

Quantum Optics, IPT5340

Time: T7T8F7F8 (15:30-17:20, Tuesday, and 16:00-17:20, Friday), at Room 208, Delta Hall

Ray-Kuang Lee¹

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(Dated: Spring, 2020)

- **References:**

1. **Text Book:** G. S. Agarwal, "*Quantum Optics*", Cambridge University (2013).
2. U. Leonhardt, "*Essential Quantum Optics*," Cambridge (2010).
3. D. F. Walls and G. J. Milburn, "*Quantum Optics*," 2nd Ed. Springer (2008).
4. M. Fox, "*Quantum Optics, an introduction*," Oxford (2006).
5. C. C. Gerry and P. L. Knight, "*Introductory Quantum Optics*," Cambridge (2005).
6. Y. Yamamoto and A. Imamoglu, "*Mesoscopic Quantum Optics*," Wiley (1999).
7. M. O. Scully, and M. S Zubairy, "*Quantum Optics*," Cambridge (1997).

- **Teaching Method:**

In-class lectures with discussions and assignments.

- **Expected Outputs:**

- Quantum properties of Electromagnetic Fields;
- Non-classical light and its generation, measurement, and applications;
- Interaction between photon-atoms;
- Test of Quantum Mechanics by Optics;
- Applications in Quantum Metrology, Quantum Communication, and Quantum Computing.

- **Evaluation:**

- Assignments, 100%;

- **Class suspended:**

~~3/5~~ March 5th, Friday: Mei-Chu games
~~3/19~~, March 19th, Friday: MOST scoping
~~4/2~~, April 2nd, Friday: Spring break

- **Office hours:**

- By appointment.

- **TA:**

Miss Yi-Ru Chen, PhD student, IPT/NTHU
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Syllabus:

Date	Topic	To Know	To Think
Feb. 23rd (Tue.)	Introduction	Scope	<input type="checkbox"/> Your and My Expectations. <input type="checkbox"/> What is the nature of light? <input type="checkbox"/> Anything else ?
Feb. 26th (Fri.)	Simple Harmonic Oscillator (SHO)	<input type="checkbox"/> classical trajectory <input type="checkbox"/> analogue to EM waves	<input type="checkbox"/> Bohmian mechanics <input type="checkbox"/> Inverted SHO <input type="checkbox"/>
week 1 (3/2, 3/9)	Quantum SHO	<input type="checkbox"/> Fock states, $ n\rangle$ <input type="checkbox"/> creation operator, \hat{a}^\dagger	<input type="checkbox"/> single-photon detection <input type="checkbox"/> Wave-Particle Duality <input type="checkbox"/> photon-number resolving <input type="checkbox"/>
(3/12, 3/16, 3/19)		<input type="checkbox"/> Vacuum state <input type="checkbox"/> Quantum Fluctuations	<input type="checkbox"/> Shot Noise Limit <input type="checkbox"/> Casimir Force <input type="checkbox"/>
week 2 (3/23, 3/26)	Quantum Mechanics	<input type="checkbox"/> Schrödinger picture <input type="checkbox"/> Heisenberg picture <input type="checkbox"/> Interaction picture	<input type="checkbox"/> Uncertainty Relation <input type="checkbox"/> Probability Interpretation <input type="checkbox"/> Measurement problem <input type="checkbox"/> Non-locality <input type="checkbox"/> Macrorealism <input type="checkbox"/>
week 3 (3/30, 4/2, 4/6)	Coherent states, $ \alpha\rangle$	<input type="checkbox"/> photon statistics <input type="checkbox"/> bunching <input type="checkbox"/> Correlation function	<input type="checkbox"/> Minimum Uncertainty States <input type="checkbox"/> Classical-Quantum boundary <input type="checkbox"/>
week 4 (4/9, 4/13)	Quantum Phase Space	<input type="checkbox"/> Wigner function	<input type="checkbox"/> Quasi-probability <input type="checkbox"/> Quantum State Tomography <input type="checkbox"/>
week 5 (4/20, 4/23)	Squeezed states	<input type="checkbox"/> $ \xi\rangle$ <input type="checkbox"/> OPO	<input type="checkbox"/> Continuous Variables <input type="checkbox"/>
week 6 (4/27, 4/29)	Two-mode Squeezed states	<input type="checkbox"/> EPR pair <input type="checkbox"/> Cat states <input type="checkbox"/> non-Gaussian states	<input type="checkbox"/> Quantum Discord <input type="checkbox"/> Entanglement <input type="checkbox"/> Steering <input type="checkbox"/> Bell's inequality <input type="checkbox"/>
week 7 (5/4, 5/7)	Optical devices	<input type="checkbox"/> Beam splitter <input type="checkbox"/> Mach-Zehnder interferometer	<input type="checkbox"/> linear optics <input type="checkbox"/>
week 8 (5/11, 5/14)	Interferometry	<input type="checkbox"/> Young's Interferometry, $g^{(1)}$ <input type="checkbox"/> HBT-Interferometry, $g^{(2)}$	<input type="checkbox"/> Quantum Phase Estimation <input type="checkbox"/> Quantum Fisher Information <input type="checkbox"/>

Syllabus:

Date	Topic	To Know	To Think
week 9 (5/18, 5/21)	Photon-Atom Interactions	<input type="checkbox"/> Einstein's AB coefficients <input type="checkbox"/> Classical model <input type="checkbox"/> Semi-Classical	<input type="checkbox"/> Rabi-frequency <input type="checkbox"/> Wavefunction Revival <input type="checkbox"/>
weeks 10-11 (5/25, 5/28, 6/1)	Full Quantum model	<input type="checkbox"/> Jaynes-Cummings <input type="checkbox"/> Dicke model <input type="checkbox"/> Cavity-QED	<input type="checkbox"/> Vacuum Rabi oscillation <input type="checkbox"/> Collective interaction <input type="checkbox"/> Circuit-QED <input type="checkbox"/>
week 12-13 (6/4, 6/8, 6/11)	Open systems	<input type="checkbox"/> Weisskopf-Wigner approximation <input type="checkbox"/> Born-Markovian approximation <input type="checkbox"/> Master equation <input type="checkbox"/> Lindblad equation	<input type="checkbox"/> dissipation-fluctuation theorem <input type="checkbox"/> non-Markovian <input type="checkbox"/>
week 14-15 (6/15, 6/18, 6/22)	Selected Applications of QO	<input type="checkbox"/> Quantum Sensor <input type="checkbox"/> Test of Quantum Mechanics <input type="checkbox"/> Quantum Communication <input type="checkbox"/> Quantum Computing <input type="checkbox"/>	<input type="checkbox"/> Gravitational Wave Detectors <input type="checkbox"/> Quantum Zeno effect <input type="checkbox"/> Quantum Key Distribution <input type="checkbox"/> Quantum Photonic Circuit <input type="checkbox"/>
Related Courses	<input type="checkbox"/> Quantum Mechanics <input type="checkbox"/> Atomic Physics <input type="checkbox"/> Nonlinear Optics <input type="checkbox"/> Quantum Information <input type="checkbox"/> Quantum Computing <input type="checkbox"/> Quantum Communication <input type="checkbox"/> Quantum Simulation <input type="checkbox"/>	<input type="checkbox"/> AMO-Physics <input type="checkbox"/> QIS <input type="checkbox"/> IBM Qiskit <input type="checkbox"/> Quantum Machine Learning <input type="checkbox"/>	
Open Questions	<input type="checkbox"/> Quantum in Macroscopic <input type="checkbox"/> Extended QM <input type="checkbox"/> Quantum Gravity <input type="checkbox"/>		