# M. Sc. Applied Physics (Photonics)

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

## Stakeholders:

(i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

## Eligibility for Students:

The candidate should possess Bachelor's degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

**OR**

B. Tech. (Any discipline)

**Organization:** The M. Sc. programme is of four-semester duration. In each of the first three semesters there are six theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

**PEO1:** The M. Sc. in Photonics programme aims at developing skilled human resources in the field of Optics, lasers, Electro-optics and overall Photonics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

**PEO2:** With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

**PEO3:** At the end of the programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national programmes like Make in India.

## PROGRAMME OUTCOMES (POs)

**PO1:** An ability to independently carry out research /investigation and development work to solve practical problems

**PO2:** An ability to write and present a substantial technical report/document

**PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program

**PO4:** Having adaptive thinking and adaptability in relation to environmental context and sustainable development

**PO5:** Having a clear understanding of professional and ethical responsibility

**PO6:** Having a good cognitive load management skill related to project management and finance

## PROGRAMME SPECIFIC OUTCOMES (PSOs)

**On completion of M. Sc. (Photonics) programme, graduates will be able to**

**PSO1:** The M. Sc. in Photonics aims at developing a skilled knowledgeable Human task force in the field of Photonics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing M. Sc. course, the students develop an ability to carry out independent research in the area of optical devices.

**PSO2:** The dissertation work of the M. Sc. students leads to publications in high impact international journals which trains them in technical documentation and report writing.

**PSO3:** The goal of the M. Sc. in Photonics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

# Credit Structure

**SEMESTER I**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AM-606 | Mathematical methods | 3 | 1 | | 4 |
| 2 | AP-501 | Quantum Mechanics | 3 | 1 | | 4 |
| 3 | AP -502 | Introduction to Optics & Photonics | 3 | | 1 | 4 |
| 4 | AP -503 | Introduction to Lasers | 3 | | 1 | 4 |
| 5 | AP - 504 | Semiconductor Photonic Devices | 3 | 1 | | 4 |
| 6 | AP - 505 | Photonics Lab -1 | 0 | | 4 | 2 |
| | | **Total** | **15** | **03** | **06** | **22** |

**SEMESTER II**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP-506 | Electronic devices and circuits | 3 | | 1 | 4 |
| 2 | AP-507 | Solid State Physics | 3 | 1 | | 4 |
| 3 | AP -508 | Computational Photonics | 2 | | 2 | 4 |
| 4 | AP -509 | Nanophotonics | 3 | 1 | | 4 |
| 5 | AP - 510 | Electronics and Photonics Lab | 0 | | 4 | 2 |
| 6 | | Elective 1 | 3 | | | 4 |
| | | **Total** | **14** | **02** | **07** | **21** |

**List of Electives**

1. Laser Applications AP-631
2. Tera Hertz Devices and Applications AP-642
3. Free Space Optical Communication AP-643

**SEMESTER III**

| Sl. No. | Course Code | Course | Contact Hours/week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | EE-624 | Digital System Design using FPGA | 2 | | 2 | 4 |
| 2 | AP-623 | Introduction to Fiber Optics | 3 | | 1 | 4 |
| 3 | AP -511 | Non-linear Optics | 3 | 1 | | 4 |
| 4 | AP -512 | Advanced Photonics Lab | 0 | | 4 | 2 |
| 5 | PGC 601 | PGC 601 Research Methodology and IPR | 3 | 0 | | 2 |
| 6 | | Elective II | 3 | | | 4 |
| | | **Total** | **14** | **01** | **07** | **19** |

Elective: II.

1. NPTEL MOOC course
2. AP 513 Introduction to Programming
3. Fabrication Technology AP 603

**SEMESTER IV**

| Sl. No. | Course Code | Course | Contact Hours /week | | | Credits |
|---|---|---|---|---|---|---|
| | | | L | T | P | |
| 1 | AP-520 | Project Phase | | | 40 | 20 |
| | | **Total** | | | | **20** |

## AM 606 Mathematical Methods

| | |
|---|---|
| **CO-1 :** | Will understand and know the analytical techniques to solve the differential equations of specific nature. Also, students will understand the power series representation of various functions like Bessel / Legendre when the given differential equation is not in the standard form. |
| **CO-2 :** | Students will learn Laplace and Fourier transforms techniques of various functions to Solve ODEs further Will be able apply to model physical phenomenon and then solve. |
| **CO-3 :** | Will be able to find rank of a matrix, able to diagonalize a matrix and give the related interpretation, can find the basis and dimension of a vector space, Image and kernel of a linear transformation. |
| **CO-4 :** | Students will learn what is Haar and Shannon wavelets are, and how they are used to represent and transform to apply them in various applications. |

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | **Differential Equations:** Review of solution methods for first order as well as second and Higher order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. | **9** |
| Unit II | **Applications:** Orthogonal Trajectories, Population Growth and Decay, Newton's Law of Cooling, Free Falling Bodies. Simple Harmonic Motion, Damped Motion, Forced Motion, Other Applications in Electronics and Pendulum Problem | **8** |
| Unit III | **Linear Algebra:** General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity , Eigen values and eigen vectors, Diagonalization, Orthogonal diagonalization and symmetric matrices, Quadratic forms. | **9** |
| Unit IV | **Transform Techniques:** Over View of Laplace Transforms – Inverse Laplace Transforms – Fourier transform: Flourier integral formula – Fourier transform – Inversion theorem for complex Fourier transform – Fourier Sine and Consine transforms – Inversion formulae – Finite Fourier sine and Cosine Transform – Inversion formulae – | **9** |
| Unit V | Application of transform techniqes to solutions of differential equations, integral equations and boundary value problems. Wavelets – The Haar wavelets – A wavelets expansion – Multiresolution analysis with Haar Wavelets – General construction of wavelets and multiresolution analysis - Shannon wavelets. | **9** |

**Texts / References:**


1. Advanced Engineering Mathematics, 10th Ed, 2005, Erwin Kreyszig Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert-Strang, Academic press.
3. Applied Linear Algebra & Matrix Analysis, 2007, Thomas S Shores, Springer.

4. Advanced Engineering Mathematics, Peter V. O'Neil Thomson Brooks /Cole
5. Ordinary Differential Equations by Deo and Raghavendra
6. Fourier analysis with Applications of boundary value problems schaum series.
7. Integral Transforms by Goyal and Gupta.

## AP-501 – Quantum Mechanics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of quantum mechanics Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in quantum mechanics |
| **CO-3 :** | Examine different 1D problems in quantum mechanics |
| **CO-4 :** | Illustrate the implementation to 1 electron atoms |
| **CO-5 :** | Explain Quantum mechanics to Lasers |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I | Historical Origin of Quantum mechanics: Thermal radiation, Plank's postulates, Black body radiation, stationary states, correspondence principle, Bohr Atom, shortcomings of old quantum theory. | **9** |
| Unit II | The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, The uncertainty principle | **6** |
| Unit III | Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well | **9** |
| Unit IV | Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation | **6** |
| Unit V | One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular | **8** |
| Unit VI | Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, Introduction to Quantum Optics, Coherent States | **8** |

**References Textbooks:**

1. Quantum Mechanics, John Powell, Bernd Crasemann, Narosa Publishing House
2. Quantum Mechanics, Leonard Schiff, Mc-Graw Hill Book Company
3. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
4. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
5. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing

**AP-502 –** Introduction to Optics and Photonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of optical electronics |
| **CO-2 :** | Analyze the working principle of ME Theory, EO, MO and AO effects |
| **CO-3 :** | Examine the working mechanism of different types of Optical components, EO, MO and AO effects |
| **CO-4 :** | Illustrate the practical use of Optical components, EO, MO and AO effects |
| **CO-5 :** | Summarize different applications of optical electronics devices |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Fundamentals of Photonics and Optics:** Wave equation, Plane waves, Applications of photonics, Reflection and Refraction of plane waves, Fresnel Equations, Wave propagation in different mediums, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid' | **9** |
| Unit II: | **Polarisation of light and Basic optical components:** Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses. | **10** |
| Unit III | **Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications. | **9** |
| Unit IV | **Acousto-optics:** Strain waves in solids and liquids, the strain-optic tensor; theory of Raman-Nath and Bragg diffraction; small-angle and large-angle Bragg diffraction. Accousto-optic devices: Modulators, deflectors, scanners, interconnections, and acoustooptictunable filters. | **10** |
| Unit V | **Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications. | **6** |
| | | |

**References Textbooks:**


1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
4. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.
5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

**AP-503 –** Introduction to Lasers

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of laser technology |
| **CO-2 :** | Analyze the working principle of lasers |
| **CO-3 :** | Examine the laser radiation beams |
| **CO-4 :** | Illustrate and construct the practical laser systems |
| **CO-5 :** | Summarize different types of laser systems and its working principals |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser | 10 |
| Unit II: | **Lasers Oscillation**: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Pumping techniques. | 10 |
| Unit III | **Laser Resonators and Gaussian Beams**: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality. | 10 |
| Unit IV | **Laser Systems 1:** Solid-state lasers, Gas lasers, | 8 |
| Unit V | **Laser Systems 2:** Fiber laser and amplifiers | 8 |
| | | |

Reference Book:


1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
5. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

**AP-504 –** Semiconductor Photonic Devices

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basics of Optical Physics |
| **CO-2 :** | Interpret all the optical properties and processes in semiconductors and dielectrics |
| **CO-3 :** | Examine the working mechanism of different kinds of LEDs and LASERs |
| **CO-4 :** | Illustrate the implementation of Modulation and Switching Devices |
| **CO-5 :** | Explain different types of photodiodes and photodetectors |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Review of Optical Physics:** Energy Bands of Direct and Indirect Semiconductors, Semiconductor Optoelectronic materials, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Electron-hole pairs | **9** |
| Unit II: | **Light Emitting Diodes:** The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting. | **9** |
| Unit III | **Semiconductor Lasers:** Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. | **9** |
| Unit IV | **Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator. | **9** |
| Unit V | **Photodetectors:** Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Quantum Well IR Detectors, Detectors for long wavelength operation, Wavelength selective detection, Coherent detection. CCDs (EMCCD, ICCD) and Photonic Integrated Circuits. **Photo multiplier tubes (PMT),** Superconducting Nano-wire based detector, | **9** |
| | | |

**References Textbooks:**


1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.
4. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3rd Ed. (2000), Ch.4, 6.

5. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).
6. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
8. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

**AP-505 –** Photonics Laboratory I

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | To understand basic electronics |
| **CO-2 :** | To interprete characteristics of the devices |
| **CO-3 :** | Examine the working of basic electronic components |
| **CO-4 :** | Illustrate working of optical components |
| **CO-5 :** | Explain difference in diode and Laser characteristics |

**Syllabus:**

| **Syllabus Details** | **Hrs** |
|---|---|
| Photonics<br>1. Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.<br>2. Determination of the Electrical and Optical Characteristics of LED and Laser diode.<br>3. Designing of Optical Window, Concave and Convex Lens<br>4. Detection of polarisation states using polarisation components like polarizers, waveplates etc.<br>5. Analysis of various light source spectra using OSA.<br>6. Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.<br>7. Macro and Microbending loss in optical fibers and its application<br>8. Measurement of Photodiode characteristics<br>9. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.<br>10. Optisystem Training Modules | 48 |
| | |

**AP-506 –** Electronic Circuits and Devices

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Basics of semiconductor and Introduction to Diodes:<br><br>The energy band theory of crystals, Intrinsic and Extrinsic semiconductors. P-N Junction diode as a Rectifier, Photo-Diode, Filters using Diode, Clipping & clamping circuits, LED, Zener diode | 8 |
| Unit II | Transistors and Oscillators<br><br>Basics of Transistor, Transistor characteristics and applications, basics of oscillators and multivibrators (IC555 as timer). | 10 |
| Unit III | Field Effect Transistor<br><br>Structure and working of: JFET, I-V characteristics and parameters (Pinch off voltage, trans conductance, drain resistance, amplification factor); MOSFET (construction and application only) Applications: FET as Voltage Variable resistance (VVR), switch, memory cell, DRAM | 10 |
| UNIT IV: | OPAMPS & Multivibrators<br><br>Idea op-amplifier characteristics, Block diagram, Basic Inverting & non inverting amplifier, Basics of oscillator, Basics of Timer IC 555 as astable multivibrator. | 10 |
| UNIT V: | Sequential circuits and Counters<br><br>RS, Clocked RS, JK, Master Slave JK, D Flip flop, Counter-synchronous, asynchronous, up-down counter, modulo-N counter, Decade counter (IC 7490); shift register (IC 7495), ring counter | 8 |

**Reference Books:**


1. Millman's Integrated Electronics - Analog and Digital Circuit and Systems | 2nd Edition
by Jacob Millman, Christos Halkias, Chetan Parikh

2. Electronic Principles | 7th Edition by Albert Malvino , David J. Bates

**AP-507 –** Solid State Physics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand the basic concepts of Solid State Physics |
| **CO-2 :** | Interpret the physical meaning of formulation in Condensed Mateer |
| **CO-3 :** | Examine different Structure related properties |
| **CO-4 :** | Study the Electronic and magnetic properties of solids |
| **CO-5 :** | Develop skills to solve physics problems |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Crystal Structure and Diffraction:** Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by crystals - Ewald sphere construction, Bragg condition in k-space. Geometric structure factor and atomic form factor. Point defects, line defects and dislocations. | 8 |
| Unit II: | **Lattice Dynamics:** Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories , thermal conductivity. | 10 |
| Unit III | **Electronic Band Structure in Crystals**: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect. | 10 |
| Unit IV | **Dielectric and Magnetic Properties of Solids:** Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity. | 10 |
| Unit V | **Magnetism** – Diamagnetism, Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order. | 8 |

**Reference Books:**


1. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).
2. Solid State Physics, A. J. Dekkar (Prentice Hall).
3. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.).

**AP-508 –** Computational Photonics

**Course Objectives:**

| | |
|---|---|
| **CO-1 :** | Understand the simulation methos of photonics devices and fiber Optics |
| **CO-2 :** | Study on mode solution method of photonics devices |
| **CO-3 :** | Study on beam propagation method for Photonics devices |
| **CO-4 :** | Study on FDTD method for photonics band gap |
| **CO-5 :** | Understanding the recent advance in photonics Devices |

**Syllabus:**

| **Units** | **Syllabus Details** | **Hrs** |
|---|---|---|
| Unit I: | Unit-1<br>**Mode Solver Method:** Theory of fully vectorial mode solvers in 2D and 3D structures, low-index polymer waveguides, high-index silicon (SOI) and GaAs/AlGaAs waveguides, buried, etched (rib, ridge), and diffused geometries commonly used in opto-electronics slot waveguides, slanted-wall and graded structures, plasmonic and microwave waveguides, | 9 |
| Unit II: | Unit-2<br>**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters. | 9 |
| Unit III | Unit-3<br>**FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices. | 9 |
| Unit IV | Unit-4<br>**Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation | 9 |
| Unit V | **Nanodesign:** Mask designing for nanofabrication of different device geometry | 9 |
| Unit VI | **Introduction to Finite Element Method** | 3 |

Reference Books:


1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

**AP-509 –** Nanophotonics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarization to the concept of Metamaterials |
| **CO-2** | Illustration of Optical Properties in Metamaterials |
| **CO-3** | Examine Surface Plasmon Resonance |
| **CO-4** | Analyze Photonic Bandgap Crystals in different dimensions |
| **CO-5** | Understanding the Importance of Silicon Photonics and Its Applications |

**Syllabus:**

| **Units Divisions** | **Syllabus Details** | **Hours** |
|---|---|---|
| Unit I | Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties | **9** |
| Unit II: | **Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations | **9** |
| Unit III: | **Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects. | **9** |
| Unit IV | **Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy | **9** |
| Unit V | **Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices, | **12** |

**References Textbooks:**


1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
2. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
3. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
5. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
6. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005

## **AP-510 –** Electronics and Photonics Laboratory II

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understand basic logic circuits |
| **CO-2 :** | Analyze the working of A/D and D/A convertors |
| **CO-3 :** | Illustrate the working Holography |
| **CO-4 :** | Examine the losses in fiber optical communication |
| **CO-5 :** | Interprete the working of fiber lasers |

**Syllabus:**

| **Syllabus Details** | **Hrs** |
|---|---|
| Electronics:<br>1. To study the I-V Characteristics of Diodes (Simple and Zener Diode)<br>2. To study the I-V Characteristics of Transistors in CB, CE, CC modes (NPN and PNP Transistors)<br>3. To study the I-V Characteristics of MOSFETs<br>4. To study the Half, Full, and Bridge rectifier<br>5. To study the Voltage and Current regulation with a fixed load<br>6. To study the Clipping and clamping Circuit<br>7. To study the Characteristics of 741 OPAMPs<br>8. To analyze the inverting and non-inverting amplifier<br>9. To Design Active filters | 20 hrs |
| Photonics:<br>1. Beam Width, Divergence, and $M^2$ measurement of He-Ne/Diode Laser with and without collimation lens.<br>2. Fiber optic link design<br>3. Measurement of attenuation and dispersion in optical fibers<br>4. Fiber to Fiber splicing and splicing loss measurement.<br>5. Setting up of Mach-Zender interferometer<br>6. Design of driver circuit for LED and Laser diode<br>7. Characterization of Erbium Doped Fiber Amplifier<br>8. Holography<br>9. Design of signal conditioning circuits for Photodetectors | 28 hrs |

## **EE-624 – DIGITAL SYSTEM DESIGN USING FPGAs**

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs |

| | |
|---|---|
| **CO-2 :** | Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL |
| **CO-3 :** | In-depth analysis of Faults and testability in digital systems including modelling and detection |
| **CO-4 :** | Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes |
| **CO-5 :** | Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Digital system design techniques:** Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction - Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic. | 12 |
| Unit II: | **IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements – Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis. | 6 |
| Unit III | **Fault modeling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test generation for combinational logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST.. | 6 |
| Unit IV | **Digital system design with real-time I/O interface:** Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx and .doc file - implementation of modulation schemes | 12 |
| Unit V | **Contemporary designs and solutions:** | 10 |

| | | |
|---|---|---|
| | Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design - ChipScope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations. | |

**LIST OF EXPERIMENTS:**

| SL No | NAME OF EXPERIMENTS |
|---|---|
| 01. | The Basic FPGA Design Flow<br>1. To understand use of Xilinx ISE<br>2. To understand Xilinx Synthesis Technology or XST.<br>3. Familiarization of Xilinx Vivado Design Tools. |
| 02. | Familiarization of FPGA Boards<br>1. Xilinx FPGA Boards (Virtex 6,Kintex7)<br>2.Implementation of Full adder, ALU , Memory and FIFO on FPGA |
| 03. | Fault Detection Logic Implementation on FPGA<br>1. Stuck at Fault<br>2.Memory BIST |
| 04. | Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers. |

**REFERENCE TEXT BOOKS:**


1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998
5. Digital Circuits and Logic Design – Samuel C. Lee , PHI
6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
7. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002


## AP-623 – Introduction to Fiber Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Understand the basics concepts of Fiber Optic Communication |
| **CO-2** | Understand all the sub-components of Fiber Optics |
| **CO-3** | Examine the working mechanism of Fiber Optics |
| **CO-4** | Illustrate the practical implementation of Fiber Optic Communication |
| **CO-5** | Summarize different applications of Fiber Optic Communication |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Optical Fibers:** Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, SM and GI Fibers, Fiber Materials, PhC fibers, Fiber fabrication.<br>**Optical Fibers Characteristics:** Fiber Attenuation, Absorption losses, scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in the communication link, Dispersion reduction, and compensation techniques. | **10** |
| Unit II: | **Power Launching and Coupling:** Source to Fiber launching and Launching Schemes for Coupling Improvements. Fiber to Fiber joints, Laser coupling to SM fiber, Fiber splicing, Optical Fiber Connector.<br>**Optical Receivers:** Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance | **9** |
| Unit III | **Fiber Amplifier:** Optical Amplification in rare-earth-doped fibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier | **9** |
| Unit IV | **Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications. | **9** |
| Unit V | **Overview of Optical Fiber Communication:** Lightwave communications, Optical Spectrum Bands, and Visible Units, Network Information rate and WDM concepts. Key Elements of fiber optics system, Standards for Optical fiber communications. | **9** |

**References Textbooks:**


1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998
4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988


## **AP-511 –** Non-linear Optics

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Interpret the concepts of nonlinear process |
| **CO-2 :** | Analyse the optical response of NLO devices |
| **CO-3 :** | Examine the working principle of different NLO devices |

| | |
|---|---|
| **CO-4 :** | Illustrate the application of NLO for ultrashort pulse generation |
| **CO-5 :** | Understand the quantum optics |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Nonlinear optics basics**: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients | **8** |
| Unit II: | **Second order nonlinear effects**: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, Periodically poled materials and their applications in nonlinear optical devices. | **10** |
| Unit III | Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications. Spantaneous Parametric Down Conversion (SPDC) | **8** |
| Unit IV | **Third order non linear effects**: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering. | **10** |
| Unit V | **Ultrafast Optics**: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation. | **8** |
| | **Applications of Nonlinear optics, Raman Amplifiers, Nonlinear fiber optics and devices** | **4** |

## AP-512 – Laboratory -III

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Characterization of Fiber Optics Devices |
| **CO-2 :** | Analyse the optical multiplexing techniques and its device performance |
| **CO-3 :** | Examine the working principle of different electro-optic and magneto-optic effects |
| **CO-4 :** | Illustrate the different beam characterization methods |
| **CO-5 :** | Understand the design of different spectroscopic systems |

**Syllabus:**

| Syllabus Details | Hrs |
|---|---|
| 1. Characterization of Fiber Bragg grating<br>2. Power budget analysis using Optical Time Domain Reflectometer (OTDR) | 48 hrs |

| | | |
|---|---|---|
| 3. | Study of Time Division Multiplexing of digital signals | |
| 4. | Study of a Wavelength Division Multiplexing(WDM) in optical fiber link | |
| 5. | Study of Add/drop multiplexer | |
| 6. | Study of Bit error rate and Eye pattern analysis | |
| 7. | Setting up a Free space Laser Communication experiment link | |
| 8. | Measurement of third order nonlinear optical coefficient using Z-scan | |
| 9. | Study of Faraday effect | |
| 10. | Design of a fiber optic sensor | |
| 11. | Line coding and decoding, voice coding | |
| 12. | Measurement of insertion loss of an isolator, coupler and multiplexer | |
| 13. | Beat length measurement in birefringent fibers. | |
| 14. | Laser Raman Spectroscopy Experiments | |
| 15. | Holography | |
| | **Note: Any 12 experiments are mandatory** | |

## PGC-601 – Research Methodology and IPR

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Understanding the fundamentals of research and its methodology |
| **CO-2 :** | Choose the appropriate research design and develop appropriate 3 hypotheses for a research project |
| **CO-3 :** | Knowledge of manuscript preparation, patents and Intellectual property |
| **CO-4 :** | Technology transfer and application of IPR in various domains |

**Syllabus:**

| Units Divisions | Syllabus Details |
|---|---|
| Unit I: | Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations |
| Unit II: | Effective literature studies approach, analysis Plagiarism, Research ethics, |
| Unit III | Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee |
| Unit IV | Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process ofPatenting and Development: technological research, innovation, patenting, development.International Scenario: International cooperation on Intellectual Property. Procedure forgrants of patents, Patenting under PCT. |
| Unit V | Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications |
| Unit VI | New Developments in IPR: Administration of Patent System. New developmentsin IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs. |

**References Textbooks:**


1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
2. science & engineering students’”
3. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
4. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
5. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
6. Mayall, “Industrial Design”, McGraw Hill, 1992.
7. Niebel, “Product Design”, McGraw Hill, 1974.
8. Asimov, “Introduction to Design”, Prentice Hall, 1962.
9. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”, 2016.
10. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008


**List of Electives**

**Elective Course Content for Semster -II**

### AP-631 – Laser Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Familiarize to a variety of applications on lasers |
| **CO-2** | Interpret how laser-based metrological techniques work |
| **CO-3** | Understand laser spectroscopy applications |
| **CO-4** | Investigate various methods of how a laser can be used for defence applications |
| **CO-5** | Summarize different applications of lasers |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG. | **6** |
| Unit II | **Laser Spectroscopy:** IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers | **12** |
| Unit III | **Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components | **6** |
| Unit IV | **Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles | **9** |
| Unit V | **Defence Applications:** Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications | **12** |

## AP-642 – Terahertz Devices and Applications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of terahertz technology |
| **CO-2** | Analyze the working principle of different types of terahertz signal sources |
| **CO-3** | Examine the working mechanism of different types of terahertz detectors |
| **CO-4** | Illustrate the practical implementation of fabrication of components and circuits for terahertz systems |
| **CO-5** | Summarize different applications of terahertz technologyfor imaging, sensing and communications |

**Syllabus:**

| Units | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Basics of Terahertz Technology:** Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies | **9** |
| Unit II | **Terahertz Sources:** Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources | **9** |
| Unit III | **Terahertz Detectors:** Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and Design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and Design, Terahertz MMICs: Theory and Design, Terahertz detectors based on photonics | **9** |
| Unit IV | **Terahertz Components:** Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and Design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components. | **9** |
| Unit V | **Terahertz Applications:** Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, Space Communication, Cutting-edge terahertz technologies | **9** |

**References Textbooks:**


1. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.
2. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000.
3. K. Sakai, Terahertz Optoelectronics, Springer, 2004.

4. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
5. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

## AP-643 – Free Space Optical Communications

**Course Outcomes:**

| | |
|---|---|
| **CO-1** | Interpret the concepts of Free Space Optical Communication |
| **CO-2** | Understand all the sub-components |
| **CO-3** | Examine the working mechanism of FSOC |
| **CO-4** | Illustrate the practical implementation of FSOC |
| **CO-5** | Summarize different applications of FSOC such as VLC/UWOC |

**Syllabus:**

| Units Divisions | Syllabus Details | Hours |
|---|---|---|
| Unit I: | **Introduction FSOC/OWC,** Basic Link configuration of FSOC, various application areas of FSOC, Indoor Channel modelling, various link configurations, Artificial light interference effects in indoor channel. | **9** |
| Unit II: | **Channel Modelling -Outdoor channel,** Atmospheric channel loss related issues, Atmospheric turbulence effects, Measurement of $C_n^2$, Various atmospheric turbulence models, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds | **9** |
| Unit III | **Modulation Techniques:** Importance of modulation in FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. and error propagation<br>**FSO link Performance under atmospheric turbulence:** performance of FSO link in various modulation formats, comparison across the modulation formats, the turbulence-induced penalty in FSO link, Link budget analysis, Power budget analysis | **11** |
| Unit IV | **Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques. | **9** |
| Unit V | **Laser beam Tracking, pointing & acquisition:** Acquisition and Tracking systems, System description, Acquisition methodology, tracking and pointing control system, RF cross-link system design, link equation Intoduction to Free Space Quantum Optical Communication | **10** |

**References Textbooks:**

1. Arun K. Majumdar, Free-Space Laser Communications Principles and Advances. Springer Publications
2. Hemani Kaushal, Free Space Optical Communication. Springer Publication
3. J. Franz and V.K. Jai, Optical Communication Systems. Narosa Publications

4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

**Elective Course Content for Semster -III**

## AP-603 – Technology and Packaging of MEMS systems

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Students to be able to understand concepts involved in MEMS |
| **CO-2 :** | Students to understand the technologies involved in MEMS fabrication and packaging, their advantages and limitations |
| **CO-3 :** | Students to be able to understand working principles in micro sensors and actuators |
| **CO-4 :** | Students to become capable of conceptualizing the design of a microsystem |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | **Evolution of Microsystems:** Concept & History of Micro systems & MEMS, Benefits of Micro Systems, Comparison between Microsystems & microelectronics, Multidisciplinary nature of microsystems development. | **2** |
| Unit II: | **Scaling Laws in Miniaturization:** Introduction to scaling, geometric scaling, scaling in rigid body dynamics, scaling in electrostatic forces, scaling in electromagnetic Electricity, scaling in fluid mechanics, Scaling in Heat Transfer. | **4** |
| Unit III | **Engineering, Science & Materials for Microsystems**: Atomic structure, Crystal Structures, Bonding in materials, Ionization, Doping in Semiconductors, Diffusion Process, Plasma Physics, Electrochemistry, Silicon as a substrate material for MEMS, Compounds of silicon, Si Piezo resistors, other Piezo electric materials, GaAs, Polymer, Materials used in packaging | **8** |
| Unit IV | **Fabrication of Microsystems**: Photolithography, Ion Implantation, Diffusion, Oxidation, chemical & physical vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching. | **8** |
| Unit V | **Micromachining processes:** Bulk Micromachining**,** Surface Micromachining, The LIGA Process. | **4** |
| Unit VI | **Working principles of microsystems:** Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors.<br>MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer<br>Microfluidics | **8** |
| Unit VII | **Microsystem packaging:** Levels in microsystem packaging, Interfaces in Microsystem packaging, Essential packaging technologies, 3-d Packaging, assembly of Microsystems. Multi User MEMS Program (MUMPs) | **4** |

| Lab Assignments | | Hrs |
|---|---|---|
| Lab 1 | To study the etching process in silicon | 4 |
| Lab 2 | Thin film deposition and analysis | 4 |
| Lab 3 | 3D Printing | 4 |

**References Textbooks:**

1] Tai-Ran Hsu, 'MEMS & Microsystem, Design and Manufacture',McGraw Hill, 2012
2] Physics of Semiconductor Devices by S.M. Sze,Wiley Publications(2006)
3] Mark J Jackson, Micro and Nano-manufacturing , Springer; First Edition, (2006)ISBN
4] Zheng Cui,Micro-nanofabrication: Technologies and Applications, Springer First Edition (2006),ISBN-10:3540289224
5] R. Kassing, P. Petkov,W.Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print) 978-1-4020-4594-3(Online)

## AP-513 – Introduction to programming

**Course Outcomes:**

| | |
|---|---|
| **CO-1 :** | Learn a language, Python, for expressing computations |
| **CO-2 :** | Develop an informal understanding of computational complexity |
| **CO-3 :** | Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem |
| **CO-4 :** | Illustrate the useful set of algorithmic and problem reduction techniques |
| **CO-5 :** | Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data |

**Syllabus:**

| Units | Syllabus Details | Hrs |
|---|---|---|
| Unit I: | Introduction to Python & Simple Numerical Programs<br>Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson | 12 |
| Unit II: | Functions, scoping, and abstraction<br>Functions, Scoping, Using functions to modularize code, Functions as objects, | 6 |
| Unit III | Structured types and mutability<br>Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries | 6 |
| Unit IV | Recursion, global variables, modules and files, classes<br>Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes | 12 |
| Unit V | Object-oriented programming, algorithms, data structures, Plotting<br>Search algorithms, sorting algorithms, Matplotlib | 10 |

**References Textbooks:**

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

**<u>Any MOOC course from NPTEL equivivalent to at least 3 credits or higher</u>**