PHY-PHY-927 Atom Optics

Credit Hours: 3-0

Prerequisite: Quantum Mechanics

Course Objectives: This lecture course aims to provide students with the necessary theoretical background to pursue the research in matter-wave optics, such as, cooling and trapping of atoms, atomic wave guides, Bose-Einstein condensation, atomic interferometry etc.

Core Contents: The core contents include the fundamental concepts of light, especially laser field, basic concepts of matter waves and their applications, optical forces on atoms during atom-field interaction, cooling and trapping of atoms. Further it includes the linear atom-optical elements, such as, atom- optical lenses, atom diffraction, atom-optical mirrors, atom traps and cavities and their application, such as, optical lattices, atomic waveguides, atom and molecule interferometry and atom holography. Moreover, the nonlinear atom optical phenomena, such as, the matter equivalent of laser light: Bose-Einstein condensation, atomic interactions, nonlinear wave mixing, and matter-wave amplification are included.

Detailed Course Contents: The detailed contents are given the table below along with week-wise breakdown.

Textbooks: P. Meystre (PM), Atom Optics, Springer Science & Business Media, (2001).

Reference Books:

1. M. O. Scully and M. S. Zubairy, Quantum Optics, Cambridge University Press 1997.
2. L. Mandel and E. Wolf, Optical Coherence and Quantum Optics, Cambridge University Press, New York, 1995.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Handouts	Fundamental concepts of waves and particles, photons, and atoms in the perspective of wave-particle duality, matter- waves and their potential applications
2	Handouts	Introduction to quantum states of light, photon-atom interaction, Jaynes-Cummings model and Dicke model
3	PM: 1.1-1.4	Light forces on atoms: two-level atoms, adiabatic elimination, dipole and radiation pressure forces, dissipation
4	PM: 2.1-2.5	Ray and wave atom optics, Doppler cooling, Sisyphus cooling, evaporative cooling
5	PM: 3.1-3.5	Collimation by radiation pressure forces, focusing, channeling by standing waves, optical lattices, evanescent field mirrors, focused laser beam mirrors
6	PM: 4.1-4.3	Raman-Nath and Bragg diffraction regime, Stern-Gerlach regime, Spontaneous emission
7	PM: 4.4-4.5, 5.1-5.2	Mechanical gratings, atom interferometers, magneto-optical traps, magnetic traps, quadrupole trap, Ioffe-Pritchard trap
8	PM: 5.3-5.5	Optical traps, gravitational cavities, atomic wave guides
9	6.1-6.2, 7.1	Near-resonant dipole-dipole interaction, propagation effects, dipole-dipole interaction in an atomic cavity
10	PM: 7.2, 8.1	Atomic diffraction by Schrödinger fields, Schrödinger field quantization
11	PM: 8.2-8.3	The Hartree approximation, quasiparticles
12	PM: 9.1-9.5	Review of optical coherence theory, coherence of matter waves, electronic coherence, density coherence, field

		coherence
13	PM: 10.1-10.3	Bose-Einstein condensation in free space, BEC in traps, experimental realization in Alkali vapors
14	PM: 10.4-10.6 M	Mean field theory, finite temperatures, coherence and BEC
15	PM: 11.1-11.3, 12.1	Atom laser experiments, theory of binary-collision atom laser, matter-wave solitons, nonlinear wave-mixing