EMA 601 / NE 602 Quantum Engineering with Atoms and Photons (Fall 2020)

Instructor: Prof. Jennifer Choy, Department of Engineering Physics

Description: This special topics course will cover the fundamentals of atomic and optical physics, the basic principles behind quantum technologies, and their diverse applications in sensing, computation, and communication. Topics will include: properties of various quantum platforms, fundamental quantum mechanics concepts, benefits and engineering challenges involved with quantum applications and instruments.

Number of credits: 3

Learning outcomes: By the end of the course, students will be able to:

- Explain critical concepts in quantum mechanics, including wave-particle duality, the uncertainty principle, entanglement, quantum noise, interference, etc.
- Identify quantum material platforms (neutral atoms, ions, solid-state systems, etc.) and describe their defining characteristics
- Recognize experimental approaches to prepare, manipulate, and detect quantum states using photons
- Give examples of current and future applications of quantum technologies in sensing and information processing
- Define critical parameters that drive performances of quantum devices

Tentative list of topics:

Quantum properties of matter and their measurement via photons:

- Wave-particle duality, uncertainty, and Schrodinger's equation
- Quantum phenomena: coherence, entanglement, interference
- Atoms and two-level systems
- Interactions of atoms with electro-magnetic fields and with light

Quantum material systems and their preparation:

- Techniques in laser cooling and trapping: cold atoms and ion traps
- Color center engineering and solid-state quantum spins

Experimental techniques in quantum engineering and their applications:

- Laser spectroscopy, optical pumping, and Faraday rotation – vapor cell atomic magnetometer
- Matter wave interferometry – quantum timekeeping and inertial sensing
- Single photon generation and measurement – quantum communication and cryptography
- Fabrication and coherent control of solid-state spins
- Cavity Quantum Electrodynamics
- State-of-the-art and future of quantum computation

Pre-requisites: Physics 205, 241, 244, or 249, or graduate students from any program