Department of Physics **IIT Kanpur**

PHY643: Coherence and Quantum Entanglement; Semester-II, 2024-25; 3-0-0-9

Course Objectives:

This course is for PhD and advanced undergraduate students who want to gain a solid understanding of the concept of coherence as well as its applications in modern quantum optics and quantum information technologies. The course will have two main parts. The first part will discuss the concept of coherence associated with waves and one-particle systems. In the second part, we will transition into quantum entanglement by building the idea of a two-photon system and the associated concept of two-particle coherence.

Course content:

(1) Coherence: Spectral properties of stationary random processes, Wiener-Khintchine theorem, Angular spectrum representation of wavefields, Introduction to the second-order coherence theory, Propagation of coherence, The van Cittert-Zernike theorem, Coherent mode representation of sources and fields.

(2) Quantum Entanglement: Basics of nonlinear optics, Two-photon field produced by parametric down-conversion, EPR paradox, Bell inequalities and its experimental violations, Quantum theory of higher-order correlations, Two-photon coherence and two-photon interference effects. Two-photon entanglement in the following variables: time-energy, position-momentum, and angle-orbital angular momentum; Introduction to Quantum Information, applications of quantum entanglement: Quantum Cryptography, Quantum Teleportation, Quantum Imaging.

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Reference books:

1. L. Mandel and E. Wolf, Optical Coherence and Quantum Optics (Cambridge university press, New York, 1995).
2. R. W. Boyd, Nonlinear Optics, 3rd ed. (Academic Press, New York, 2008).
3. J. W. Goodman, Statistical Optics, (John Wiley and Sons, 2000)
4. R. Loudon, *The Quantum Theory of Light*, 3rd ed. (Oxford University Press, New York, USA, 2000).
5. M. Born and E. Wolf, *Principles of Optics*, 7th expanded ed. (Cambridge University Press, Cambridge, 1999).