 0-521-49730-2
[8] M. Sargent III, M. O. Scully, W. E. Lamb, Jr., “Laser Physics”, Addison-Wesley Publishing, 1993 six printing, ISBN: 0-201-06903-2
[9] W. Demtroder, “Laser Spectroscopy”, Springer, 1998, second edition, ISBN:3-540-57171-X

[10] F. Schwabl, “Quantum Mechanics”, Springer, 1995, ISBN 3-540-59187-7
[11] H. J. Metcalf, P. Van der Straten, “Laser Cooling and Trapping”, Springer, 1999, ISBN: 0-387-98728-2
[12] P. Meystre and M. Sargent III, “Elements of Quantum Optics”, Springer, 1998, third edition, ISBN: 3-540-64220-x
[13] C. Cohen-Tannoudji, J. Dupont-Roc & G. Grynberg “Atom-Photon interaction” [14] P. Meystre, “Atom optics”
[15] C. J. Pethick & H. Smith ,“Bose-Einstein condensation in dilute gases”

- **Evaluation**

1. **Middle term examination. 30%**
2. **Finial report 30%**
3. **Oral representation 30%**
4. **Class attending 10%**

How to prepare for the middle term examination?

1. We will ask some questions on class from time to time, and we also write down the essential questions in this note. We will pick up some of those questions as the references in the middle examination.
2. Middle examination is a writing test and takes for two hours.

How to prepare for the Final Report and Oral Representation?

1. A+: Your talk/report is impressive and new ideas to us.
2. A: You work hard that let us feel touched.
3. A-: You don’t work hard but you are smart that we think you are good in this class.
4. B+, B, B-: You don’t work hard and you are not smart, then we give you grade according to the content of your report and your comprehension of the report.

5. C and below: we don’t think you are serious about this class!