Quantum Optics, IPT5340

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

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Syllabus:

Date	Topic	To Know	To Think
week 1 (3/2, 3/9)	Quantum SHO	☐ Fock states, $\|n\rangle$ ☐ creation operator, $\hat{a}^\dagger$	☐ single-photon detection ☐ Wave-Particle Duality ☐ photon-number resolving ☐
(3/12, 3/16, ~~3/19~~)		☐ Vacuum state ☐ Quantum Fluctuations	☐ Shot Noise Limit ☐ Casimir Force ☐

- **Take-home Messages:**
  1. Class Materials: http://mx.nthu.edu.tw/∼rklee
  2. Discussion Channel: Quantum Optics, Lecture@NTHU, Slack, quantumoptics-zgq1695.slack.com
  3. *"God does not play dice with the universe."* — Albert Einstein, The Born-Einstein Letters 1916-55
  4. *"Not only does God play dice but... he sometimes throws them where they cannot be seen."*— Stephen Hawking
  5. eigen-energy of SHO: $E = \hbar\omega(n + \frac{1}{2}), \qquad n = 0, 1, 2, 3, \ldots.$
  6. Number operator $\hat{N}$
  7. Creation operator $\hat{a}^\dagger$
  8. Annihilation $\hat{a}$

- **References:**

  1. Chapter I, in C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, *"Photons & Atoms"*, John Wiley & Sons (1989).
  2. Chapter 2, in J. J. Sakurai, *"Modern Quantum Mechanics,"* Addison Wesley (1994).
  3. Chapter 7, in A. Goswami, *"Quantum Mechanics,"* WCB Publishers (1992).
  4. Chapters 3-4, in J. B. Marion and S. T. Thornton, *"Classical dynamics of particles and systems,"* Saunders College (1995).

- **From Scratch !!**
- Quantum SHO:

$$\hat{H} = \frac{1}{2}\frac{\hat{p}^2}{m} + \frac{1}{2}k\,\hat{x}^2, \tag{1}$$

where the $\hat{x}$ and $\hat{p}$ are non-commute operators, *i.e.*,

$$[\hat{x}, \hat{p}] = i\hbar. \tag{2}$$

- The *Hermite-Gaussian* solutions associated with Hermite polynomials H_n

$$\psi(\xi) = H_n(\xi)\mathrm{exp}[-\xi^2/2], \qquad \epsilon = 2n+1, \qquad n = 0, 1, 2, 3\ldots \tag{3}$$

- For the corresponding eigen-energy:

$$E = \frac{\hbar\omega}{2}\,\epsilon = \hbar\omega(n + \frac{1}{2}), \qquad n = 0, 1, 2, 3, \ldots. \tag{4}$$

- Quantum SHO:

$$\hat{H} = \hbar\omega(\hat{a}^\dagger\hat{a} + \frac{1}{2}). \tag{5}$$

- **More to know ....**
  - The Axiom of QM.
  - Pure ad Mixed states.
  - Purity of a quantum state.
  - Parity-Time ($\mathcal{PT}$)-symmetric SHO
    - Ludmila Praxmeyer, Popo Yang, and RKL, *"Phase-space representation of a non-Hermitian system with PT-symmetry,"* Phys. Rev. A 93, 042122 (2016).
  - Entanglement.

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