Course Type	Course Code	Name of Course	L	T	P	Credit
DE	NPHD512	Ultrafast Optical Science and Technology	3	0	0	3

Prerequisite

- Students must have detailed knowledge of Optics and Electrodynamics. Students should have completed courses on Mathematical Physics and Quantum Mechanics. Students should preferably have the fundamental knowledge laser and Gaussian beam.

Course Objective

The objective of the course is

- To introduce the students to various aspects of ultrafast science and technology and its relevant applications in modern science.
- To motivate the students about the importance of optical science and its technological developments.
- To introduce the students to modern ultrafast science and research in atomic, molecular, condensed matter and plasma systems.

Learning Outcomes

Upon successful completion of this course, students will learn about:

- The field of ultrafast optical science and its various modern applications.
- The generation of short pulsed lasers, their characterization, and interaction with medium, manipulate and change of their characteristics.
- Various aspects of high intensity laser matter interactions including its applications in spectroscopy, laser plasma physics, material science and condensed matter physics.

Unit No.	Topics to be Covered	Lecture Hours	Learning Outcome
1	**Introduction to ultrafast optics:** Introduction to ultrafast science and technology, ultrashort pulse characteristics, applications of ultrafast optics, review of laser essentials, light pulses, relationship between duration and spectral width, propagation of a light pulse in a transparent medium, second-order susceptibility, third-order susceptibility, Kerr lens effect, self-phase-modulation, saturable absorbers.	10	This unit provides a broad knowledge about the field of ultrafast science. Students will learn about characteristics of ultrashort laser pulses and its interaction with medium.
2	**Introduction to high intensity light matter interaction:** Nonlinear ionization mechanisms-multiphoton ionization, tunnelling ionization, over-barrier ionization. Introduction to extreme form of light. Applications of intense short pulse laser matter interactions	4	This unit provides a knowledge about the interaction of high intensity ultrashort laser pulses with atomic and condensed phase of matter.
3	**Generation of ultrashort laser pulses:** Q-switched and mode locked operations for ultrashort laser pulses	5	Students will learn about the physics and technologies for the generation of ultrashort laser pulses
4	**Manipulate and Change the Characteristics of ultrashort Laser Pulses**: Pulse compression and amplification, Chirped Pulse Amplification (CPA) for high power ultrashort pulses, second- and third-harmonic generation, brief overview of optical parametric generators (OPGs) and amplifiers (OPAs)	6	Students will learn how to manipulate and amplify ultrashort pulses, about its nonlinear interactions with medium
5	**Ultrashort Pulse Characterization**: Pulse characterization techniques relevant to ultrashort lasers pulses: Autocorrelation, FROG etc.	4	Students will learn about the experimental techniques to measure ultrashort pulses
6	**Introduction to modern ultrafast measurement techniques**: Pump-probe measurements, streaking, Electro-optic sampling, Kerr gating etc.	5	Students will learn various ultrafast measurement techniques using ultrashort pulses.
7	**Introduction to High harmonic generation and attosecond science:** Historical scientific background of high harmonic generation (HHG). Introduction to the fundamental physics of HHG, three step model, properties of HHG emission from gas and solid, atto chirp, attosecond pulses	6	In this unit, the students will learn about the physics of the HHG and will be introduced to the field of attosecond science.

8	**Recent developments related to ultrafast science and technology**	2	Students will be introduced to modern scientific and technological developments in the research relevant to ultrafast science.
	Total	**42**	

Textbooks:

1. Femtosecond Laser Pulses: Principles and Experiments by Claude Rulli`ere, Springer; 2nd ed. 2005.
2. Ultrafast Lasers: A Comprehensive Introduction to Fundamental Principles with Practical Applications, by Ursula Keller, Springer; 1st ed. 2021 edition (March 8, 2022).

Reference Books:

1. Nonlinear Optics, by Robert W. Boyd, Academic Press Inc; 3rd edition (13 May 2008).
2. Lasers, by Anthony E. Siegman, University Science Books,U.S.; 1990th edition (17 October 1990).
3. Ultrafast Optics by Franz Kärtner, Online textbook 2005 via MIT OpenCourseWare. https://ocw.mit.edu/courses/6-977-ultrafast-optics-spring-2005/pages/lecture-notes/