V SEMESTER B.E.

LASER PHYSICS AND NON-LINEAR OPTICS
(OPEN ELECTIVE))

Subject Code:17PHY561	**CIE Marks:**	**40**
Number of Lecture Hours/Week: 03	**Exam Hours:**	**03**
Total Number of Lecture Hours: 40	**SEE Marks:**	**60**

Credits - 03

Course objectives:
This course will

- Enable the students to understand the mode of working of different types of Laser with relevant theoretical background
- Benefit to identify the applications of laser in various fields
- Support them to learn the fundamentals of optical fiber materials and various fabrication methods
- Aid to recognize the relevance of NLO in Laser technology and learn its fundamentals

MODULE-1	**Teaching hours**	**Revised Bloom's Taxonomy Level**
Theory of Vibrations and Resonance: 1. *Equation for simple harmonic motion, Differential equation for SHM:* Mention definition of SHM, Hooke's law and derive the equation from Hooke's' law, write the solution, mention the expression for time period $T = 2\pi\sqrt{m/K}$ **(1.5hr)** 2. *Free vibrations, natural frequency of vibration*: Qualitative Explanation **(1hr)** 3. *Damped vibration*: Definition, Analytical treatment of Damped vibration, Cases of Over damping, critical damping & Under damping **(1.5hr)** 4. *Forced Vibration:* Definition, Analytical treatment of forced vibrations, discussion on effect of driving frequency when it is higher, lower and equal to natural frequency. condition for resonance, effects of resonance with examples (Tacoma bridge collapse) Sharpness of resonance: **(1.5hr)** 5. *Applications of resonance*: **(1hr)** *i.* Acoustic cavity resonance - Helmoltz volume resonator or any musical instrument, *ii.* Laser cavity resonance- Same as in I/II SEM engg Physics syllabus **6. PROBLEMS on SHM Time period, Free, Damped and Forced oscillations and resonance (1.5hr)**	**8**	L1 L2 L3 L4

MODULE-2	Teaching hours	Revised Bloom's Taxonomy Level
Types of Lasers: (80 min each) 1. *Review of basic principles*: Brief explanation of spontaneous absorption, spontaneous emission and stimulated emission, conditions for laser 2. Discussion of Lasing action through A & B coefficients 3. *Types of Laser*: Mention types of laser like Solid, Liquid and Gas laser, etc. 4. *Construction and working with energy level diagram/chemical reactions of* i. Nd-YAG Laser ii. Liquid Laser- Dye Laser (Rhodamine 6-G) iii. Chemical Laser (HF Laser)and iv. Excimer Laser, 5. Qualitative discussion of Free electron Laser and X-ray Laser 6. *Laser amplifiers:* Block diagram approach (Only qualitatitve) **Problems on Lasing action, Einstein A & B co efficients.**	**8**	L1 L2

MODULE-3	Teaching hours	Revised Bloom's Taxonomy Level
Applications of Lasers: (2hrs each) 1. Defense applications: *i.* *Laser range finder*: What is laser range finder? Brief explanation of its working. Advantages of LRF. Factors affecting range finder (for ex: reflectivity, object size, atmospheric conditions, obliqueness, and vibrations of the object). Where it is used?(Military, forestry, sports etc, just 2-3 lines for each) **with problems on range detection** *ii.* *Laser guided antitank missile*: Brief explanation of Anti-Tank Missile (ATM) and its working. Different types of guiding (brief explanation in 2-3 lines each) a) Command Guidance (wire link guidance) b) Homing Guidance (EM radiation guidance) c) Beam Guidance (illumination of target by radar signals) Mention of India's ATM(like Nag and Amogh) along with specification. Working of LGAM 2. Industrial applications: i. *Data storage*: Mention of previous data storage devices, optical storage/holographic data storage. Explanation of optical storage using low power laser beam. Advantages of optical storage ii. *Laser printing:* Construction and working of laser printer along with either ray diagram or with actual 3-d diagram. Advantages 3. Research and development applications: *i.* *Lithography:* Definition of lithography. Photolithography, Qualitative explanation of Deep UV Lithography using Excimer laser with block diagram.	**8**	L1 L2

ii. Laser cooling: Principle of laser cooling. Working of laser cooling (Doppler cooling) *iii. Laser fusion:* Brief explanation of condition for fusion. Explanation of *Laser Inertial Fusion Energy(LIFE).* Mention of 2 laser fusion devices namely SHIVA and NOVA *iv. Isotope separation:* Definition of Isotopes with examples. Brief explanation of • Atomic vapor laser isotope separation (AVLIS), applied to atoms • Molecular laser isotope separation (MLIS), applied to molecules **4.** Biomedical applications: i. *Eye surgery:* Mention different types of laser eye surgery, LASIK, PRK, LASEK and EpiLASIK. Explain the procedure of laser eye surgery using LASIK. *ii. Endoscopy:* Define endoscopy. Explain the procedure in brief with block diagram *iii. Dentistry:* Qualitative explanation of any 2 applications (like bleaching, cavity treatment, root canal, etc) in dentistry		
MODULE-4	**Teaching hours**	**Revised Bloom's Taxonomy Level**
Optical Communication: (I hr. each) 1. *Review of basic principles of Optical fibers*: TIR, angle of acceptance, NA 2. *Fiber materials*: Requirements of fiber optic materials, mention of plastic and glass materials with examples. Advantages/disadvantages 3. *Fiber fabrication-Vapor-deposition methods*: Explain in detail, Outside vapor deposition, axial deposition 4. Fiber optic cables: Qualitative discussion of different types of cables, cable structures, Indoor cable designs, outdoor cables. Fiber buffering, cable sheath, water barrier and cable core 5. Optical fiber connections, joints and couplers: Factors that lead to loss during fiber connections. Different types of Splices- mention of Fusion splice, V-groove splice, Elastic Tube splice. Mention types of couplers and their description. 6. Attenuation and dispersion in optical fibers: Types of attenuation, Absorption, scattering, & bending, derivation of attenuation coefficient, absorption loss in silica glass, transmission windows in attenuation versus wavelength plot for a standard fiber. Dispersion due to Intra modal delay—Material dispersion, wave modal dispersion, waveguide dispersion. Intermodal dispersion or chromatic dispersion. 7. Industrial, medical and technological applications of optical fiber: Any one industrial application. Anyone laparoscopic application. Point to point application. 8. Fiber optic sensors -Intensity modulated, phase modulated and polarization modulated sensors. **Problems on attenuation and dispersion loss**	**8**	L1 L2 L3

MODULE-5	Teaching hours	Revised Bloom's Taxonomy Level
Nonlinear Optics: 1. Relevance of Nonlinear optics in Laser technology: Definition of NLO, mention of effect of high intensity, coherence etc of LASER on optical properties of the medium **(1Hr)** 2. Descriptions of nonlinear optical processes: Brief explanation of second harmonic generation (SHG), third harmonic generation (THG), sum and different frequency generation, optical parametric amplification (OPA), optical parametric generation (OPG) and optical parametric oscillation (OPO) **(1.5Hr)** 3. Nonlinear susceptibility of a classical anharmonic oscillator: describe briefly nonlinear susceptibility based on simple experiment using Ruby laser, formal definition of the nonlinear susceptibility. Mention the expression $\chi^{(2)} \cong (4\pi\epsilon_0)^3 h^4/m^2 e^5$ and its value for condensed matter, properties of the nonlinear susceptibility. **(1Hr)** 4. time-domain description of optical nonlinearities, Derivation of Kramers–Kronig relations in linear and nonlinear optics. **(1Hr)** 5. The wave equation for nonlinear optical media: mention the equation $\nabla^2\vec{E} - \mu_0\epsilon\frac{\partial^2\vec{E}}{\partial t^2} = \mu_0\frac{\partial^2\overrightarrow{P(N)}}{\partial t^2}$ (No derivation) and explain the terms. coupled-wave equations for sum-frequency generation **(1Hr)** 6. phase matching, quasi-phase-matching, the Manley–Rowe relations, sum-frequency generation, second-harmonic generation, difference-frequency generation and parametric amplification¸ **(1.5Hr)** 7. optical parametric oscillators: Definition of OPO, construction and working, comparison with laser. **(1Hr)**	**8**	L1 L2 L3
Revised Bloom's Taxonomy Level	L1 – Remembering, L2 – Understanding, L3 – Applying. L_4 - Analyze	

Course outcomes:

1. Able to distinguish and analyze different types of vibrations.
2. Proficient to understand fabrication and working of different types of Lasers.
3. Learn the applications of Lasers in various fields.
4. Acquire the knowledge of optical fibers and appreciate its applications in sensor designing.
5. Understand the basics of nonlinear phenomena from the fundamental perspective of quantum mechanics.

Question paper pattern:

Note:- The SEE question paper will be set for 100 marks and the marks will be proportionately reduced to 60.

- The question paper will have ten questions.
- Each full Question consisting of 16 marks. There will be 2 full questions (with a maximum of four sub questions) from each module.
- Each full question will have sub questions covering all the topics under a module.
- The students will have to answer 5 full questions, selecting one full question from each module.

Text Books:

1. *Engineering Physics*, R. K. Gaur and S. L. Gupta, Dhanpath Rai and Sons.
2. *Lasers: Theory and Applications*, K. Thyagarajan and A.K. Ghatak, Springer (1981).
3. *Laser and Fundamentals*, W. T. Silfvast, , Cambridge University Press (2004).
4. *Introduction to optical fiber*, A.K.Ghatak, Cambridge University Press.
5. *Lasers and Nonlinear optics*, B. B. Laud, John Wiley & Sons Inc. (1985).

Reference Books:

1. *Nonlinear optics by* Robert W. Boyd (3rd edition).
2. *Essentials of Nonlinear optics by* Y.G.S. Murthy and C. Vijayan