REVISED LIST OF ELECTIVES AND SYLLABUS
(2018 Admission)

LIST OF ELECTIVES

Sl. No	Course Code	Elective Course
1	20-351-0721	Advanced Quantum Mechanics
2	20-351-0722	Advanced Electromagnetic Theory and Computational Methods
3	20-351-0723	Nanophotonics
4	20-351-0724	Optical Sensor Technology
5	20-351-0821	Quantum Optics
6	20-351-0822	Biophotonics
7	20-351-0823	Optomechanical Engineering
8	20-351-0921	Industrial Photonics
9	20-351-0922	Photonic Bandgap Structures and Metamaterials
10	20-351-0923	Holography and Speckle Metrology
11	20-351-0924	Laser Spectroscopy
12	20-351-0925	Computational Material Science

ELECTIVE COURSES

20-351-0721 ADVANCED QUANTUM MECHANICS

Course Outcomes

After completing this course, the students will be able to:

1. Recall the classical idea of rotation and angular momenta. *(Understand)*
2. Understand rotations and angular momenta in quantum mechanics. *(Understand)*
3. Apply Schrodinger's equation to treat many particle systems. *(Apply)*
4. Analyse the energy levels of electrons by the interaction of charged particles with the magnetic field. *(Analyse)*
5. Apply the idea of quantization to study the quantization of electromagnetic fields and quantum field theory. *(Apply)*
6. Apply Dirac equation to study the intrinsic spin of elementary particles. *(Apply)*

Module 1

Rotations in classical physics. Rotations in quantum mechanics, infinitesimal rotations, finite rotations, properties of rotation operator, Euler rotations, representation of the rotation operator, rotation matrices and the spherical harmonics.
Addition of angular momenta, Clebsch-Gordan coefficients, eigenvalues of J^2 and J_z, calculation of Clebsch-Gordan coefficients. Coupling of orbital and spin angular momenta, spin orbit functions, addition of more than two angular momenta.

Module 2

Many particle systems: Schrodinger equation, interchange symmetry, system of distinguishable non-interacting particles, system of identical particles, exchange degeneracy, symmetrisation postulate, constructing symmetric and anti-symmetric functions, systems of identical non-interacting particles, wave functions of two, three and many particle systems, the Pauli exclusion principle, the exclusion principle and periodic table.

Module 3

Effect of magnetic fields on central potentials: effect of magnetic field on charged particle, the normal Zeeman Effect. Perturbation theory: spin-orbit coupling, anomalous Zeeman effect. Interaction of atoms with radiation: classical treatment of incident radiation, quantization of electromagnetic field, Transition rate for absorption and emission of radiation, transition rates within dipole approximation, electric dipole selection rule, spontaneous emission.

Module 4

Relativistic quantum mechanics - Klein-Gordon equation, plane wave solutions, interpretation of KG equation, Dirac equation, Dirac matrices, plane wave solution, positron theory, spin of Dirac particles. Spin magnetic moment, the spin-orbit energy, introductory ideas in Quantum Field Theory. Necessity of a field view, Klein- Gordon field as harmonic oscillators.

References

1. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, John Wiley & Sons (2001) (Text)
2. Quantum Mechanics, G. Aruldhas, Prentice Hall India (2004) (Text for module 4)
3. An Introduction to Quantum Field Theory, Michael E. Peskin and Daniel V. Schroeder, Westview Press (1995) (Text for field theory part)
4. Quantum mechanics, P. M. Mathews and K. Venketesan, Tata McGraw Hill (2006)
5. Advanced Quantum Mechanics- J. J. Sakurai, Pearson Education (2006)
6. Quantum Mechanics - Thankappan V. K. , New Age International (P)Ltd, 2nd Ed. (2003)
7. Lectures on Quantum Field Theory 2nd Ed., Ashok Das, World Scientific Publishing Company, (2008)

20-351-0722 ADVANCED ELECTROMAGNETIC THEORY AND COMPUTATIONAL METHODS

Course Outcomes

After completing this course, the students will be able to:

1. Recall Maxwell's equations and electromagnetic waves in vacuum *(Remember).*
2. Understand wave propagation in media and dielectric response of materials *(Understand).*
3. Understand retarded potential *(Understand).*
4. Apply the idea of retarded potential to study the field due to time varying configurations *(Apply).*
5. Analyse the field of electromagnetic systems by plotting them using octave software *(Analyze).*
6. Evaluate the field of complex electromagnetic geometries using electromagnetic simulations *(Evaluate).*

Prerequisites: Boundary value problems in electrostatics, Maxwell's equations, Constitutive relations, Electromagnetic boundary conditions, Electromagnetic waves.

Module 1

Frequency dispersion characteristics of dielectrics, conductors and plasma, simple model of dispersion, anomalous dispersion and resonant absorption, low frequency behaviour and conductivity, high frequency behaviour and plasma frequency.
Dielectric function of metals, Drude model, Interband transitions, Bulk plasmons, Surface modes, Localized modes in metallic particles, Excitation of the localized modes.

Module 2

Inhomogeneous electromagnetic wave equation, Retarded potentials and fields of a continuous charge distribution, Lienard-Wiechert potentials and electric and magnetic fields for a moving point charge, Electric dipole radiation, Magnetic dipole radiation, Radiation by an arbitrary source, Radiation pattern and power radiated by a moving point charge, Total power radiated by an accelerated charge:

Larmor formula and its relativistic generalization, Angular distribution of radiation emitted by an accelerated charge, Radiation reaction force.

Module 3

Electromagnetic scattering and antennas: Multipole expansion of potential, field of a dipole in coordinate-free form and plotting it using Octave, Electric field due to a uniformly polarized sphere and plotting it using Octave.

Dyadic Green's functions, Plotting the electric near-field and far-field of a radiating dipole using Green's functions.
Dipole antenna, Fundamental Antenna parameters, Half-wave dipole, Antenna array and diffraction.
Rayleigh and Mie scattering, Mie modes, Mie modes in dielectric particles and their antenna properties.
Antenna modes in metallic particles of simple geometry, Dark and bright modes.

Module 4

Computational methods in electromagnetics: Simple systems and analytical solution: field of a homogeneous sphere placed in a quasi-static electric field. Discrete dipole approximation (DDA), Boundary element method (BEM). Finite difference time domain method (FDTD), finite element method (FEM).

References

1. Classical Electrodynamics, J. D. Jackson, 3rd Ed. Wiley (2009).
2. Principles of Nano-optics, Lukas Novotny and Bert Hecht, Cambridge University Press (2006).
3. Introduction to Electrodynamics, David J. Griffiths, Prentice Hall of India, 4th Ed. (2012).
4. Plasmonics: Fundamentals and Applications, Stefan A. Maier, Springer (2007).
5. Absorption and Scattering of Light by Small Particles, Craig Bohren and Donald Huffman, John Wiley and Sons (1998).
6. Antenna Theory: Analysis and Design, Constantine A. Balanis, 4th Ed. Wiley (2016).
7. Computational Electrodynamics: The Finite-Difference Time-Domain Method, Allen Taflove and Susan C. Hagness, Artech House (1995).
8. David B Davidson - Computational electromagnetics for RF and microwave engineering- Cambridge University Press (2011).
9. Computational Electromagnetics, Thomas Rylander, Par Ingelström, Anders Bondeson,Springer-Verlag New York (2013).
10. Discrete-Dipole Approximation for Scattering Calculations, Bruce T. Draine and Piotr J. Flatau, JOSA A 11, 1491-1499 (1994).
11. The Boundary Element Method for Electromagnetic Problems, C. A. Brebbia, R. Magureanu, Engineering Analysis, 4, 178-185 (1987).

20-351-0723 NANOPHOTONICS

Course Outcomes

After completing this course, the students will be able to:

1. Describe the photon propagation through mediums of different dielectric constants and electron propagation under various interaction potentials. *(Understand)*
2. Express the quantum confinement effects in optical properties of materials *(Understand)*
3. Examine plasmonic effects in metal nanoparticles *(Apply)*
4. Explain various methods for nanostructure fabrication. *(Understand)*
5. Calculate the size of nanoparticles using x-ray technique and electron microscopy *(Analyze).*
6. Describe Photonic crystals *(Understand)*
7. Manipulate nanostructures to enhance secondary radiation *(Apply).*

Module 1

Foundations for nanophotonics; photons and electrons: similarities and differences, Confinement of photons and electrons, Propagation through a classically forbidden zone: Tunneling, Localization under a periodic potential: Bandgap, Cooperative effects for photons and electrons, Nanoscale optical interactions, Nanoscale confinement of electronic interactions, Quantum confinement effects, Nanoscale electronic energy transfer. Near-field interaction and microscopy; Near-field optics, Near-field microscopy, Nanoscale enhancement of optical interactions.

Module 2

Quantum confined materials: Quantum wells, Quantum wires, Quantum dots, Quantum rings, Manifestations of quantum confinement, Optical properties, Quantum confined stark
effect, Dielectric confinement effect.
Nanoplasmonics: optical response of metals, Plasmons, Optical properties of metal nanoparticles, Size dependent absorption and scattering, Coupled nanoparticles, Metal- dielectric core-shell nanoparticles. Local electromagnetic fields in metal nanoparticles,

Metamaterials.
Experiential Learning: simulate energy spectrum of a potential well with infinite and finite walls.

Module 3

Growth Methods for Nanomaterials, MBE, MOCVD, LPE, Laser-Assisted Vapor Deposition (LAVD). Characterization of Nanomaterials, X-Ray diffraction, X-Ray photoelectron spectroscopy (XPS), Transmission electron microscopy (TEM), Scanning electron microscopy (SEM), RHEED, EDS, Scanning probe microscopy (SPM), Scanning tunneling microscopy (STM).
Demonstration: LAVD, calculate particle size from XRD and compare it with the size
estimated by TEM, AFM working.

Module 4

Photonic Crystals: Basics concepts, Bandgap and band structures in two and three dimensional lattices. Periodic structures in nature, Experimental methods of fabrication, Photonic crystal fibers (PCF).
Plasmonic enhancement of secondary radiation; classification of secondary radiations, Enhancement of emission and scattering of light, Local density of states in plasmonic nanostructures, Hot-spots in plasmonic nanostructures, Raman scattering enhancement in metal–dielectric nanostructures, Luminescence enhancement in metal–dielectric nanostructures
Experiential Learning:: Photoluminescence spectra of Eu3+ ions in sol–gel films containing silver nanoparticles.

References

1. Nanophotonics :P N Prasad, Wiley interscience (2003) (Text)
2. Introduction to Nanophotonics, Sergey V Gaponenko, Cambridge University Press,

2010 (Text)
3. Principles of Nanophotonics, M Ohtsu, K Kobayashi, T Kawazoe, T Yatsui and M Nuruse, CRC Press, 2008.
4. Devices, Circuits and Systems: Nanophotonics, P P Yupapin, K Srinuanjan, S Kamoldilok, Pan Stanford Publishing, 2013.

20-351-0724 OPTICAL SENSOR TECHNOLOGY

Course Outcomes

After completing this course, the students will be able to:

1. Compare the principles of measurement used in different sensing schemes. *(Understand)*
2. Examine the application of important interferometric techniques in high precision measurements *(Analyze)*
3. Analyze the features and applications of a variety of optical fiber sensors used for the sensitive measurements of various physical and chemical parameters. *(Analyze)*
4. Construct and study the response of some sensing systems and understand the basic elements required for the realization of sensors for a particular measurand *(Apply)*
5. Examine the role of optical micro-cavities for sensing applications. *(Understand)*
6. Explain some emerging sensors based on photonic crystal fibers and fiber loop ringdown spectroscopy *(Understand)*

Module 1

Introduction to sensors, Active and Passive sensors, Sensor performance parameters, light beam as a sensing tool (optical sensor) - broad classification of optical sensors , photoelectric effect, photoconductivity, photodiode, phototransistor. Simple optical sensors - single and double optic lever; Method of Triangulation; Projected fringe technique; Remote sensing using laser-lidar for atmospheric remote sensing and lidar equation

Module 2

Interferometry for precision measurements, two-beam interferometry- Michelson, Mach Zehnder, Sagnac interferometers and applications, fringe displacement and fringe counting; Homodyne interferometer, heterodyne interferometer, super heterodyne interferometry; Multiple beam interference-Fabry Perot etalon and applications; Electron speckle pattern interferometry; Photoelastic measurements; Moire technique
Experiential Learning: Moire pattern- displacement and ref index (liquid) measurement, radius of curvature, focal length

Module 3

Optical fibre sensors - general features- type of OFS- intrinsic and extrinsic sensors-major classification based on modulation; Transmissive & Reflective FOS and applications; simple optical fibre based sensors for displacement, temperature and pressure measurements

Light transmission in microbend fibres- microbend OFS- measurements with microbend sensors; Evanescent wave (EW) phenomenon – Absorption and fluorescence, Beer lambert law, absorption and complex index, evanescent wave FOS, chemical sensors using EWFOS, evanescent wave fluorescence based sensor; Surface Plasmon resonance based fiber sensor-principle and applications; Fibre Bragg grating and Long period grating sensor

Distributed fiber optic sensing and applications- OTDR and its applications, fully distributed & quasi-distributed systems; FO smart sensing-basic architecture and example

Experiential Learning:

1. *Study the shift in absorption or fluorescence characteristics of dyes/nanoparticles with pH and concentration.*
2. *Evanescent wave optical fiber sensor- U shaped, Tapered etc fabrication and application to refractive index and chemical sensing application*

Module 4

Interferometric FOS basic principles, interferometric configurations- component, and construction of interferometric FOS - Mach-Zehnder, Michelson, Sagnac & fiber gyro-open loop and closed loop biasing scheme, Fabry-Perot configurations – application of interferometric FOS examples-
Optical microcavities, Whispering Gallery Modes in Optical microcavities, Passive and Active WGM microcavities, Polymer optical fiber based WGM microcavities, WGM Microcavities based sensors.

Photonic crystals and photonic crystal fiber sensors, fiber loop ringdown spectroscopy

Experiential Learning:

1. *Michelson, Mach Zehnder fiber optic sensors (using 3 dB couplers)*
2. *Whispering gallery mode sensing using optical microcavities.*

References

1. Optical measurement techniques and applications- P. K. Rastogi. Artech House (1997) (Text)
2. Fibre Optic Sensors principles and applications - B. D. Gupta, NIPA (2006)
3. Optical Sensors: Basics and Applications, Jörg Haus, Wiley-VCH, GmBH (2010)
4. Optical fiber sensors (Volume 4)-Applications,Analysis & Future trends, (Ed.) Brian Culshaw
5. Optical Fibre sensors, components and subsystems Vol. 3- Brain Culshaw and John Dakin, Artech House Inc. (1996)
6. Fundamentals of Fibre Optics in Telecommunications and Sensor Systems- B. P. Pal, Wiley Eastern (1994)
7. Francis T.S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors, Marcel Dekker Inc., New York, 2002
8. Optics - Ajoy Ghatak, Tata Mc Graw Hill, 3rd Ed (2005)
9. Jose Miguel Lopez-Higuera (Ed), Handbook of optical fiber sensing technology, John Wiley and Sons Ltd., 2001
10. Vollmer, Frank, and Y. Deshui. Optical Whispering Gallery Modes for Biosensing. Springer: Berlin, Germany, 2020.
11. Duong Ta, Van, et al. "Whispering gallery mode microlasers and refractive index sensing based on single polymer fiber." Laser & Photonics Reviews 7.1 (2013): 133-139.
12. Fiber Loop Ringdown — a Time-Domain Sensing Technique for Multi-Function Fiber Optic Sensor Platforms: Current Status and Design Perspectives, *Sensors* 2009, *9*, 7595-7621

20-351-0821 QUANTUM OPTICS

Course Outcomes

After completing this course, the students will be able to:

1. Outline the concept of quantized electromagnetic field *(Understand)*
2. Illustrate the concept of coherent states and squeeze states *(Understand)*
3. Explain optical coherence, photon correlation and photon statistics *(Understand)*
4. Summarize the techniques for generation of squeezed light and its applications *(Understand)*
5. Analyse the concepts of hidden variable, entanglement and interferometric measurements *(Analyze)*
6. Discover the interaction between atoms and quantized fields. *(Analyze)*

Prerequisite: Advance level knowledge in Quantum Mechanics (20-351-0721 ADVANCED QUANTUM MECHANICS)

Module 1

Concept of density matrix and its properties: Quantization of EMF, Field quantisation, Fock/Number states, Expansion in number states, Coherent States, Displacement operator, Squeezed States, Squeezing operator, Correlation and characteristic functions.
Coherence properties of EMF: First order optical coherence, Coherent field, Photon correlation measurements, Hanbury Brown-Twiss experiments

Module 2

Photon counting measurements, Classification light by photon statistics, Photon bunching, Photon antibunching, Squeezed light: Generation and application of squeezed light, Resonant light atom interactions, Two level atom approximation, Rabi oscillations

Module 3

EPR argument, experimental studies , Bell's inequalities in quantum optics , nondemolition measurements, quantum coherence, Entanglement and interferometric measurements.

Module 4

Deflection of atoms by light, Kapitza- Dirac effect, Optical Stern-Gerlach experiment, Interaction between Atoms and quantized fields- dressed fields, Jaynes - Cummings model.

References

1. Quantum Optics -D F Walls, G J Milburn Springer Verlag, 2nd edition (2008) (Text).
2. Quantum Optics an Introduction - Mark Fox Oxford University press Press (2004) (Text)
3. Introductory Quantum Optics Christopher Gerry and Peter L knight, Cambridge University [Text]
4. Optical Coherence and quantum optics, Leonard Mandel, Emil Wolf, Cambridge University Press, 2nd Edition (2013)
5. Fundamentals of Quantum Optics- John R Klauder and ECG Sudarshan, Dover publication (2006)
6. Quantum Optics- Werner Vogel, Dirk-Gunnar Welsch, Wiley VCH,3rd edition(2006)

20-351-0822 BIOPHOTONICS

Course Outcomes

After completing this course, the students will be able to:

1. Understand the basic theory and science of interaction of light with cells and tissues, optical imaging techniques, to analyze different optical biosensors and its implications. *(Understand)*
2. Understand material properties of photo sensitizers used for photodynamic therapy.*(Understand)*
3. Examine different tissue engineering strategies using light *(Analyze)*
4. Analyze the role of various optical geometries in bio sensing. *(Analyze)*
5. Understand the basic concepts of optical tweezers and practical implementation *(Understand)*

Module 1

Photobiology; interaction of light with ISPls with ISPls and tissues, Photo-process in Biopolymers-human eve and vision, Photosynthesis; Photo-excitation free space propagation, optical fibre delivery system, articulated arm delivery, hollow tube wave-guides.
Optical coherence Tomography, Fluorescence, resonance energy transfer imaging.

Module 2

Bio-imaging: Transmission microscopy, Kohler illumination, microscopy based on phase contrast, dark-field and differential interference contrast microscopy, Florescence, confocal and multi-photon microscopy, STED microscopy.

Module 3

Optical Biosensors: Fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, Biosensors based on fibre optics, planar waveguides, Flow Cytometry: basis, fluorochromes for flow cytometry, DNA analysis.
Laser activated therapy; Photodynamic therapy, photo-sensitizers for photodynamic therapy, applications of photodynamic therapy, two photon photodynamic therapy. Tissue engineering using light; contouring and restructuring of tissues using laser, laser tissue regeneration, femto-second laser surgery.

Module 4

Laser tweezers and laser scissors: design of Laser tweezers and laser scissors, optical trapping using non Gaussian optical beam, manipulation of single DNA molecules, molecular motors, laser for Genomics and Proteomics, semiconductor Quantum dots for bioimaging, Metallic nano-particles and nano-rods for bio-sensing, Photonics and biomaterials: bacteria as bio-synthesizers for photonics polymers.

References

1. Introduction to biophotonics P.N. Prasad Wiley Interscience (2003) (Text)
2. Biomedical Photonics A handbook T.Vo Dinh (CRC Press) (2002)

20-351-0823 OPTO-MECHANICAL ENGINEERING

Course Outcomes

After completing this course, the students will be able to:

1. Understand the principles and materials required for opto-mechanical systems *(Understand).*
2. Design an optical configuration utilizing basic optical components such as lenses and mirrors *(Apply)*
3. Construct opto-mechanical drawings for different optical components *(Apply)*
4. Design and set up basic opto-mechanical configurations on the optical table *(Apply)*
5. Analyse and investigate basic opto-mechanical tasks such as mechanical deformation and optical stability using commercial software and tools *(Analyse)*
6. Design and accomplish opto-mechanical mounting systems and fixtures *(Apply)*

Module 1

Basic computerized drawing, drawings of optical components and systems, dimensional tolerances and error budgets. Principles of opto mechanical design-structural and kinematic aspects- vibration control. Materials properties and selection criteria.

Module 2

Opto-Mechanical Characteristics of Materials: Materials for opto-mechanical systems - physical, mechanical, thermal properties, dimensional stability, hysteresis, Inhomogeneity and anisotropy, temporal stability, integrated tolerance analysis.

Module 3

Design and Mounting of Small Mirrors and lenses, Surface contact mounting, stress variations with surface radius, preload, material, temperature, cemented and air space doublet, linear, tilt and rotary adjustment mechanisms, kinematic constraints and degrees of freedom, coupling methods, design guide lines.

Module 4

Analysis of the Opto-Mechanical Design Interface, structural analysis using Finite Element principles, modelling, analysis and optimization of simple opto-mechanical mounts, optimum design for minimum stress transfer, Fabrication methods.

References

1. Ahmad, Anees - Handbook of Optomechanical Engineering-CRC Press (2017)
2. Matrices and Tensors for Physicists - A W Joshi, New Age International (1995)
3. Paul Yoder, Daniel Vukobratovich - Opto-Mechanical Systems Design, Volume 1_ Design and Analysis of Opto-Mechanical Assemblies. 1-CRC Press (2015)
4. Keith J. Kasunic - Optomechanical Systems Engineering -Wiley (2015)

20-351-0921 INDUSTRIAL PHOTONICS

Course Outcomes

After completing this course, the students will be able to:

1. Understand about various fiber optic components. *(Understand)*
2. Understand different optical networks. *(Understand)*
3. Examine photonic packet switching, *(Analyze)*
4. Analyze the role of various tools for fiber optic assembly. *(Analyze)*
5. Understand the basic concepts of fiber optic assembly *(Understand)*

Module 1

Optical fiber transmission, fiber components-couplers, isolators, circulators, multiplexers, filters, fiber gratings, optical switches, wavelength converters, optical amplifiers, Transmitters, Receivers-Principle of operation, Performance parameters, Specifications, Applications

Module 2

Optical Node-design concepts, broadcast and select network, wavelength routed network, configurations, logical topologies, advantages, demonstrators, LAMBDANET, STARNET, RAINBOW- AON, MONET, DWDM networks, FTTx (x=home, curb, building, antenna)

Module 3

Control and Management Functions- Configuration, Performance and Fault Management- Access network, architecture, deployment- Photonic Packet switching

Module 4

Fiber Optic Assembly- Reliability requirements, Fiber Optic Standards, Assembly environment-clean rooms, classification- Tools for Fiber optic assembly- strippers, cleavers-Instruments for test purpose-IL Meter, BR Meter, Optical Spectrum Analyzer, Optical power meters, OTDR, Fiber optic Sources-Fiber joints-connectors, splices, Fusion splicers-Fiber polishing-Fiber cable design and structures-Photonic Packaging-Passive and active component packaging

References

1. Optical Networks: A Practical Perspective 3rd Edition, 2010 by R Ramaswamy and Kumar N Sivarajan (Text)
2. WDM Optical Networks Concepts, Design and Algorithms, 2002 – Sivaram Murthy and Mohan Guruswamy
3. Understanding Optical Communications by Harry J.R.Dutton (pdf version available at http://cs5517.userapi.com/u133638729/docs/3745fff272ed/Dutton_HJR_Understanding_Optical_Communications.pdf)
4. Optoelectronic Packaging by Alan R. Mickelson, Nagesh R. Basavanhally, Yung-Cheng Lee
5. Wdm Technologies: Active Optical Components, Volume 1 By Niloy K. Dutta, Masahiko Fujiwara
6. Clean Assembly Practices to Prevent Contamination and Damage to Optics by J.Pryatel, W.H.Gourdin (pdf version available at https://e-reports-ext.llnl.gov/pdf/328839.pdf)

20-351-0922 PHOTONIC BANDGAP STRUCTURES AND METAMATERIALS

Course Outcomes

After completing this course, the students will be able to:

1. Comprehend the basic theory underlying photonic crystals and metamterials *(Understand)*
2. Explain how light can be manipulated using photonic bandgap structures and metamaterials *(Understand)*
3. Design simple photonic crystals based on required performance. *(Analyze)*
4. Illustrate the design considerations for various metamterials *(Apply)*

Pre-requisites: Basic understanding of electromagnetic theory, basics of material science including electrical, magnetic and optical properties of materials

Module 1

Electromagnetism in mixed dielectric media- macroscopic Maxwell's equations-electromagnetism as an Eigenvalue problem-general property of harmonic modes-scaling properties of Maxwell's equations

Discrete translational symmetry- photonic band structures-rotational symmetry and irreducible Brillouin zone-time reversal invariance- Bloch wave propagation velocity

Module 2

1D Photonic crystals- multilayer film- physical origin of photonic band gaps- the size of the band gap-evanescent modes in PBG

Two dimensional Photonic crystals-localization of light by point defects-linear defects and waveguides-surface states- preliminary concepts of 3D PBG structures-crystals with complete PBG-localization at a point defect and linear defect

Experiential Learning: *Simulation of 1-D photonic crystal structures using TMM method*

Module 3

Applications of Photonic crystals-periodic dielectric waveguide-two dimensional model-symmetry and polarization-quality factor of lossy cavities- photonic crystal slabs-rod and hole slabs- designing a mirror-designing a cavity-narrow band filter

Module 4

Optical Metamaterials- optical properties of metal dielectric composites-electric and magnetic metamaterials-negative index metamaterials-nonlinear optics using metamaterials

Experiential Learning: Simulation of transmission properties of certain metamaterials

References

1. Photonic Crystals: Molding the Flow of Light, John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn & Robert D. Meade, Princeton University Press, Second Edition (2008) (Text)

2. Optical Metamaterials Fundamentals and Applications, Wenshan Cai, ,Vladimir Shalaev, Springer New York (2010) ISBN 978-1-4419-1151-3 (Text)
3. Photonic Crystals: The Road from Theory to Practice, Steven G. Johnson, John D Joannopoulos, Springer New York (2002)
4. Tutorials in Metamaterials (Series in Nano-Optics and Nanophotonics), Edited by Mikhail A. Noginov, Viktor A. Podolskiy, CRC Press, 1st Edition (2012) ISBN-13: 978-1420092189

20-351-0923 HOLOGRAPHY AND SPECKLE METROLOGY

Course Outcomes

After completing this course, the students will be able to:

1. Summarize the physical basis of primary phenomena (Interference & Diffraction) for hologram and speckle formation. *(Understand)*
2. Demonstrate the essential requirements to set up different off-axis digital holographic recording schemes and subsequent various numerical reconstruction techniques. *(Understand)*
3. Utilize the concept of holographic Interferometry to perform the precise Interferometric measurements. *(Apply)*
4. Infer the practical uses of holography with detailed descriptions of specific examples such as Holographic diffraction gratings, Holographic filters and Head-up displays. *(Understand)*
5. Examine knowledge about essential theoretical concepts and experimental methods of major speckle metrology techniques such as speckle photography, speckle interferometry and speckle shearing interferometry. *(Analyse)*
6. Explain the origin of Biospeckle phenomenon in biological and non-biological specimens. *(Understand)*
7. Develop biospeckle technique as a feasible nondestructive method to evaluate spatial dynamics of biological specimens such as fruits and vegetables. *(Create)*

Module 1

Theoretical foundation for holography and speckle: preliminaries of wave equations and intensity, two wave interference with different frequency, and different amplitudes, between two plane and collinear waves, Scalar Theory of Diffraction: Kirchhoff Diffraction, Fresnel Diffraction, Fraunhofer Diffraction. Diffraction by Apertures-rectangular and circular.
Experiential Learning: Diffraction: prism/grating, interference: Newton's ring/Michelson interferometer

Module 2

Holography: photography and holography, digital holography - general principles, digital Holographic Recording Process, stability requirements, Reconstruction Methods, classification of holograms, holographic interferometry, holography applications-Holographic diffraction gratings, Holographic filters, Head-up displays and Head-up displays.
Experiential Learning: Recording and reconstruction of Wavefront/Amplitude division digital holograms.

Module 3

Speckle metrology: Introduction, speckle statistics, Speckle photography, electronic speckle correlation interferometry – formation of correlation fringes and its analysis using digital image processing, in-plane and out of plane configuration, Digital speckle photography, speckle shearing interferometry, Digital speckle shearing interferometry, phase evaluation methods, phase shifting-temporal and spatial, phase unwrapping.
Experiential Learning: Electronic speckle pattern Interferometry/Shearography experimental configuration for viewing deflection profile/deformation analysis using mechanical/thermal loading.

Module 4

Dynamic speckle and its applications: Dynamic speckle/Biospeckle, statistics of biospeckle, first order statistics, spatial contrast and temporal contrast, second order statistics, autocorrelation function, Brier's contrast.
Experiential Learning: Laser speckle analysis for biological samples/ specklegram image processing

References

1. Speckle Metrology. In: Laser Measurement Technology. Springer Series in Optical Sciences, vol 188, Donges A., Noll R. Springer, Berlin, Heidelberg (2015).
2. New Directions in Holography and Speckle, H. John Caulfield and Chandra S. Vikram. American Scientific Publishers (2006).
3. Holographic and Speckle Interferometry, Jones, R., and Wykes, C., Cambridge University Press, London 1983.
4. Speckle Metrology, Sirohi, R. S., Marcel Dekker, New York, 1993.
5. Holography Principles and Applications, Raymond K. Kostuk, CRC press,2019

20-351-0924-LASER SPECTROSCOPY

Course Outcomes

After completing this course, the students will be able to:

1. Explain the basic characteristics of a single mode lasers *(Understand)*
2. Understand various applications of lasers in the identification and characterisation of materials available in small quantities *(Understand)*
3. Analyse the various aspects of control and manipulation of laser beams for selected spectroscopic applications *(Analyse)*
4. Identify specific spectroscopic methods for understanding the structure of complex molecular systems *(Apply)*
5. Understand various applications of lasers in chemistry, biology, medicine and research *(Understand)*

Module 1

Experimental Realization of Single-Mode Lasers, Suppression of Transverse Modes, Selection of Single Longitudinal Modes, Mode selection in the case of broad gain profiles and CW dye laser. Intensity and Wavelength Stabilization, Long-term stabilization of the laser wavelength, Wavelength

Tuning of Single-Mode Lasers, Continuous Tuning Techniques, Wavelength Calibration, Linewidths of Single-Mode Lasers.

Module 2

Advantages of Lasers in Spectroscopy, High-Sensitivity Methods of Absorption Spectroscopy, Frequency Modulation, Intra-cavity Laser Absorption Spectroscopy, Cavity Ring-Down Spectroscopy, Fluorescence Excitation Spectroscopy, Photoacoustic Spectroscopy, Optothermal Spectroscopy, Ionization Spectroscopy – photoionization, collision-induced and field ionization, Sensitivity of ionization Spectroscopy

Module 3

Laser magnetic resonance and Stark spectroscopy, Laser-Induced Fluorescence, experimental aspects, applications in Polyatomic Molecules. Nonlinear spectroscopy, Laser Raman spectroscopy-stimulated Raman scattering, Coherent Anti-Stokes Raman Spectroscopy, resonance and surface enhanced Raman scattering.

Module 4

Applications of Laser spectroscopy (qualitative study only)

Applications in Chemistry, Single-Molecule Detection, Laser-Induced Chemical Reactions, Coherent Control of Chemical Reactions, Laser Femtosecond Chemistry, Isotope Separation with Lasers, Applications for environmental research, Atmospheric Measurements with LIDAR, Detection of Water Pollution, Applications in material science, Laser-Induced Breakdown Spectroscopy, Measurements of Flow Velocities in Gases and Liquids, Applications in biology, Energy Transfer in DNA Complexes, Time-Resolved Measurements of Biological Processes, Correlation Spectroscopy of Microbe Movements, Medical applications, Raman Spectroscopy in Medicine, Heterodyne Measurements of Ear Drums, Cancer Diagnostics and Therapy with the HPD Technique, Laser Lithotripsy, Laser-Induced Thermotherapy of Brain Cancer, Foetal Oxygen Monitoring.

References

1. Laser Spectroscopy Vol. 1 Basic Principles, Wolfgang Demtröder, Springer Berlin Heidelberg (2008)
2. Laser Spectroscopy Vol. 2 Experimental Techniques, Wolfgang Demtröder, Springer Berlin Heidelberg (2008)
3. Lasers in Dermatology and Medicine - Dental and Medical Applications, Keyvan Nouri, Springer International Publishing (2018).
4. Lasers in Medicine, Waynant, Ronald W, CRC Press (2001).
5. Laser Spectroscopy and Laser Imaging - An Introduction, Helmut H. Telle, Ángel González Ureña, CRC Press (2018).
6. Introduction to Laser Spectroscopy, Halina Abramczyk, Elsevier Science (2005).

20-351-0925- COMPUTATIONAL MATERIAL SCIENCE

Course Outcomes

After completing this course, the students will be able to:

1. Remember Quantum description of materials *(Understand)*
2. Discuss Hartree Fock and Density Functional theory methods *(Understand)*
3. Extend the DFT knowledge to Molecular dynamics simulations *(Understand)*
4. Practice Energy minimizations techniques and Band structure calculations *(Apply)*
5. Employ DFT calculations to obtain Density of states related properties *(Apply).*
6. Compare DFT results and experimental data *(Analyze).*
7. Formulate DFT calculations to develop materials for industry *(Create)*

Module 1

Quantum description of materials, Born-Oppenheimer approximation, Hartree method, Hartree-Fock method, Configuration interaction, Density functional theory (DFT): Thomas Fermi Model, Hohenberg-Kohn theorem, Kohn-Sham equations, Comparison of DFT with Hartree and Hartree-Fock methods, Local density approximation (LDA), Extension to magnetic systems, Generalized gradient approximations (GGAs)

Module 2

LDA+U methods, Self-interaction correction, GW approximations,
Time-dependent density functional theory, Classical Molecular dynamics: Born-Oppenheimer Molecular dynamics, Car-Parinello molecular dynamics, Hellmann-Feynman theorem, Plane wave expansion method, Orthogonalized plane wave method, pseudopotential method, Calculation of total energy, Ultrasoft pseudopotential and projected augmented wave methods, non-periodic systems and the concept of supercell.

Experiential Learning:

1. Calculate the total energy of a molecule (Urea) and a bulk materials (Si) using pseudopotential and DFT formalism.

2. Create a supercell of 1-D (H2 molecule Chain), 2D (graphene) and 3D (NaCl) material.

Module 3

Energy minimization techniques, Band structure calculations and comparison with ARPES, Fermi surface, density of states, local density of states and projected density of states, charge density, Construction of surfaces, Interfaces and superlattices, surface relaxation and reconstruction.

Experiential Learning:

1. Calculate the DOS and band structure of Bulk Silicon and Graphene and compare the data with ARPES data from literature.

2. Calculate the Magnetic moment of Fe bulk in the FM and AFM ordering.

3. Create the (100),(110),(111) and (211) surface of Bulk Cu (1x1 cell) and relax the geometry using DFT

Module 4

Comparison of DFT structure with X-ray crystallography, DFT-surface reconstruction vs STM, Simple IR and Raman spectra of molecules using DFT, Dielectric functions using DFT, DFT Simulation of: 2D materials, topological insulators, Ferroelectric materials, Spintronic Materials, Battery materials.

Experiential Learning:

1. Calculate the IR and Raman Spectra of H2O molecule

2. Calculate the Voltage of a representative anode material for Li-ion battery (LiFePO4)

References

1. Electronic Structure of Materials, Rajendra Prasad, CRC Press, 1st Edn, 2013 (Text)
2. Materials Modelling using Density Functional Theory, Oxford university press, 1st Edn, 2014 (Text)
3. Electronic structure: Basic theory and practical methods, Richard M Martin, Cambridge University press, 1st Edn, 2004 (Text)
4. Density-Functional Theory of Atoms and Molecules; Robert G. Parr, Weitao Yang, Oxford University Press, 1st Edn (1989).
5. Chemist's Guide to Density Functional Theory; Wolfram Koch, Max C. Holthausen, Wiley-VCH Verlag GmbH, 2nd Edn (2001).
6. Density Functional Theory: A practical introduction, David S Holl and Janice A Steckel, Wiley, 1st Edn (2009)