Syllabus

M.Tech.

(Laser Science & Applications)

Revised w.e.f 01-09-2021

(Session 2021 – 2023)

School of Physics

Devi Ahilya Vishwavidyalaya

Indore

M. Tech (Laser Science & Applications)

Course of Studies

Semester I

LA 701 APPLIED OPTICS	4
LA 703 LASER PHYSICS	4
LA 705 FIBRE OPTICS	4
LA 707 LASER APPLICATIONS -I	4
LA 709 CHOICE BASED-I*(NUMERICAL TECHNIQUES BASED ON C++)	4
LA 711 PRACTICALS-I	6
COMPREHENSIVE VIVA	4

Semester II

LA 702 HIGH VOLTAGE ENGINEERING FOR LASERS	4
LA 704 LASER SYSTEMS	4
LA 706 LASER APPLICATION-II	4
LA 708 CHOICE BASED-II* (QUANTUM OPTICS)	4
LA 710 SEMINAR	2
LA 712 PRACTICALS-II	6
COMPREHENSIVE VIVA	4

Semester III

LA 721 PROJECT (Part I)	11
LA 723 Project presentation	4
COMPREHENSIVE VIVA	4

Semester IV

LA 722 PROJECT (Part II)	11
LA 724 Project presentation	4
COMPREHENSIVE VIVA	4

Total Credits	96

* Choice Based Papers: Student can opt these papers or any other Choice based paper(s) from other M.Tech. offering Schools/ departments/ Institutes of the University)

M.Tech. Syllabus

M. Tech.(Laser Science & Applications)

SEMESTER-I

LA 701 APPLIED OPTICS:

Ray optics and matrix optics.

Polarized light, Jones matrices.

Theory and practical examples of diffraction, interference, reflection and refraction of electromagnetic waves.

Fourier optics, spatial frequency filtering, spatial light modulators, charged coupled devices, speckle interferometry

Wave propagation in anisotropic media, crystal optics, electro-optics and electro-optic devices, acousto-optics, magneto optic effect and acousto-optic devices.

General description of wave propagation of in nonlinear media. Degenerate and nondegenerate four wave mixing phenomena. Nonlinear refraction, Nonlinear absorption, Self focusing and defocusing phenomena and Optical bistability.

REFERENCES:

1. M. Born and E. Wolf, Principles of Optics, Macmillan, New York.
2. Fourier Optics by Joseph Goodman, Tata McGraw Hill, (II Edition).
3. A Yariv and P .Yeh, Optical Waves in crystals (Wiley, New York, 1984).
4. A.K. Ghatak and K. Thyagrajan, Optical Electronics (Cambridge Univ., Cambridge Press, 1989).
5. A. Yariv, Quantum Electronics, 3rd edition , Wiley, New York-1989.
6. R.W. Boyd, Nonlinear Optics, 2nd edition, Academic, San Diego- 2003.
7. Y.R. Shen, Principle of Nonlinear Optics, John Wiley, New-York, 1984.
8. G.P. Agrawal : Nonlinear fibre optics, Academic Press, 1989.

LA 703 LASER PHYSICS:

Properties of laser beams: Intensity, monochromaticity, coherence, directionality, and brightness. Interaction of radiation with matter: Absorption & stimulated emission, line broadening mechanism, transition cross section, absorption & gain coefficient, gain saturation (homogenous and inhomogeneous broadened line). Continuous wave and transient laser behaviour: Rate equations(Four level and three level laser). CW laser behaviour, power in laser oscillator, optimum output coupling, single mode oscillation, reasons for multimode oscillations, spatial hole burning,

spectral hole burning, Lamb dip and active stabilization of laser frequency, Frequency pulling, relaxation oscillations in single mode lasers.

Optical resonator: Matrix formulation of geometrical optics, Fabry Perot interferometer, photon life time and cavity Q, plane parallel resonator, confocal resonator, Gaussian beam propagation and ABCD law, generalized spherical resonators, unstable resonators.

Gain switching and cavity dumping, Q-switching and mode locking.

REFERENCES:

I. K. Shimoda, Introduction to Laser Physics(Springer Verlag, Berlin, 1984)
2. M. Sargent III, M.O.Scully and W.E.Lamb. Jr. Laser Physics, Forth Printing. (Addison Wesley, Reading, 1982).
3. D.C.O.Shea. An Introduction to Lasers and Their Application (Addision -Wesley. Reading, 1978)
4. O.Svelto, Principles of Lasers, (Plenum, New York, 1982).
5. K. Thyagrajan and A.K.Ghatak, Laser: Theory and Applications. (McMillan India. New Delhi, 1984).
6. A.K.Ghatak and K.Thyagrajan, Optical Electronics,(Cambridge Univ. Press, 1989).
7. A.Yariv, Quantum Electronics, 2nd Edition (John Wiley, New York, 1975).
8. I. Marcuse, Principles of Quantum Electronics, (Academic, New York, 1980).
9. Laser Physics by P. W. Miloni, John Wiley and Sons.
10. Laser Fundamentals, W.T. Silfvast (Cambridge University Press 1999).

LA 705 FIBRE OPTICS:

Introduction to the optical fibre, comparison of optical fibre with other interconnectors. Concept of an optical waveguide, rays and modes, principle of light guidance in optical waveguides, fibre types. Electromagnetic analysis of simple optical waveguide: Basic waveguide equation, propagation mode of symmetric step index planar waveguide, TE and TM modes of symmetric step index planar waveguide, mode cut-off condition, mode theory for optical fibre waveguide, scalar wave-equation and modes of fibre, modal analysis for step index fibre, WKB analysis for multi mode fibre, fractional power in the core modal analysis of parabolic index medium.

Transmission characteristics of optical fibers: Attenuation and dispersion, linear and nonlinear scattering losses, fiber bending losses, Intramodal dispersion losses. Dispersion shifted and dispersion modified fibers. Fabrication of fibers. Fiber alignment joint losses, coupling losses, splices and connectors. Beam connectors and expanders, couplers, wavelength division multiplexing couplers. Fiber Bragg grating. Fiber optic network and distribution.

Fiber Optic sensors: Optical fiber sensor systems. Intrinsic and extrinsic fiber optic sensors. Fiber based sensors: Phase modulated, frequency modulated and polarization modulated fiber optic sensors.

REFERENCES:

1. A. H. Cherin: An Introduction to Optical Fibres,(McGraw Hill, 1983).
2. A. Ghatak and K. Thyagrajan, Optical Electronics,[(Cambridge Univ. Press 1989).
3. G. Kaiser: Optical fibre communication (McGraw Hill, Book Company, 1989).
4. D. Marcuse: Theory of Dielectric Optical waveguides, (Academic press New York: 1972).

5. N.S. Kapani: Fibre Optics (Academic Press, New York, 1967).
6. Optical Fiber sensing and signal processing y B. Culshaw, Peter peregrinus Ltd., London (UK),1984.
7. Optical Fiber Communications: Principles and Practice, John M. Senior and M. Yousif Jamr, Prentice Hall, Third edition, 2009.

LA 707 LASER APPLICATION-I :

Laser instrumentation:

Laser in length measurement: Measurement of length; interferometry, surface topology & optical component testing, beam modulation telemetry, laser Doppler velocimetry, surface velocity measurement using speckle patterns, measurements of rate and rotation using laser gyroscope, LIDAR.

Laser Plasma interaction:

Introduction to plasma Physics ,Basic concepts and two-fluid description of plasmas, electromagnetic wave propagation in plasmas, Kinetic theory of plasma ,Landau damping and its application to plasma based Laser accelerator

Holography:

The wavefront reconstruction process: Inline hologram, the off axis hologram, Fourier hologram, the lens less Fourier hologram, image hologram.The reconstructed image: Image of a point, image magnification, orthoscopic and pseudoscopic images, effect of source size and spectral bandwidth. Thin hologram, volume hologram, volume transmission hologram and volume refraction holograms. Materials for recording holograms, holograms for displays, colour holography, holographic optical elements. Holographic interferometry: Real time holographic interferometry, double exposure holographic interferometry.

REFERENCES:

1. R.M. Measures, Laser Remote Sensing: Fundamentals and Applications (John Wiley, New York, 1984).
2. Laser Plasma Interaction by Willian L. Kruer, Addison-Wesley Publishing Company.
3. W.O.N.Giummarres, C.T.Lin and A.Mooradian, eds, Lasers and Applications (Springer - Verlag, Berlin, 1981).
4. H. Moth, The Physics of Laser fusion (Academic, New York, 1979).
5. A K Ghatak and K. Thyagrajan, Optical Electronics, (Cambridge University Press, 1989).
6. A. Yariv, Quantum Electronics, 2nd Ed.(John Wiley, New York, 1975).
7. K. Iizuka, -.-Engineering Optics, Springer series in Optical Sciences Vol.35 (Springer Verlag, Tokyo, 1983).
8. R. J. Collier, Optical holography, (Academic Press, 1971).
9. P. Hariharan, Optical holography, (Cambridge University Press, 1984).
10. Laser Principles and Applications by J.Wilson and Hawkens.
11. Plasma Physics by F.F. Chen (Plenum Press).

LA 709 Choice Based Paper : NUMERICAL TECHNIQUES BASED ON C++:

Introduction to C++ language- Fundamentals, expressions and statements, structures, functions, classes, objects and arrays.

Solving Simultaneous linear equations, algebraic nonlinear equations, least square line fitting, Interpolation techniques, integration and differentiation, and ordinary differential equations.

REFERENCES:

1. Turbo C++ Robert Lafore
2. Numerical Methods for Mathematics, Science and Engineering by J.H. Mathews.
3. Computer Oriented Numerical Methods by V. Rajaraman.

LA 711 PRACTICALS-I

1. Verification of ray transfer matrix
2. Construction and Characterization of Beam expander
3. Determine the coherence length using Michelson's Interferometer
4. Comparison of geometrical and Gaussian optics
5. Measurement of thread angle, pitch, and diameter of a screw.
6. Virtual Experiments with ray trace
7. Determination of Gaussian beam parameters.
8. Experiments on spatial frequency filtering.
9. Understanding role of damping on lasing action.
10. Understanding the role of pumping and cavity parameters for lasing action.
11. Measurement of laser threshold and output power at CW laser operation.
12. Measurement of the relaxation time of upper laser level of Nd3+ : KGd(WO4)2 .

SEMESTER – II

LA 702 HIGH VOLTAGE ENGINEERING FOR LASERS

Power conditioning system (PCS) for lasers: Basics of PCS, components in PCS, L, transfer switches, Basic circuits, details of thyratrons, krypton etc., semiconductor switches, line type pulses, C-C charge transfer, LC inversion circuits, examples for gas lasers, Q-switching circuit, PCS for flash lamps, measurements, EMI & safety aspects. Comparison of linear & SMPS, magnetic materials & HF components, Basic topologies in SMPS, Bridge circuits, PWM and resonant mode control, HF rectification, filtering & control circuits, need for MPC, Saturable inductor circuit, MPC theory, practical design example based on MPC.

Electrical discharge pumping for CW low power lasers: DC Discharge, RF Discharge, Longitudinal Discharge, Transverse Discharge, Segmented Electrodes, Ballast Resistors,

Capacitive Coupling, Inductive Coupling. Electrical discharge pumping for pulsed high power lasers: Townsend Discharge, Modified Paschen Curves, E/P Criterion, Streamer Breakdown. Electron beam pumping for pulsed high power lasers: Electron Beam Generation, Interaction of Electron Beam in Gases. Excitation, Ionization, Attachment and Recombination. High voltage pulse techniques: Nanosecond & Microsecond pulse techniques: Marx generators, tesla transformers, pulse forming Lines, blumleins, sparkgap switches, equivalent circuits & analysis. Microsecond & Millisecond pulse techniques: Capacitor banks, switches, resistive charging, constant current and power chargings, equivalent circuits & analysis. High Voltage Pulse Measurement: Sparkgaps, crest voltmeters. resistive voltage dividers, capacitive voltage dividers, V-dot capacitive sensor, electro-optical techniques using Kerr & Pockel Effect.

High Current Pulse Measurement: Current shunts, rogowskii coils. inductive probes, current transformers, and Magneto-optical techniques.

REFERENCES:

1. Introduction to High Power Pulse Power Technology by S.T. Pai and Qi Zhang, World Scientific.
2. High Voltage Engineering by E. Kuffel and M. Abdullah, Pergamon Press.
3. Dr. P.H. Ron's Notes on Pulse Power Technology.

LA 704 LASER SYSTEMS

Laser pumping requirement and techniques: Optical Pumping and Electrical discharge pumping. Optically and diode pumped solid state lasers: Properties of solid state laser materials, Ruby, Nd:YAG lasers, Er:lasers, Ti: Saphire laser . Dye laser, spectra of organic dyes, requirements for starting oscillation, cavity arrangement. FIR laser: CH3OH laser. Electrical discharge pumped laser: Ar+ ion, N2, He-Ne, CO2, Metal vapour, and excimer lasers. Gas dynamic CO2 lasers Chemical lasers: HF, DF and Free electron lasers

Semi Conductor Lasers: Energy bands in solids, E-K diagram, Density of states in bulk and quantum well structures.

Occupation probability, carrier concentration and Fermi level. Semiconductor materials and their heterostructures. Lattice matched and strained layers in quantum well structures.

Band gap engineering, Heterostructure p-n junction. Fermi level in doped and undoped, biased and unbiased semiconductor junctions.

Interaction of photons with electrons and holes in semiconductors. Optical joint density of states.

Rate of emission and absorption in semiconductors. Amplification by stimulated emission. Absorption spectrum of semiconductors.

Semiconductor laser device structure, output characteristics, single frequency lasers.

Quantum well lasers. Gain in quantum well lasers, multi quantum well lasers, Distributed feedback lasers, Distributed Bragg reflectors. Vertical cavity surface emitting lasers.

REFERENCES:

1. O. Svelto, Principles of lasers (Plenum Press, New York, 1982).
2. Laser Fundamentals, W.T. Silfvast (Cambridge University Press 1999).

3. Solid State Laser Engineering, Walter Koechner
4. M.L. Wolbarshi, Ed. Laser Applications in Medicine & Biology, Vol.1, 2 & 3 (Plenum, New York, 1971,74,77).
5. Laser Material processing by W.M. Steen.
6. Lasers: Principles and Applications by J. Wilson and J.F.B. Hawkes, Printice Hall.
7. Laser Spectroscopy by Demtröder.
8.Y.R. Shen, The principles of Nonlinear Optics (Wiley, New York, 1984).
9.A. Yariv, Quantum Electronics, 2nd edition (Wiley, New York,1975').
10.C. Flytzanis and J.L. Oudar, Nonlinear Optics, Device and Application (Springer. Berlin, 1986).
11.D.C. Hanna, M: Yuratich and D.Cotter. Nonlinear Optics of free atoms and free molecules (Springer- Verlag, Berlin. 1979).
12.Harry: Industrial Lasers and their applications (McGraw Hill, 1974).
13.H. Koebner, Industrial application of Lasers (John Wiley, New York, 1984)
14.Physics of Semiconductor laser Devices, By G.H.P. Thompson (John Wiley & Sons 1980).
15. Bahaa E. A. Saleh, Malvin Carl Teich, Fundamentals of Photonics (John Wiley & Sons, Inc. 1991)

LA 706 Laser Application –II

Laser material processing:

Laser matter interactions, mode of coupling energy from beam to the material. CW and pulsed heating and the resulting effect. Thermal processing of materials with lasers, Drilling, cutting, welding, heat treatment, glazing, alloying, cladding, hardening of surfaces, semiconductor annealing and trimming.

Laser in Medicine & Biology:

Laser light scattering, application in biomedicine. Light transport in tissue. Photochemical, photothermal, photomechanical effects and their therapeutic applications. Optical imaging and diagnosis.

Laser Spectroscopy: High Resolution spectroscopy: Lamb dip or saturation spectroscopy, two photon absorption spectroscopy. Laser induced fluorescence spectroscopy, opto acoustic spectroscopy, photothermal spectroscopy. Time resolved spectroscopy. Raman, SRS, CARS, Multiphoton spectroscopy.

REFERENCES:

1. Solid State Laser Engineering, Walter Koechner
2. M.L. Wolbarshi, Ed. Laser Applications in Medicine & Biology, Vol.1, 2 & 3 (Plenum, New York, 1971,74,77).
3. Laser Material processing by W.M. Steen.
4. Lasers: Principles and Applications by J. Wilson and J.F.B. Hawkes, Printice Hall.
5. Laser Spectroscopy by Demtröder.
6.A. Yariv, Quantum Electronics, 2nd edition (Wiley, New York,1975').
7.Harry: Industrial Lasers and their applications (McGraw Hill, 1974).
8.H. Koebner, Industrial application of Lasers (John Wiley, New York, 1984)

LA 708 Choice Based Paper II: Quantum Optics

Introduction to quantum optics

Quantum mechanics: Formalism of quantum mechanics, The Schrodinger equation, Properties of wave functions, Measurements and expectation values, Angular momentum and Dirac notation.

Quantized states in atoms, Fine and hyperfine structure, The harmonic oscillator, Stern–Gerlach experiment and the band theory of solids.

Radiative transitions in atoms: Einstein coefficients, Radiative transition rates, Selection rules, Width and shape of spectral lines, broadening, Laser oscillation, modes and properties.

Photons: Photon statistics, Photon-counting statistics, Poissonian photon statistics, Classification of light by photon statistics.

Photon antibunching: Introduction, Hanbury Brown–Twiss experiments and classical intensity fluctuations, The second-order correlation function $g(2)(\tau)$, and Photon bunching and antibunching.

Coherent states and squeezed light: Light waves as classical harmonic oscillators, Phasor diagrams and field quadratures, Light as a quantum harmonic oscillator, The vacuum field, Coherent states, Squeezed states, and Detection of squeezed light 139

Photon number states: Operator solution of the harmonic oscillator, The number state representation, Photon number states and Coherent states.

Resonant light–atom interactions: Preliminary concepts, The two-level atom approximation, Coherent superposition states, The density matrix, The time-dependent Schrodinger equation, The weak-field limit: Einstein's B coefficient, and the strong-field limit: Rabi oscillations.

Atoms in cavities: Optical cavities, Atom–cavity coupling, Weak coupling, Free-space spontaneous emission, Spontaneous emission in a single-mode cavity: the Purcell effect,

Strong coupling, and Cavity quantum electrodynamics.

Cold atoms: Introduction to Laser cooling, Basic principles of Doppler cooling, Optical molasses, Sub-Doppler cooling, Magneto-optic atom traps, Experimental techniques for laser cooling, Cooling and trapping of ions, and Bose–Einstein condensation.

REFERENCES:

1.Quantum Mechanics: J. J. Sakurai.
2.Quantum Mechanics: B. H. Bransden and C.J. Joachain.
3.Quantum Electronics, 3rd edition , A. Yariv, Wiley, New York-1989.
4.Nonlinear Optics, 2nd edition, R.W. Boyd, Academic, San Diego- 2003.
5.Principle of Nonlinear Optics, Y.R. Shen, John Wiley, New-York, 1984.
6. Quantum Optics an Introduction, Max Fox, Oxford University Press, 2006.

LA 710 SEMINAR

A seminar on topic of your choice relevant to Laser Science and Applications.

LA 712 PRACTICALS:

1. Determination of numerical aperture of a glass fibre.

2. Determination of fibre attenuation.

3. Measurement by connector/alignment losses.

4. Identification of mode loses.

5. Measurement of threshold current of a semiconductor laser.

6. Measure the mode field intensity of the given single mode fibre.

7. Construct Mac-Zender Interferomer using single mode fiber and use it as a temperature/pressure sensor.