LASER SYSTEM

Programme Structure

Course Code	Course Title	Lectures (L) Hours per week	Tutorial (T) Hours per week	Practical (P) Hours per week	Total Credits
LOE2351	Basics of Lasers	2	-	2	3
LOE2451	Laser Technology & Applications	3	-	-	3
LOE2551	Laser Systems & Devices	3	-	-	3
LOE2651	Lasers in Defense Applications	3	-	-	3
LOE2751	Lasers in Industrial Applications	3	-	-	3
LOE2851	Lasers in Atmospheric Studies	3	-	-	3
	TOTAL				**18**

LASER SYSTEM

Syllabus

BASICS OF LASERS

Course Code: LOE2351 **Credit Units: 3**

Course Objective:
The basic aim of this Course is to make students (with Physics &Maths background up to 12th standard) appreciate the fundamentals of lasers and their diversified applications. The approach will stress more on the concepts & fundamentals with very simple or sometimes no mathematical equations. The outcome of this Course will make the students/trainees more excited to more about lasers and their applications in specific fields of their interest.

- **Overview of Lasers :**History, Types and Applications of Lasers
- **Nature of Light**: Corpuscular Theory, Wave Theory, Electromagnetic Spectrum, Qunatum nature of light, Dual nature of nature, De Broglies's hypothesis, wavelength associated with particle, momentum of photon, Energy-mass relation, Momentum of photon. Mass of photon.
- **Matter:** Structure of Atoms & Molecules. Energy Levels, Electronic, Vibrational and Rotational Energy Levels with Examples. Two-level representation.
- **Interaction of Radiation with Matter:** Absorption, Spontaneous Emission, Stimulated Emission, Einstein's A & B Coefficients of Transitions, Maxwell Boltzmann Distribution, Planck's law of blackbody radiation.
- **Principle of Laser action:** Population inversion, metastable states, gain medium, Pumping mechanisms, feedback mechanism, threshold condition for laser beam generation.
- **Optical Resonators :**Types of Resonators, Stability Criteriia, g-parameters.
- **Characteristics of Laser Beams:**Monochromaticicity, Directionality, Brightness, Coherence: temporal & spatial, Focusability, Ultra-short pulse generation.
- **Types of Lasers:**Three- level and Four-level Lasers, Solid, Liquid and Gas Lasers. Brief description of Ruby, He-Ne, Nd:YAG, Carbon Dioxide Lasers, Semiconductor Lasers. X-Ray Lasers, Free-electron Lasers. Fiber Lasers.
- **Longitudinal & Transverse Modes** : Temporal modes, Spatial Modes & characteristics.
- **Application of Lasers:** General Applications of Lasers, Laser Applications in Industry, Defence, Medicine, Entertainment etc.

Examination Scheme:

Components	A	CT	S/V/Q	HA	EE
Weightage (%)	5	10	8	7	70

CT: Class Test, HA: Home Assignment, S/V/Q: Seminar/Viva/Quiz, EE: End Semester Examination; A: Attendance

Text & References:

- Laser Principles, Types & Applications: K R Nambiar, New Age International, 2004.
- Lasers: Theory and Applications : A K Ghatak and K Thyagarajan, McMillan, 2003.

LASER TECHNOLOGY & APPLICATIONS

Course Code: LOE2451 **Credit Units: 3**

Course Objective: The aim of this Course is to make students/traineesunderstand the fundamentals of lasers, laser systems, their characteristics and diversified applications including industry, medicine & Defence. The approach will be to stress more on the fundamentals with the help of very simple mathematical equations. The outcome of this Course will prepare the students/trainees to use this knowledge for applications of lasers in specific fields of their interest.

Module I: INTERACTION OF LIGHT WITH MATTER Einstein coefficients, Relation between these coefficients, Lifetime of excited state, Line Broadening mechanisms, Population inversion, Threshold condition for Laser, Laser-Rate equations for three-level and four-level systems, Conditions for CW and pulsed laser action.

Module II: DIFFERENT POPULATION INVERSION TECHNIQUES WITH EXAMPLES
Optically pumped lasers, solid state lasers, dye lasers, electrical-discharge pumped lasers, gas lasers, chemical lasers, gas dynamic lasers, semiconductor lasers, free-electron lasers, gamma ray lasers, fiber lasers (only introductory description of these lasers).

Module III: OPTICAL RESONATORS
General considerations, Laser resonators,General conditions of stability, Plane and spherical mirror cavities, Modes and optical resonators, Gaussian beam propagation,Theory of Q-switching and experimental methods - Theory of Mode locking and experimental methods. Frequency stabilization of laser beams.Multimode oscillation.

Module-IV: CHARACTERISTICS OF LASER BEAMS AND APPLICATIONS
Monochromaticity, Spatial & temporal coherence, temporal coherence & monochromaticity relation, connection between spatial coherence and directionality, rightness, Focusability, ultra-short pulse generation. Peak Power, Average Power, Duty Cycle in Pulsed Lasers.

Module V: TYPES OF LASERS
Solid, Liquid and Gas Lasers. Brief description of Ruby, He-Ne, Nd:YAG, Nd:glass, Er:glass, Er:YAG, Carbon Dioxide Lasers, Nitrogen Lasers, Semiconductor Lasers. X-Ray Lasers, Free-electron Lasers. Fiber Lasers, Femtosecond lasers, Raman Lasers.

Module VI: APPLICATION OF LASERS
General Applications of Lasers including Industry, Defence, Medicine, Entertainment etc.

Examination Scheme:

Components	A	CT	S/V/Q	HA	EE
Weightage (%)	5	10	8	7	70

CT: Class Test, HA: Home Assignment, S/V/Q: Seminar/Viva/Quiz, EE: End Semester Examination; A: Attendance

REFERENCES:

- Laser Principles, Types & Applications: K R Nambiar, New Age International, 2004.
- Lasers: Theory and Applications : A K Ghatak and K Thyagarajan, McMillan, 2003.
- Lecture Notes on “Laser Technology & Applications” (LOE2451) by Prof. (Dr.) Jai Paul Dudeja

LASER SYSTEMS & DEVICES

Course Code: LOE2551 **Credit Units: 3**

Course Objective: This course describes in details the principles, energy level diagrams, block diagrams and operation of various types of laser systems: solid, semiconductor, liquid and gas lasers. These laser systems are further classified according to the pumping schemes employed and systems output characteristics of each laser system are then explained. This course will make the students understand the actual functioning of various laser systems.

Module I: OPTICAL MATERIALS
Optical materials for IR to UV wavelengths

Module II: LASER COMPONENTS
(a) MLD Components: metal coated, multilayer dielectric coated, AR coated, thin film polarizers, narrow-band filters.
(b) Optical Components: Polarizers, beam splitters, beam expanders and collimators, gratings, graticules.
(c) Arc/Flash Lamps: Electrical and spectral characteristics of arc/flash lamps, pulse forming networks for flash lamps.

Module III: LASER POWER SUPPLIES
Simple DC high-voltage power supplies, switch-mode power supply (SMPS), constant current power supply. High-voltage fast switches: spark gaps, SCR, thyratrons, krytrons, saturable magnetic core, avalanche transistors. Pulsed power supplies for lasers: Marx generators for CO_2 lasers, pulsed circuits for nitrogen, copper, excimer and semiconductor lasers,

Module IV: DESIGN OF OPTICALLY-PUMPED LASERS
(a) Optically Pumped Lasers: Ruby, Nd:YAG, Er:glass, Dye lasers, FIR lasers, Raman shifted lasers
(b) Electrical Discharged Lasers: He-Ne, Nitrogen, Various types of CW and Pulsed Carbodioxide lasers, argon-ion, copper and copper compound lasers, Excimer lasers.
(c) Brief Description of Other Lasers: Chemical Lasers, Semiconductor Lasers, Free electron laser, X-ray laser, Fiber Lasers.

Module V: LASER PARAMETRS MEASUREMENTS
Types of detectors (for UV, IR and visible wavelenghths) and their characteristics, Measurement laser average power, peak power, energy, wavelength, frequency, linewidth, pulse duration, pulse repetition rate, beam quality, divergence, beam diameter etc. Choppers, Monocromators, Lock-in Amplifiers, Box-car averagers, Spectroradiometers, Spectrophotometers, spectrum analyzers, wavemeters, densitometers.

Module VI: LASER HAZARDS AND SAFETY MEASURES
Types of hazards, hazards to eyes and skin, Maximum Permissible Exposure (MPE), Classification of lasers, from the point of view of hazards, safety measures, NOHD, buffer zone, laser safety measures.

Examination Scheme:

Components	A	CT	S/V/Q	HA	EE
Weightage (%)	5	10	8	7	70

CT: Class Test, HA: Home Assignment, S/V/Q: Seminar/Viva/Quiz, EE: End Semester Examination; A: Attendance

Text & References:

- Laser Principles, Types and Applications , K R Nambiar, New Age International 2004.
- Laser Fundamentals, William T Sifvast, Cambridge University Press, 2004
- J. Verdeyen, Laser Electronics, Prentice Hall, 1995
- Solid State Laser Engineering, W. Koechner, Springer Series in Optical Sciences, Vo. 1, Springer Verlag

LASERS IN DEFENSE APPLICATIONS

Course Code: LOE2651 **Credit Units: 3**

Course Objective: This course describes various applications of lasers Defence.

Module I: LASER BEAM PROPAGATION THROUGH ATMOSPHERE
Atmospheric absorption and scattering by molecules and aerosols, Atmospheric transmission, Beer's law, atmospheric windows. Absorption of laser radiation by carbon dioxide, ozone and water molecules.Scattering of laser radiation by air molecules, haze particles, fog droplets, cloud droplets and rain drops. Types of atmospheric scattering : Rayleigh, Mie scattering, diffraction theory. Atmospheric attenuation coefficient.Visibility of the atmosphere.Atmospheric turbulence and turbidity.Refractive-index structure coefficient. Nonlinear effects in the atmosphere: thermal blooming, beam bending, kinetic cooling, bleaching, self-induced transparency, Air breakdowm.

Module II: LASER RANGE FINDERS
Solid-state (Nd:glass, Nd:YAG and Er:glass) laser rangefinders (LRFs), Waveguide carbondioxide LRFs, Semiconductor LRFs. Discussion in each about the laser transmitter, receiver, signal processing unit, optical arrangement. Laser range equation, maximum and minimum ranges, range accuracy, range blocking, first echo/last echo logic, field of view, boresighting. Eye safe laser rangefinders.Optoelectronic proximity fuze, Satellite to Submarine Laser Range Finders.

Module III: LASER TARGET DESIGNATORS AND LASER-GUIDED WEAPONS
Laser Guidance, Laser target designators, laser guided missiles, laser guided bomb. Laser beam riding of missiles.Laser & electro-optic surveillance systems.IR guidance.

Module IV: LASER WEAPONS : Laser blinding gun, gas dynamic laser-baser weapon, COIL-based lassr weapon, HF/DF laser based weapon.

Module V: LASER GYROSCOPES & SENSORS: Laser ring gyro, optical fiber gyro, optical sensors (including fiber-optic sensors) in tanks, ships, aircraft etc.

Examination Scheme:

Components	A	CT	S/V/Q	HA	EE
Weightage (%)	5	10	8	7	70

CT: Class Test, HA: Home Assignment, S/V/Q: Seminar/Viva/Quiz, EE: End Semester Examination; A: Attendance

Text& References:

- Laser Principles, Types and Applications , K R Nambiar, New Age International 2004.
- Laser Fundamentals, William T Sifvast, Cambridge University Press, 2004
- J. Verdeyen, Laser Electronics, Prentice Hall, 1995

LASERS IN INDUSTRIAL APPLICATIONS

Course Code: LOE2751 **Credit Units: 3**

Course Objective: To endow the students with knowledge about industrial laser systems and interaction of laser radiation with matter and applications of lasers in various materials processing like cutting, welding, surface treatment etc.

MODULE I INDUSTRIAL LASER SYSTEMS
High power laser systems - Focusing optics - Steering optics - Mechanisms - Overview of industrial lasers - CW &pulsed - Q-switched and Mode locked.

MODULE II THERMAL PROCESSES IN INTERACTION ZONE
Depth of penetration with respect to laser energy density - Reflectivity of Metals with respect to wavelength - Rate of heating and cooling - Maximum temperature rise and depth of hardened layer - Different gases used during laser materials processing - Operational parameters in laser materials processing - Key hole effect.

MODULE III SURFACE TREATMENT
Surface modification:- surface cladding - surface alloying - Hard facing - Shock hardening - laser parameters for surface alloying - process variables - Beam profiles - Different methods to obtain desired penetration depths - Experimental set-up.

MODULE IV LASER WELDING
Different modes of laser beam welding - Comparison between laser beam and electron beam welding - Influence of different parameters - Absorptivity - Welding speed - Focussing conditions - Advantages and limitations of laser welding - Laser welding of industrial materials - Recent developments in laser welding techniques

MODULE V LASER CUTTING AND DRILLING
Laser energy density for cutting and drilling - Melt flashing mechanism - Various assisting gases and their importance - Advantages of laser cutting - Laser instrumentation for cutting and drilling - Factors affecting cutting rates - Effect of laser pulse energy on diameter and depth of drilled hole.

Examination Scheme:

Components	A	CT	S/V/Q	HA	EE
Weightage (%)	5	10	8	7	70

CT: Class Test, HA: Home Assignment, S/V/Q: Seminar/Viva/Quiz, EE: End Semester Examination; A: Attendance

TEXTS & REFERENCES:

- Reddy J.F., 'High Power Laser Applications', Academic Press, 1977.
- Ian W. Boyd, 'Laser Processing of Thin Films and Microstructures', Springer - Verlag, 1987.
- Duley W.W., 'Laser Processing and Analysis of Materials', Plenum Press, New York, 1983.

LASERS IN ATMOSPHERIC STUDIES

Course Code: LOE2851 **Credit Units: 3**

Course Objective:
This course aims to train the students on the basics of applications of lasers and various laser-based techniques to remotely detect and measure the concentration and size etc. of various constituents of the atmosphere including aerosols, pollutants and other toxic agents.

MODULE I: Introduction and Overview of Laser-Based Remote Sensing Techniques
Why Lasers for Remote Sensing of Environment. Aerosols, Pollutants, CBW Agents, Toxicity Levels, Non-Laser based Detection Techniques.

MODULE II: Lidar Techniques

Aerosol Lidar Differential Absorption Lidar (DIAL), Heterodyne Lidar, Micro-Pulse Lidar, LIF-Based Lidar, Raman Lidar, Doppler Lidar, Space Borne Lidar

MODULE III: Laser Sources for Remote Detection
Nd: YAG Laser, Carbondioxide Laser, UV Lasers, Tunable Lasers, Semiconductor Lasers

MODULE IV: Detectors and Telescopes and Data Processing:
Various Types of Detectors and their characteristics for different wavelengths and applications, Telescopes, Data acquisition and processing systems

MODULE V: Laser Based Techniques forStandoff Detection of Explosive Materials
Laser Induced Breakdown Spectroscopy (LIBS). Laser Induced Fluorescence (LIF). Raman Techniques, Hybrid (Integrated) Sensors.

Examination Scheme:

Components	A	MP	EE
Weightage (%)	5	25	70

MP: Mini Project, EE: End Semester Examination; A: Attendance

TEXTS & REFERENCES:
Laser Remote Sensing: Fundamentals and Applications. RM Measures. John Wiley