

# **University of Kerala**

M.Tech Degree Course

**Electronics & Communication**

(Optoelectronics & Optical Communication)

Syllabus

**2015 Admission onwards**

**UNIVERSITY OF KERALA  
DEPARTMENT OF OPTO ELECTRONICS**

**M. TECH IN ELECTRONIC AND COMMUNICATION  
(OPTOELECTRONICS & OPTICAL COMMUNICATION)**

**Objective:** With the advent of lasers and other optical sources and their use in different fields has increased in various regimes such as optical communication, medicine, engineering, defense and industrial applications. Optical communication plays a vital role in today's communication technology. This intellectually challenging subject underpins the core technologies of the 21<sup>st</sup> century, and can route to many different career paths. The programme of M.Tech in Electronics and Communication (Optoelectronics and Optical communication) is well structured in order to meet the demand of both industry and research. The choice of subjects has been done very judiciously so that they suitably fit with the latest trends in engineering and interdisciplinary fields. The course provides students with a strong understanding underlying fiber optics, optical communication, laser technology, design principles and operations of optical networks which helps to pursue research in future. More emphasis is laid on dissertation work, practical's and mini projects to replicate industrial practice and develop skills to maximize employability. The best part of this programme is that it combines the concepts of electronics and optical communication to provide students an overall understanding of technological challenges they may face in engineering in the next generation communication system.

**Eligibility:** At least a second class B.E / B. Tech. or equivalent degree with 55% marks in Electronics / Electrical and Electronics / Electronics and Communication Engineering, Applied Electronics and Instrumentation or M. Sc. Degree in Physics / Applied Physics / Electronic Science or Electronics of the University of Kerala or equivalent.

The curriculum of the course consists of the following components as prescribed in the respective curriculum

***M.Tech in Electronics and Communication (Optoelectronics and Optical communication)***

1. Core courses
2. Elective courses
3. Project work /dissertation
4. Laboratory courses
5. Case studies
6. Seminars
7. Practical training

**Project work / Dissertation**

- Mini projects shall be carried out under the supervision of a qualified teacher in the concerned Department
- The candidate is permitted to work on Project / Dissertation work in an Industry / Research Organization.
- The Project Report / Dissertation report / Drawings prepared according to approved guidelines and duly signed by the supervisor(s) and the Head of the Department.

## COURSE STRUCTURE

### SEMESTER I

| Subject code      | Subjects                                 | L | T | P | C |
|-------------------|--|---|---|---|---|
| OPE 611           | Modern Optics                            | 3 | 1 | 0 | 3 |
| OPE 612           | Digital Communication                    | 3 | 0 | 0 | 3 |
| OPE 613           | Optoelectronic Devices                   | 3 | 0 | 0 | 3 |
| OPE 614           | Fiber Optics Technology                  | 3 | 0 | 0 | 3 |
|                   | Elective I                               | 3 | 0 | 0 | 3 |
|                   | Elective II                              | 3 | 0 | 0 | 3 |
| OPE 615           | Mini Project I (Design and Development)  | 0 | 2 | 3 | 1 |
| OPE 616           | Optoelectronics and Image Processing Lab | 0 | 3 | 4 | 3 |
| <b>Total = 22</b> |  |   |   |   |   |

### SEMESTER II

| Subject code      | Subjects   | L | T | P  | C |
|-------------------|--|---|---|----|---|
| OPE 621           | Fiber Optic Sensors and Applications                             | 3 | 0 | 0  | 3 |
| OPE 622           | Optical Fiber Communication Systems                              | 3 | 1 | 0  | 3 |
|                   | Elective III   | 3 | 0 | 0  | 3 |
|                   | Elective IV  | 3 | 0 | 0  | 3 |
|                   | Elective V   | 3 | 0 | 0  | 3 |
| OPE 623           | Seminar  | 2 | 2 | 0  | 1 |
| OPE 624           | Mini Project II(Design and Development)                          | 0 | 2 | 3  | 2 |
| OPE 625           | Photonic Design, Communication and Digital Signal Processing Lab | 0 | 0 | 12 | 4 |
| <b>Total = 22</b> |  |   |   |    |   |

**SEMESTER III**

| Subject code      | Subjects                                 | L | T | P  | C |
|-------------------|--|---|---|----|---|
| OPE 631           | Research Methodology                     | 0 | 1 | 3  | 3 |
| OPE 632           | Mini Project III(Design and Development) | 0 | 2 | 3  | 2 |
| OPE 633           | Study on Current Advanced Research       | 0 | 6 | 0  | 1 |
| OPE 634           | Dissertation Phase I                     | 0 | 0 | 20 | 6 |
| <b>Total = 12</b> |  |   |   |    |   |

**SEMESTER IV**

| Subject code      | Subjects              | L | T | P  | C  |
|-------------------|-----------------------|---|---|----|----|
| OPE 641           | Dissertation Phase II | 0 | 5 | 25 | 16 |
| <b>Total = 16</b> |                       |   |   |    |    |

**Total number of credits = 72**

**ELECTIVE COURSES**

| <b>Subject code</b> | <b>Subjects</b>                              | <b>L</b> | <b>T</b> | <b>P</b> | <b>C</b> |
|---------------------|--|----------|----------|----------|----------|
| OPE 601             | Lasers                                       | 3        | 0        | 0        | 3        |
| OPE 602             | Optical Signal Processing                    | 3        | 1        | 0        | 3        |
| OPE 603             | Advanced Digital Signal Processing           | 3        | 0        | 0        | 3        |
| OPE 604             | Image Processing                             | 3        | 0        | 0        | 3        |
| OPE 605             | Pattern Recognition                          | 3        | 0        | 0        | 3        |
| OPE 606             | Artificial Neural Networks                   | 3        | 0        | 0        | 3        |
| OPE 607             | Holography & Speckle Interferometry          | 3        | 0        | 0        | 3        |
| OPE 608             | Optical Instrumentation                      | 3        | 0        | 0        | 3        |
| OPE 609             | Laser Remote Sensing                         | 3        | 0        | 0        | 3        |
| OPE 6010            | Non Linear Optics                            | 3        | 0        | 3        | 3        |
| OPE 6011            | Nanophotonics                                | 3        | 0        | 3        | 3        |
| OPE 6012            | Integrated Optics                            | 3        | 0        | 0        | 3        |
| OPE 6013            | Solar Photovoltaics                          | 3        | 0        | 0        | 3        |
| OPE 6014            | Satellite and Mobile Communications          | 3        | 0        | 0        | 3        |
| OPE 6015            | Digital System Design                        | 3        | 0        | 0        | 3        |
| OPE 6016            | Communication Networks and Telecommunication | 3        | 0        | 0        | 3        |
|                     | System Engineering                           |          |          |          |          |
| OPE 6017            | Optical Metrology                            | 3        | 0        | 0        | 3        |
| OPE 6018            | Mathematical physics                         | 3        | 1        | 0        | 3        |
| OPE 6019            | Biophotonics                                 | 3        | 1        | 0        | 3        |
| OPE 6020            | Optical Networks                             | 3        | 1        | 0        | 3        |
| OPE 6021            | Micro Electro Mechanical Systems             | 3        | 1        | 0        | 3        |
| OPE 6022            | Laser Material Processing                    | 3        | 1        | 0        | 3        |
| OPE 6023            | Laser Spectroscopy                           | 3        | 1        | 0        | 3        |

**L- Lecture hours; T- Tutorial hours; P- Practical hours; C- Total credits**

## Core Courses

### OPE 611 Modern Optics

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 3 |

Objective: To introduce the basic phenomena in Optics

#### Module I

Harmonic waves, phase velocity and group velocity. Matrix representation of polarization, Jones vector, Jones matrices, Jones calculus, orthogonal polarization. Reflection and refraction at a plane boundary, Fresnel's equations, Brewster angle, total internal reflection, evanescent wave in total reflection. Ray vectors and ray matrices, lens waveguide, identical-lens waveguide, Rays in lens like media, Gaussian beams in a homogeneous medium, fundamental Gaussian beam in a lens like medium- ABCD law, Gaussian beam focusing as an example . Propagation of light in isotropic dielectric medium, dispersion, Sellmeier's formula, propagation of light in crystals, wave-vector surface, Ray-velocity surface.

#### Module II

Diffraction – Kirchoff integral theorem, Fresnel-Kirchoff formula, Babinet's principle, Fraunhofer and Fresnel diffraction, Fraunhofer diffraction patterns, single slit, rectangular aperture, circular aperture, double slit, multiple slits, Fresnel diffraction patterns, zone plate, Cornu's spirals. Fourier transforms in optics, application to diffraction, apodization, spatial filtering, phase contrast and phase grating, reconstruction of wave front – holography Fourier transforming property of a thin lens Fabry Perot etalon, Optical spectrum analyzer

#### Module III

Coherence- Theory of partial coherence, fringe visibility, temporal coherence, spatial coherence, coherence time and coherence length, intensity interferometry. Nonlinear optics-on the physical origin of nonlinear polarizations, nonlinear optical coefficients, second harmonic generation, phase matching, parametric amplification, phase matching, parametric oscillation, frequency tuning.

#### Text books

1. Fowles G.R., Introduction to Modern Optics, 2<sup>nd</sup> Edition, Holt, Rinehart and Winston,1975.
2. Amnon Yariv, Optical Electronics, Fourth Edition, Holt, Rinehart and Winston,1991.
3. Ghatak A and Thyagarajan K, Optical Electronics, Cambridge University Press, 1993.
4. E.Hecht and A.R.Ganesan, Optics, 4<sup>th</sup> Edition, Pearson, 2011

#### Reference

1. Stark H, (Ed.), Applications of Optical Fourier Transforms, Academic Press, 1982
2. Goodman (Joseph N), Introduction to Fourier optics, McGrawHill, 1996

## **OPE 612: Digital Communication**

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 3 |

Objective: To introduce the basic theory and techniques in digital communication.

### **Module I**

Digital communication system (description of different modules of the block diagram), Complex baseband representation of signals, Gram-Schmidt orthogonalization procedure. M-ary orthogonal signals, bi-orthogonal signals, simplex signal waveforms. Pulse modulation – Sampling process – PAM – Quantization – PCM – Noise in PCM system - TDM – Digital multiplexers – Modifications of PCM – Delta modulation – DPCM – ADPCM – ADM. Baseband pulse Transmission – Matched filter - Error rate due to noise – ISI – Nyquist criterion for distortion less transmission-MATLAB Practices for signal representation, Pulse modulation schemes

### **Module II**

Application of passband transmission – Voice band Modems – Multichannel modulation – Discrete multitone. Synchronization. Spread spectrum communication – Pseudo-noise sequences – Spread Spectrum – Direct sequence spread spectrum with coherent binary phase shift keying – Signal space dimensionality and processing gain – Probability of error – Frequency Hop spread spectrum – Maximum length and Gold codes. Multiple Access Techniques. Statistical characterization of multi path channels. Binary signaling over a Rayleigh fading channel – Diversity techniques. TDMA and CDMA – RAKE receiver. Performance analysis of cellular DS-CDMA, power control, soft handoffs, IS-95A and 3G CDMA system. B3G systems, rate and power adaptation, LTE standard, its air interface. MATLAB practice: TDMA, Spread Spectrum Techniques

### **Module III**

Introduction to Information Theory: Concept of amount of information, units- entropy, marginal, conditional and joint entropies - relation among entropies - mutual information, information rate. Source coding: Instantaneous codes- construction of instantaneous codes - Kraft's inequality, coding efficiency and redundancy, Noiseless coding theorem - construction of basic source codes - Shannon - Fano Algorithm. Channel capacity -redundancy and efficiency of a channel., binary symmetric channel (BSC), Binary erasure channel (BEC)- capacity of band limited Gaussian channels, Shannon- Hartley theorem - bandwidth - SNR trade off -capacity of a channel of infinite bandwidth, Shannon's limit. Quantum Error Correcting Codes, Coding for Cooperative Communication; Network Coding-MATLAB Practice: Channel coding theorems.

**Text Books:**

- 1.Simon Haykin - Communication Systems, 4 thEdn. John-Wiley & Sons, 2001.
- 2.Nielsen, M.A., and Chuang, I.L., Quantum Computation and Quantum Information, Cambridge University Press, 2006
- 3.B. P. Lathi, Modern Digital and Analog Communication Systems, PHI, 1998
- 4.Sesia, S., Toufik, I., Baker, M., LTE – The UMTS Long Term Evolution, John Wiley and Sons, First Edn, 2009.
- 5.Yeung, R.W., Information Theory and Network Coding, Springer, 2008

**References:**

1. Harold Kolimbris: Digital Communication Systems, 1st Edn, Pearson Education, 2000.
2. Marvin K. Simon, Sami M. Hinedi, William C. Lindsey: Digital Communication Techniques, PHI.
3. Couch: Digital and Analog Communication Systems, 6th Edn, Pearson Education, 1997
4. Goldsmith, A., Wireless Communications, Cambridge Univ. Press, First Edn, 2005.

## **OPE 613 Optoelectronic Devices**

L T P C  
3 1 0 3

Objective: To understand the theory, working and applications of various optoelectronic devices

### **Module I**

Optoelectronic materials, Semiconductors, compound semiconductors, III-V and II-VI compounds, ZnO, ITO, GaN, direct and indirect band gap, electronic properties of semiconductors, Fermi level, density of states, life time and mobility of carriers, invariance of Fermi level at equilibrium, diffusion, continuity equation, excess carriers, Quasi-Fermi levels, optical properties, theory of recombination, radiative and non-radiative, absorption edge, photoconductivity, light emitting diodes, LED, device configuration and efficiency, LED structures, light current characteristics and device performance, frequency response and modulation band width. Laser diodes – basic concepts, heterojunction and injection lasers, output characteristics. DBR, DBR and quantum well lasers, multiple quantum well structures, surface emitting lasers.

### **Module II**

Birefringence, uniaxial and biaxial crystals, index ellipsoid, electro-optic effect, electro optic retardation. Phase and amplitude modulators, transverse electro optic modulators and design considerations- high frequency modulation considerations, transit time limitations in lumped modulators, travelling wave modulators. Acousto-optic effect, Raman-Nath and Bragg regime, acousto-optic modulators, magneto optic effects, spatial light modulators.

### **Module III**

Photodetectors, -performance criteria of a photodetector, expressions for quantum efficiency, responsivity, photoconductors and photodiodes, PIN diodes, heterojunction diodes and APDs, characteristics and device performance, high speed measurement photoresistors, CCDs, photomultiplier tube, noises in photodetectors, SNR, noise equivalent power. Solar cell materials and their properties. solar cell research: technology-Silicon, Organic and Perovskite Characterization and analysis: ideal cell under illumination- solar cell parameters, optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal quantum yield measurements – effects of series and parallel resistance and temperature - loss analysis.

### **Text Book**

1. Amnon Yariv, Optical Electronics, Holt Rinehart & Winston, Philadelphia, 1991
2. Bhattacharya P., Semiconductor Optoelectronic Devices, PHI, New Delhi. 1995
3. Ben G. Streetmann & Sanjay Banerjee, Solid State Electronic Devices, 5<sup>th</sup> Edn, 2000.
4. Solar Cells: Operating principles, Technology and System Applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981
5. Thin Film Solar Cell: Fabrication, Characterizations and Applications, Poortmans J and Arkhipov V, John Wiley & Sons, England 2006

**Reference**

1. Ghatak A. and Thyagarajan K., Optical Electronics, Cambridge University Press, New Delhi,1994.
2. Rampal V.V., Photonics Elements and Devices, Wheeler, Allahabad,1992.
3. R. P. Khare, Fiber Optics and Optoelectronics, Oxford University Press, 2004
4. Joachim Piprek, Semiconductor Optoelectronic Devices, Academic Press, 2003
5. Amnon Yariv&Pochi Yeh, Optical Waves in Crystals, Wiley & Sons, 2003
6. Bahaa E. A Saleh&Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, 1991
7. Solar Photovoltaic: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI, New Delhi, 2011.
8. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.

## **OPE 614: Fiber Optics Technology**

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 3 |

Objective: To introduce the principles and technologies of fiber optic technology

### **Module I**

Introduction to optical fibers, total internal reflection, acceptance angle, numerical aperture, fractional refractive index difference, skew rays, classification of fibers: based on refractive index profiles, modes guided applications and materials. Mode theory of fibers different modes in fibers. Dominant mode, derivations for modal equations for SI and GI fibers. Approximate number of guided modes in a fiber (SI and GI fibers). comparison of single mode and multimode fibers for optical communications. Transmission characteristics of optical fibers: attenuation, absorption, scattering losses, bending losses. Phase and group velocities. V-parameter, cut off wavelength, dispersion parameter, bandwidth, rise time and non-linearity coefficient. Impairments in fibers, group velocity dispersion (GVD), wave guide and modal dispersions. Polarization mode dispersion (PMD), birefringence- linear and circular.

### **Module II**

LED and LD modulators. coupling of light sources to fibers-LED and LD (with derivations). Theory and applications of passive optical components: connectors, couplers, splices, directional couplers, gratings-FBGs and AWGs, reflecting stars, optical add/drop multiplexers and SLM. Fiber drawing and fabrication methods- modified chemical vapor deposition (MCVD) and VAD techniques. Active components: optical amplifiers, comparative study of optical amplifiers - SLA, FRA, FBA, EDFA and PDFFA- based on signal gain, pump efficiency, noise figure, insertion loss and bandwidth. Design and characterization of forward pumped EDFA.

### **Module III**

Fiber measurements: attenuation measurement – cut back method. Measurement of dispersion- differential group delay, refractive index profile measurement. Numerical aperture (NA) measurement, diameter measurement, mode field diameter (MFD) measurement, V- parameter, cut off wavelength measurement, splicing and insertion losses-eye diagram analysis. OTDR- working principle and applications. OSA- basic block schematic and applications in measurements. Fibers for specific applications: polarization maintaining fiber (PMF), dispersion shifted and dispersion flattened fibers, doped fibers. photonic band gap effect, photonic crystal fibers- hollow core and solid core, holly fibers.

### **Text Books:**

1. Gerd Keiser. Optical Fiber Communications, McGraw Hill, 2000
2. Maynbav, Optical Fiber Technology, Pearson Education, 2001
3. John M senior, Optical Fiber Communications, PHI, 1992
4. Govind P.Agrawal, “Fiber Optic Communication systems”, John Wiley & Sons Inc, New York,1997.
5. Allen H Cherin, “An Introduction to Optical Fibers”, McGraw Hill Inc., Tokyo, 1995.

**References:**

1. Joseph C Palais, Optical Fiber Communications, Pearson Education.1998
2. Dennis Derikson, Fiber Optic Test and Measurement, Prentice Hall, 1998.
3. David Bailey and Edwin Wright, Practical Fiber Optics, Elsevier 2003
4. Franz and Jain, Optical Fiber Communication systems: Systems and Components, Narosa Publishers, 2004
5. Ajoy Ghatak and K. Thyagarajan. Introduction to Fiber optics: Cambridge University press, 1999.

## **OPE 616 Optoelectronics and Image Processing Lab**

L T P C  
0 3 4 3

Objective: To empower the students with hands-on experience and to provide practical knowledge about Optoelectronic sources, detectors, devices, optical fibers, image processing.

### **List of Experiments**

#### **Section A. Optoelectronics Laboratory**

1. Measurement of beam characteristics of lasers
2. Characteristics of laser diode,
3. Characteristics of photodiodes,
4. Characteristics of phototransistors,
5. Characteristics of opto-coupler
6. Characteristics of LDR and other optoelectronic devices
7. Measurement of losses- attenuation, bending in optical fibers.
8. Measurement of numerical aperture
9. Measurement of power gain using Erbium Doped fiber amplifier
10. Study of dispersion in optical fibers
11. Wave length division multiplexing of signals
12. Characterization of FBG and circulator
13. Analog and digital fiber optic links
14. Time division multiplexing of digital signals
15. WDM fiber optic link
16. Optical amplification in a WDM link
17. Adding and dropping of optical channels in a WDM link
18. Testing and analysis of OTDR
19. Testing and analysis of bit error rate & eye pattern analysis
20. Testing and analysis of power budgeting

#### **Section B. Digital Image Processing lab**

1. Radon transforms
2. Histogram analysis of image
3. Image compression and resizing
4. Edge detection
5. Filtering of images
6. Image encryption and decryption using transforms
7. Image coding using ANN
8. Pattern classification using ANN
9. Loss measurements in image compression

(At least 10 experiments should be provided 5 each from Section A and Section B)

## **OPE 621 Fiber Optic Sensors and Applications**

|   |   |   |   |
|---|---|---|---|
| L | T | P | C |
| 3 | 1 | 0 | 3 |

Objective: To study the use of optical fibers for sensing applications.

### **Module I**

MM and SM fibers for sensing, lasers & LEDs suitable for sensing, PIN & APDs for fiber optic sensing. Principles of electro optic modulators bulk & integrated optic modulators. Optical sensor types, advantages and disadvantages of fiber optic sensors, sensor system performance: basic specifications, sensor functions. Intensity modulated sensors, reflective concept, micro-bend concept, evanescent fiber sensors, polarization modulated sensors. In-fiber Bragg grating based sensors – sensing principles – temperature and strain sensing, integration techniques, cross sensitivity, FBG multiplexing techniques. Long period fiber grating sensors- temperature and strain sensing, refractive index sensing, optical load sensors and optical bend sensors, Signal processing techniques for fiber optic sensor.

### **Module II**

Interferometric sensors, Mach-Zehnder & Michelson interferometric sensors, theory-expression for fringe visibility, Fabry-Perot fiber optic sensor – theory and configurations, optical integration methods and multiplication techniques, applications – temperature, pressure and strain measurements, encoded sensors Sagnac interferometers for rotation sensing Fiber gyroscope sensors – Sagnac effect – open loop biasing scheme – Closed loop signal processing scheme – fundamental limit – performance accuracy and parasitic effects – phase-type bias error – Shupe effect – anti-Shupe winding methods – applications of fiber optic gyroscopes. Faraday effect sensors, magneto-striction sensors, Lorentz force sensors.

### **Module III**

Biomedical sensors, sensors for physical parameters, pressure, temperature, blood flow, humidity and radiation loss, sensors for chemical parameters. pH, oxygen, carbon dioxide, spectral sensors. Distributed fiber optic sensors – intrinsic distributed fiber optic sensor – optical time domain reflectometry based Rayleigh scattering – optical time domain reflectometry based Raman scattering – optical time domain reflectometry based Brillouin scattering – optical frequency domain reflectometry – quasi-distributed fiber optic sensor. An overview on the optical fiber sensors in nuclear power industry, fly-by-light aircraft, oil field services, civil and electrical engineering, industrial and environmental monitoring.

### **Text Books**

1. Francis T.S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors, Marcel Dekker Inc., New York,2002
2. Dakin J and Culshaw B., (Ed), Optical fiber sensors, Vol I,II, III, Artech House, 1998
3. Pal B.P, Fundamentals of fiber optics in telecommunication and sensor systems, Wiley Eastern, 1994

**References**

1. Jose Miguel Lopez-Higuera (Ed), Handbook of optical fiber sensing technology, John Wiley and Sons Ltd., 2001
2. Eric Udd (Ed), Fiber optic sensors: An introduction for engineers and scientists, John Wiley and Sons Ltd., 1991
3. B.D Gupta, Fiber optic sensors: Principles and applications, New India Publishing Agency, New Delhi. , 2006
4. Anna Grazia Mignani and Francesco Baldini, Bio-medical sensors using optical fibers, Report on Progress in Physics Vol 59(1996)1-28.

## **OPE 622 Optical Fiber Communication Systems**

| L | T | P | C |
|---|---|---|---|
| 3 | 1 | 0 | 3 |

Objective: To provide the basic understanding and knowledge about various types of optical communication systems

### **Module I**

Classification of light wave systems, need for fiber based and all-optical systems. Non linear effects in fibers: Kerr effect, SPM, XPM and FWM, SRS,SBS, nonlinear effects in PCF-super continuum generation and its application in DWDM, nonlinear optical switching, modulation instabilities. Soliton based systems: introduction to soliton theory and its applications, free space optical communication systems-applications. Noise in laser diodes relative intensity noise (RIN), phase noise and amplified spontaneous emission (ASE) noise. Effects of laser diode nonlinearity and noise in fiber communications, noises in detection, signal to noise ratio, optical fiber cable construction.

### **Module II**

Optical amplifiers (overview), design and characterization of EDFA, pumping schemes, noise in EDFA – ASE and noise factor. Transmitters - Fiber to source coupling, driving circuits, direct modulation, limitations, external modulation, electro-optic, acousto-optic modulators, dispersion management, pre-compensation and post compensation schemes. Receivers: front end, post detection circuit and data recovery. Quantum limit of performance- noise and jitter, extinction ratio and BER performance. Wavelength division multiplexing, WDM components- add/ drop multiplexers, tunable filters, optical cross connects, system performance parameters, BER, eye diagram, SNR, ASE noise, cross talk, dense wavelength division multiplexing technology – need and requirements- concept of polarization division multiplexing. Photonic systems: system components, basics of optical switching, optical and optoelectronic switching devices, SEEDs, switching architecture, space switching, time switching, wave length switching and ATM switching system.

### **Module III**

Systems: IMDD systems-design of systems with and without repeaters. - Power budget and rise time budget. Coherent Systems: sensitivity of a coherent receiver – ASK, FSK and PSK systems- comparison with IMDD systems. Overview of Digital Transmission Systems, Various Types Higher Order Digital Multiplexing, hierarchy for PDH systems, PDH multiplexer, Frame structure of 2Mb/s, 34 Mb/s & 140 Mb/s, Limitations of PDH, SDH evolution, SDH standards, Merits of SDH, Advanced features of SDH, Principles of SDH, SDH hierarchy, STM1(155 mbps) to STM-64 (10 Gbps), frame representation, SDH Network Elements, Multiplexers, Digital Cross Connect, Regenerators, Network Management System, SDH network topologies, SONET, IP over WDM, Ethernet over fiber, classic SDH to data centric NGSDH, OTN, Passive optical networks, FTTH, GPON and GEAPON

**Text Books:**

1. Gerd Keiser- Optical Fiber Communications- McGraw Hill, 2013
2. Govind P Agrawal, Optical Communications- John Wiley, 2008
3. John. M. Senior, Optical Fiber Communications, PHI, 1992
4. Franz and Jain, Optical Fiber Communication systems: Systems and Components, Narosa Publishers, New Delhi, 2004.

**Reference**

1. Harold Kolimbris- Fiber Optics Communications – Pearson education, 2004
2. Joseph C. Palais, Fiber Optic Communications, Pearson Education, 2001
3. Liu, Principles and applications of optical communication, TMH, 2010

## **OPE 625 Photonic Design, Communication and Digital Signal Processing Lab**

L T P C  
0 0 12 3

Objectives: To provide programming skills in various simulation software like MATLAB, COMSOL MULTIPHYSICS, OPTIGRATING, OPTIFIBER, OPTISYSTEM, OPTSIM, LABVIEW etc. for advanced digital signal processing, communication systems etc.

### **Section A. Digital Communication Lab (using MATLAB and LABVIEW)**

1. Generation of standard waveforms

- (a) Unit Impulse
- (b) Unit Step
- (c) Ramp
- (d) Sine Wave
- (e) Cosine wave
- (f) Square Wave

2. Analog modulation schemes (a) AM (b) FM (c) PM (d) PAM (e) PWM (f) PPM

3. Digital modulation schemes (a) ASK (b) FSK (c) PSK

4. Design and simulation of various PSK systems-BPSK, DPSK, M-Ary PSK

5. Design and simulation of Channel Coding theorems

### **Section B. Digital Signal Processing Lab (using MATLAB)**

1. DFT & IDFT

2. Convolution (with & without 'conv')

3. Scaling & Shifting

4. Digital Butterworth filters

5. Digital Chebyshev filters

6. Digital filters using FIR

### **Section C. Designing of Optical Systems and Optical Fibers**

1. Design and analysis of various FBGs using OPTIGRATING

2. Design and analysis of different types of optical fibers using OPTIFIBER

3. Design and performance analysis of optical communication systems using OPTISYSTEM and OPTSIM

4. Design and performance analysis of various optical networks using OPTISYSTEM and OPTSIM

5. Design and analysis of various types of photonic crystal fibers using COMSOL MultiPhysics

(At least 9 experiments should be provided 3 each from Section A, B and C)

**OPE 615 Mini Project I**

A project relevant to the field of optoelectronics and optical communication.

**OPE 624 Mini Projects II**

A project relevant to the field of optoelectronics and optical communication.

**OPE 631 Mini Projects III**

A project relevant to the field of optoelectronics and optical communication.

For the mini projects (OPE 615, OPE 624, OPE 631) the students have to submit a report, exhibit (if any) and have to make a presentation before the expert committee. Evaluation will be done internally by an expert committee consisting of three members.

**OPE 623 Seminar**

The seminar should be on a topic of current research. Students have to submit a detailed report and they have to make a presentation of 45 minutes-duration before the seminar committee. Evaluation (internally) will be based on the content (40%) presentation skills (25%) relevance of the topic (15%) defending of the work (10%) and active participation of the students (10%).

**OPE 632 Study on Current Advance Research**

Students have to select a technologically important relevant topic for this investigation. They have to submit a detailed report on this investigation at the end of the 3<sup>rd</sup> semester. The evaluation will be done on the basis of the report submitted and the presentation before the expert committee consisting of three members.

**OPE 633 Dissertation first phase**

Each student has to submit a first level of report of the M.Tech project that they are under going at the end of the 3<sup>rd</sup> semester. The evaluation will be done by an expert committee consisting of three members on the basis of the report submitted and presentation made by the student.

**OPE 641 Dissertation final**

At the end of 4<sup>th</sup> semester, each student has to submit a dissertation consisting of the work they have done and findings obtained during their project.

## **OPE 631 Research Methodology**

L T P C  
3 1 0 3

Objectives:

- To formulate a viable research question.
- To distinguish probabilistic from deterministic explanations.
- To analyze the benefits and drawbacks of different methodologies.
- To understand how to prepare and execute a feasible research project.

### **Module I**

Introduction to Research Methodology - objectives and types of research: motivation towards research - research methods vs. methodology. Type of research: descriptive vs. analytical, applied vs. fundamental, quantitative vs. qualitative, and conceptual vs. empirical. Research formulation - defining and formulating the research problem -selecting the problem - necessity of defining the problem - importance of literature review in defining a problem. Literature review: primary and secondary sources - reviews, treatise, monographs, patents. Web as a source: searching the web. Critical literature review - identifying gap areas from literature review - development of working hypothesis.

### **Module II**

Research design and methods: research design - basic principles- need for research design - features of a good design. Important concepts relating to research design: observation and facts, laws and theories, prediction and explanation, induction, deduction. Development of models and research plans: exploration, description, diagnosis, experimentation and sample designs. Data collection and analysis: execution of the research - observation and collection of data - methods of data collection - sampling methods- data processing and analysis strategies - data analysis with statistical packages - hypothesis-testing - generalization and interpretation.

### **Module III**

Reporting and thesis writing - structure and components of scientific reports -types of report - technical reports and thesis - significance - different steps in the preparation, layout, structure and language of typical reports, illustrations and tables, bibliography, referencing and footnotes. Presentation; oral presentation - planning - preparation -practice - making presentation - use of audio-visual aids - importance of effective communication. Application of results of research outcome: environmental impacts –professional ethics - ethical issues - ethical committees. Commercialization of the work - copy right - royalty - intellectual property rights and patent law - trade related aspects of intellectual property rights - reproduction of published material - plagiarism - citation and acknowledgement - reproducibility and accountability, impact factor of journals, paper submission procedures.

**Text books**

1. C.R Kothari, Research Methodology, Sultan Chand & Sons, New Delhi, 1990.
2. Panneerselvam, Research Methodology, Prentice Hall of India, New Delhi, 2012.

**References**

1. J.W Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, New York.
4. Donald Cooper, Business Research Methods, Tata McGraw Hill, New Delhi.
5. Leedy P D, Practical Research: Planning and Design, MacMillan Publishing Co.
6. Day R A, How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
7. Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
8. Sople, Managing Intellectual Property: The Strategic Imperative, Prentice Hall of India, New Delhi, 2012.

## **Elective Courses**

### **OPE 601 Lasers**

L T P C

3 1 0 3

Objective: To study the principle, construction and working of different lasers.

#### **Module I**

Black body radiation, Planck's law, spontaneous and induced transitions, Einstein's coefficients, gain coefficient, gain saturation and hole burning, homogenous and inhomogeneous broadened systems, laser oscillation conditions, population inversion, three and four level systems, rate equations, optimum output coupling. Optical resonators, rectangular cavity- open planar resonators- spherical resonators, modes and mode stability criteria, losses in optical resonators-quality factor, unstable optical resonators.

#### **Module II**

Q-switching, methods of Q-switching- methods, opto-mechanical methods of light- electro optic modulation- Pockels and Kerr modulators- magneto- optic modulators , acousto-optic modulators. Giant pulse lasers, mode locking in homogeneously and inhomogeneously broadened systems, passive and active mode locking beam diagnostics and characterization, thermal lensing effect, far field pattern.

Descriptive and qualitative studies of laser applications in communication, remote sensing and interplanetary missions, laser gyro, laser Doppler aneometry (LDA). Applications of lasers in holography, material processing, pulsed laser ablation. Lasers in mechanical engineering and industry, metrology, defense and security, laser cooling, lasers for fusion, lasers for biology and medicine, satellite communications, LIDAR.

#### **Module III**

Working principle of Ruby laser, dye laser, argon ion laser, tunable solid state lasers. Detailed study of semiconductor lasers Nd: YAG laser- flash lamp pumped and diode pumped lasers, He-Ne laser, CO<sub>2</sub> laser, excimer laser, nitrogen laser, free electron laser, fiber laser. Frequency convertors and parametric oscillators. Laser classification based on pulse width-nano-second, pico-second and femto-second lasers.

#### **Text Books**

1. Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998
2. Yariv A, Optical Electronics, 4<sup>th</sup>Edn, Holt, Rinehart and Winston, 1991
3. Thyagarajan .K & Ghatak A K Lasers, Theory and Applications Macmillan, 1991
4. Orazio Svelto, Principles of Lasers, 4<sup>th</sup>Edn, Plenum Press, 1998

#### **Reference**

1. Koechner (Walter), Solid State Laser Engineering, Springer-Verlag, 1992
2. Bahaa E. A Saleh & Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, 1991
3. Marvin J. Weber, Hand Book of Lasers, CRC Press, 2001
4. Jeff Hecht, The Laser Guide Book, McGraw Hill, 1986

## **OPE 602: Optical Signal Processing**

L T P C  
3 1 0 3

Objective: To provide awareness in Optical signal processing.

### **Module I**

Need for optical signal processing (OSP), fundamentals of OSP. A brief introductory study on digital signal processing (DSP), and mixed signal processing (MSP) and optical signal processing(OSP). Optical clock generation, design of a soliton based optical clock generator. optical bistability, applications-optical gates.

### **Module II**

The Fresnel transform, convolution and impulse response, transform of a slit, Fourier transforms in optics, transforms of aperture functions, inverse Fourier transform, resolution criteria. A basic optical system, imaging and Fourier transform conditions. Cascaded systems, scale of Fourier transform condition, maximum information capacity and optimum packing density. Block schematic of an optical spectrum analyzer (OSA): description of working.

### **Module III**

Ideal photo detector, noise in detection. CCD arrays: fabrication and layout, specifications, challenges faced in fabrication and design of photo detector arrays. Optical computing based on optical polarizations. Encoding and decoding of binary data using polarization states. Design of decoding and encoding systems.

### **Text Books:**

1. Anthony Vander Lugt, Optical Signal Processing, John Wiley & Sons. 2005.
2. Damask and Jay, "Polarization Optics in Telecommunications": Springer, 2005

### **Reference:**

1. D. Casasent, Optical Data Processing-Applications Springer-Verlag, Berlin, 1978
2. P.M. Duffieux, The Fourier Transform and Its Applications to Optics, John Wiley and sons 1983
3. J. Horner, Optical Signal Processing Academic Press 1988

## **OPE 603 Advanced Digital Signal Processing**

L T P C  
3 1 0 3

### **Objectives:**

- To familiarize with basics of 2 dimensional signals, systems and their processing.
- Understand the various steps in multirate processing.
- Get a thorough understanding of design of FIR filters.
- To equip the students to work with adaptive processing techniques.

### **Module I**

Multi-dimensional discrete signals and multi-dimensional systems: frequency domain characterization of multi-dimensional signals and systems, sampling two dimensional signals, processing continuous signals with discrete systems, discrete Fourier analysis of multi-dimensional signals: discrete Fourier series representation of rectangularly periodic sequences, multi-dimensional DFT, definition and properties, calculation of DFT, vector radix FFT, discrete Fourier transforms for general periodically sampled signals, relationship between M dimensional and one dimensional DFTs.

### **Module II**

Multi-rate digital signal processing: sampling the continuous time signal. Basic sampling alteration schemes: time domain representation of down-sampling and up-sampling, frequency domain characterization of down-sampling and up-sampling, decimation and interpolation, identities, cascading, sampling-rate alteration devices, poly-phase decomposition, multi-stage systems.

### **Module III**

Design and implementation of FIR filters: implementation and design using windows and frequency transformation methods. Lth-band FIR digital filters: definitions and properties, poly-phase implementation of FIR Lth-band filters, separable linear-phase Lth-band FIR filters, half-band FIR filters. Adaptive filters: introduction to LMS adaptive FIR filters, basic Wiener theory and LMS algorithm.

### **Text books:**

1. Ljiljana Milic, Multi-rate Filtering for Digital Signal Processing- MATLAB Applications, Information Science Reference, Hershey- New York, 2009
2. P.P. Vaidyanathan, Multi-rate Systems and Filter Banks, Prentice Hall, PTR, 1993.
3. N.J. Fliege, Multi-rate Digital Signal Processing, John Wiley, 1994.

### **Reference**

1. Tamal Bose, Digital Signal and Image Processing, John Wiley publishers.
2. J S Lim, Two dimensional Signal and Image Processing, Prentice Hall
3. R.E. Crochiere, Multirate Digital Signal Processing, Prentice Hall.Inc., 1983.
4. Li Tan & Jean Jiang, Digital Signal Processing, Academic Press, Elsevier Inc., 2013

## **OPE 604: Image Processing**

L T P C

3 1 0 3

### **Objectives**

- Understand the various steps in digital image processing.
- Get a thorough understanding of digital image representation and processing techniques.
- Ability to process the image in spatial and transform domain for better enhancement.

### **Module I**

Introduction to digital image processing. image representation - gray scale and colour images introduction to two dimensional sequences , convolution correlation, separability etc. 2D-Fourier and Z- transform and its properties. 2D DFT and its properties. Convolution of two dimensional sequences, convolutional filtering . Basics of 2D transform coding, 2D DCT, Walsh transform. RGB and HSV color model, contrast, brightness, match-band effect etc., image formation model - perspective projection. Equation (with derivation). Stereoscopic imaging - depth extraction and stereoscopic display. Two dimensional sampling theorem, aliasing and reconstruction with problems.

### **Module II**

Histogram of an image, computation of histogram, image enhancement operations, point operations - histogram equalization , histogram specification, contrast stretching, window slicing, bit extraction, change detection, gray scale reversal etc., median filtering, spatial low pass, high pass and band pass operations. Image Enhancement: spatial domain methods: point processing - intensity transformations, histogram processing, image subtraction, image averaging. Spatial filtering- smoothing filters, sharpening filters, frequency domain methods- low pass filtering, high pass filtering, homo-morphic filtering, generation of spatial masks from frequency domain specifications

### **Module III**

Image restoration, system identification, DTF from degraded image spectrum, noise modeling. Wiener filtering - derivation of filter transfer function - pseudo and inverse psuedo filtering. Image segmentation by thresholding, Optimal threshold selection – interactive thresholding and using two peales of histogram. Image segmentation using region growing, region merging and watershed. Image compression - lossy and non- lossy compression. Introduction to JPEG and JPEG 2000.

### **Text books**

1. Gonzalez and Woods, Digital Image Processing, Pearson Education, 2002.
2. A K Jain, Fundamentals of Digital Image Processing, Pearson education, 2003.
3. J S Lim, Two Dimensional Signal and Image Processing, Prentice Hall

### **References:**

1. W K Pratt, Digital Image Processing, John Wiley, 2004
2. Tamal Bose, Digital Signal and Image Processing, John Wiley publishers.
3. J. R. Parker : Algorithms for Image Processing and Computer Vision, Wiley Computer Publications,1997.
4. M.A. Sid Ahmed : Image Processing , McGraw Hill Publications Inc., 1995.

## **OPE 605: Pattern Recognition**

L T P C  
3 1 0 3

Objective : To provide an idea about pattern recognition.

### **Module I**

Introduction to pattern recognition, pattern recognition methods, pattern recognition system design, statistical pattern recognition – classification, principle, classifier learning, neural networks for pattern classification. Basics of image processing - sampling, 2 dimensional transforms, image enhancement, smoothing, sharpening, edge detection, image segmentation, boundary extraction.

### **Module II**

Introduction to shape analysis, shape representation, irregular shape representation, shape representation in image processing , shape representation by convex hull , SPCH algorithm for convex hull finding, stair-climbing method for simple polygon finding, properties of the simple polygon, Sklansky's algorithm for convex hull finding, convex hull based shape representation, boundary and convex hull, description function, feature extraction and shape classification, measurements, feature extraction, shape classification, examples of shape analysis, fractals, self-similarity, fractal dimension, multi-fractals, fractals based shape representation, boundary and fractal dimension, region and fractal dimension. Introduction to roundness / sharpness analysis, problem of roundness analysis, problem of circle and arc detection, Hough transform, definition of Hough transform, algorithm of Hough transform, circular, Hough transform, algorithms for circular Hough transform curve detection, basic method, directional gradient method, centre method, gradient centre method, radius method, threshold function , sharp corners, examples of roundness/sharpness analysis.

### **Module III**

Introduction to orientation analysis, problem of orientation analysis , development of orientation analysis, directed vein method, directed vein image, orientation of a vein, algorithm, convex hull method, principal component transformation, theory of principal component transformation, orientation by principal component transformation, theory of moments, central moments, orientation by moments, examples of orientation analysis, introduction to arrangement analysis, aggregates, examples of arrangements, extended Hough transform, Hough transform, extension of Hough transform, simplified extended Hough transform, arrangement features, orientation and position, description in Hough space, feature extraction, more arrangements , measurements , more features description and classification of arrangements.

### **Text Books**

- 1.Daisheng Luo, Pattern Recognition and Image Processing, Horwood Publishing, England, 1998
- 2.Milam Sonka, Vaclav HLAVAC, Roger Boyle, Image Processing, Analysis and Machine Vision, 2<sup>nd</sup>Edn, Thomson Learning, 2001

### **References:**

- 1.Jr. Parker, Algorithms for Image Processing and Computer Vision, John Wiley.
- 2.Francis T.S YU and Suganda Jutamulia (Eds), Optical Pattern Recognition, Cambridge University Press, 1998
- 3.Conelius T Leondes (Ed), Image Processing and Pattern Recognition, Academic Press, 1998

## **OPE 606: Artificial Neural Networks**

L T P C

3 1 0 3

Objective : To provide ideas inspired by human brain hybridized to perform learning tasks

### **Module I**

Introduction – uses of neural networks, biological neural networks- neuro physiology, models of a neuron-McCulloch & Pitts model, activation functions- types, multiple input neurons. Learning processes- learning paradigms- supervised and unsupervised learning. single layer perceptrons- architecture-learning rule- perceptron convergence theorem. Performance learning-quadratic functions-performance optimization-steepest descent algorithm, learning rates, Widrow-Hoff learning- ADALINE networks, LMS algorithm, linear separability- the XOR problem, multilayer perceptrons (MLPS) – back propagation algorithm.

### **Module II**

RBF networks- Cover's theorem on separability of patterns, comparison of RBF networks and MLPs. Associative learning- unsupervised Hebb rule, instar and outstar rules. Competitive learning- Winner –take-all networks, learning vector quantizers, counter propagation networks, adaptive resonance theory (ART) - ART1 clustering algorithm, ART1 network architecture.

### **Module III**

Self-organizing maps (SOM), support vector machines: optical hyper-plane for linearly separable and non-separable patterns, design of support vector machines, XOR problem. Principal component analysis (PCA) networks. Hopfield networks – discrete Hopfield networks- energy function- storage capacity of Hopfield networks, optimization using Hopfield networks- travelling salesperson problem, solution of simultaneous linear equations, character retrieval. Boltzmann machines, simulated annealing.

### **Textbooks**

1. Martin T. Hagan, Howard B. Demuth & Mark Beale, Neural Network Design, Vikas Thomson learning.
2. Simon Haykin, Neural Networks, A Comprehensive Foundation, Pearson Education.
3. Mohamad H. Hassoun, Fundamentals of Artificial Neural Networks.

### **References:**

1. Kishan Mehrotra, Chilukuri K. Mohan, Sanjay Ranka: Elements of Artificial Neural Networks, Penram International Publishing (India).
2. James A Freeman, David M. Skapura, Neural Networks, Algorithms, Applications and Programming Techniques, Pearson Education.
3. Bose & Liang, Neural Network Fundamentals, McGraw Hill.

## **OPE 607: Holography and Speckle Interferometry**

L T P C  
3 1 0 3

Objectives: To understand the basic concepts, theory and applications of Holography and Speckle Interferometry

### **Module I**

Optical Holography: basic principle, recording and reconstruction, types of holograms: transmission hologram, reflection hologram, phase holograms, rainbow hologram (qualitative analysis only), experimental techniques, detectors and recording materials, holographic optical elements, holographic scanners, application of holography: pattern recognition, information storage.

### **Module II**

Holographic interferometry : theory of fringe formation and measurement of displacement vector, Holographic nondestructive testing, different techniques: double exposure, real time, time average, sandwich, acoustic, comparative and TV holography, loading methods, holographic contouring/shape measurement, dual wavelength method, dual refractive index method, digital holography, holographic photo-elasticity, optical coherence tomography.

### **Module III**

Speckle metrology: speckle phenomena, statistics of speckle pattern, classification, objective speckle pattern, subjective speckle pattern, speckle techniques: speckle photography, speckle interferometry, speckle shear interferometry, electronic speckle pattern interferometry, theory of fringe formation and measurement of displacement vector, out of plane and in plane measurements, surface roughness measurement, vibration measurement, detection of defects.

### **Text Books:**

1. Vest.C.M., Holographic Interferometry, John Wiley & Sons Inc., 1979
2. Hariharan, Optical Holography, Academic Press, 1983
3. Sirohi R.S., (Ed), Speckle Metrology, Mercel Dekker, 1993
4. Goodman J.W , Speckle Phenomena in Optics, Robert & company 2007

### **Reference:**

1. Robert K Erf, Holographic Non-destructive Testing, Academic Press, 1974
2. Pierre Jacquot& Jean-Marc Fournier (Eds.), Interferometry in Speckle Light: Theory and Applications, Springer-Verlag, 2000
3. J. C. Dainty ed., Laser Speckle and Related Phenomena, Springer-Verlag, 1984.
4. H. J. Caulfield, Handbook of Optical Holography, Academic Press. 1979
5. Graham Saxby, Practical Volume Holography, 3<sup>rd</sup>Edn, Marcal Dekker, 1994
6. Promod K Rastogi (Ed), Digital Speckle Pattern Interferometry and Related Techniques, John Wiley & Sons, 2001
7. Wolfgang Steinchen & Lianxiang Yang, Digital Shearography, Spei Press, 2003
8. Yu.Iostrovsky, Holography and its Application, Mir Publishers, 1977

## **OPE 608: Optical Instrumentation**

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Objectives : To understand the basic concepts, theory and applications of optical instruments.

### **Module I**

Critical angle, linear and angular magnifications, cardinal points, optical aberrations-corrections. Optical materials, optical components, polarizing components. Basics of optical design, ray tracing, fabrication and testing of optical components. Types of optical glass - IR materials - gallium arsenide - optical glass making, IR materials manufacturing- abrasives, polishing compounds - tools and fixtures - spherical and plano tools - optical fabrication. Image intensifiers and night vision devices. Telescopes and microscopes- reflecting and refracting telescopes, eyepieces, microscope-objectives, binocular, stereoscopic, phase contrast, polarizing and atomic force microscopes – Airy's disc, resolving power of a telescope and microscope and brightness.

### **Module II**

Stops and photographic systems-theory of stops – aperture stop – entrance and exit pupils, tele-centric stop and applications, requirements for photographic objectives – eye as an optical instrument, defects of eye and correction methods, space optics, adaptive optics, large space structures. Lens design optimization, opto-medical instruments, optical coherence tomography, infrared instrumentation; holographic camera; IR telescopes; Moire self- imaging and speckle metrology.

### **Module III**

Spectroscopes and interferometers- Fourier transform spectroscopy, gratings and its application in spectroscopes, double beam and multiple beam interferometry – Fabry-Perot interferometer –Michelson and Twyman and Green interferometers – Zygo, MachZehnder, Jamin and Sagnac interferometers – applications –optical spectrum analyzer. Photometry, projection systems and refractometers -different sources for optical experiments – lasers – basic laws of photometry, Abbe and Kohler illuminations – episcopes , epi-dioscope, slide and overhead projectors – computer based projection systems – polarizing instruments. Ellipsometry and applications in material research.

### **Text Books**

1. Fowles G.R., Introduction to Modern Optics, 2nd Edition, Holt, Rienhart and Winston, 1975.
2. Bruce H &Walkar, Optical Engineering Fundamentals, PHI, 2003
3. Warren J. Smith, Modern Optical Engineering: The Design of Optical System, 2nd Edn, Mc Grew Hill, 1990
4. Douglas A. Skoog, F James Holler and Timothy A Nieman, Principles of Instrumental Analysis, 5th Edn, Hartcourt Image Publishers, 1998
5. Donald F. Jacob, Fundamentals of Optical Engineering, Mc Grew Hill, 1943

***M.Tech in Electronics and Communication (Optoelectronics and Optical communication)***

6. Hank H. Karow, Fabrication Methods for Precision Optics, John Wiley and Sons, New York, 1993.
7. David Malacara, Optical Shop Testing, John Wiley and Sons, New York, 1992.

**References**

1. Rudolf Kingslake, Applied Optics and Optical Engineering, Vol: I-V, Academic Press, 1985
2. Daniel Malacara & Zacaria Malacara, Handbook of Optical Design, Marcel Dekker, 2004
3. Albert T Helfrack & William D Cooper, Modern Electronic Instrumentation and Measurement Techniques PHI, 1990
4. K. Lizuka, Engineering Optics, Springer-Verlag, 1983

## **OPE 609: Laser Remote Sensing**

L T P C  
3 1 0 3

Objectives : To understand the basic concepts, theory and applications of Laser Remote Sensing

### **Module 1**

Earth's atmosphere – basics of different regions of atmosphere, composition, structure and dynamics of atmosphere, important meteorological parameters and their influence in climate. Aerosols, optical properties and their role in Earth's climate and radiation budget. Clouds: different types of clouds, clouds properties, high altitude cirrus clouds, influence of clouds on weather and climate modification. Atmospheric pollution, different types of pollutants and the sources conventional methods of measurements and limitations. Importance of air quality measurement and environmental monitoring.

### **Module II**

Remote sensing of atmosphere, passive and active methods, laser remote sensing fundamentals, advantages. Laser remote sensing methods, interaction of laser radiation with atmosphere, various scattering methods, back scattering configurations, absorption methods, basics of long path absorption and differential absorption methods. Rayleigh, Raman and Mie lidar configurations, differential absorption lidar (DIAL) system. Lidar equation lidar inversion methods, application of lidar for atmospheric measurements, characterization atmospheric aerosols, minor constituent trace gases and pollutants.

### **Module III**

Lidar system components and design, monostatic and bistatic configurations, lidar systems for the measurement of aerosols, clouds, ozone, water vapor, temperature etc. Essential elements of a lidar and DIAL system. Typical lidar systems in operation, Brief description on lidar systems for oceanic applications, lidar system for vegetation studies. Brief description on advanced lidar systems: airborne and space borne (satellite) lidar for regional and global studies. Lidar altimetry – terrain mapping, lidar for interplanetary studies. Laser altimetry for lunar studies. Mars orbiting laser altimetry – CALISPO and other lidar missions. Air borne and space borne lidars: Basic structures design and technology requirements and optimization of system parameters.

### **Text books:**

1. E.D. Hinkley (Editor), Laser Monitoring of Atmosphere, Springer Verlag, 1976
2. J. McCartney, Optics of Atmosphere, E. John Wiley & Sons, 1982
3. Monte Ross, Laser Applications, Academic Press, 1973
4. Raymond M. Measures, Laser Remote Sensing and Applications, John Wiley & Sons, 1984

### **References:**

1. Raymond M. Measures (Ed) Laser Remote Chemical Analysis, John Wiley & Sons, 1988
2. Fiocco G., Lidar Systems of Aerosol Studies, An Outline in Handbook for MAP, Vol.13, 56-68, SCOSTEP Secr., University of III. Urbana, III, 1984.
3. P. Caagani and S. S Sandroni(Editor)Optional Remote Sensing of the Air Pollution, Elsevier science Publisher B. V, pp. 123-142, 1984.
4. Reagan. J.A., McCormick, M.P., and Spinhirne, J.D., Lidar Sensing of clouds in the atmosphere and Stratosphere, Proc. IEEE, 77, pp. 433-448, 1989
5. Winker, M.D., Couch, R.H., and McCormick, M.P., Proc. IEEE, 84, pp. 164-180, 1996
6. Muller, D., K. Franke, F. Wagner, D. Althausen, A. Ansmann, and J. Heintzenberg, Vertical Profiling of Optical and Physical Particle Properties over the Tropical Indian Ocean with six wavelength lidar, I. Seasonal cycle, J. Geophysics. Res. 106, 28,567-575, 2001

## **OPE 6010: Nonlinear Optics**

L T P C

3 1 0 3

Objectives : To introduce the basic concepts and theory of Nonlinear Optics.

### **Module I**

Harmonic generation, nonlinear optical susceptibility tensor, on the physical origins of the nonlinear optical coefficients, electromagnetic formulation of nonlinear interactions, optical second harmonic generation, experimental set up, two photon absorption, parametric generation of light, basic equations of parametric amplification, parametric oscillation, frequency tuning, experimental arrangement, frequency up and down conversion.

### **Module II**

Third order optical nonlinearities, stimulated Raman scattering, coherent anti-Stokes Raman scattering, stimulated Brillouin scattering, self-focusing of optical beams, degenerate four wave mixing, nonlinear optical materials, growth and characterization of nonlinear optical materials, optical bi-stability, absorptive and dispersive, simple model, optical bistability.

### **Module III**

Propagation through a distorting medium, image transmission in fibers, theory of phase conjugation by four wave mixing, optical phase conjugation by four wave mixing, OPC by stimulated nonlinear scattering, beam coupling and phase conjugation by photorefractive effect, self-induced transparency, self-phase modulation.

### **Text Books:**

1. Amnon Yariv, Quantum Electronics 3<sup>rd</sup>Edn, John Wiley, New York, 1989
2. Govind P. Agrawal, Nonlinear Fiber Optics, 3<sup>rd</sup>Edn, Academic Press, New Delhi, 2001.
3. Introduction to Photorefractive Nonlinear Optics, Pochi Yeh, John Wiley & Sons, New York, 1993

### **Reference:**

1. Rampal V.V, Photonics, Elements and Devices, Wheeler, Allahabad, 1992
2. Fischer R.A (Ed), Optical Phase Conjugation, Academic Press, San Diego, 1983
3. Singh N.B, Growth and characterization of Nonlinear Optical Materials, Pergamon, 1990
4. R.D. Guenther, Modern Optics, John Wiley & Sons, 1990
5. Robert W Boyd, Non Linear Optics, 2<sup>nd</sup>Edn, Academic Press, 2003
6. Richard L. Sutherland, Handbook of Non Linear Optics, Marcal Dekker, 1996

## **OPE 6011 Nanophotonics**

L T P C

3 1 0 3

Objectives: To provide knowledge in the field of nano science and nanotechnology.

### **Module I**

Introduction to nanoscale interaction of photons and electrons. Near field interaction and microscopy- near field optics and microscopy- single molecule spectroscopy-nonlinear optical process. Mesoscopic physics and nanotechnologies - trends in microelectronics and optoelectronics, characteristic lengths in mesoscopic systems, quantum mechanical coherence, materials for nanophotonics -quantum confined materials - inorganic semiconductors-quantum wells, wires dots and rings-quantum confinement-optical properties with examples-dielectric confinement- super lattices. Compound semiconductors- properties-applications- white light-GaN properties-blue LED-white light.

### **Module II**

Plasmonics-metallic nanoparticles and nanorods-metallic nanoshells-local field enhancement-plasmonic wave guiding-applications of metallic nanostructures. Nanocontrol of excitation dynamics-nanostructure and excited states-rare earth doped nanostructures-up converting nanophores-quantum cutting. Growth and characterization of nanomaterials- epitaxial growth-MBE-PLD- CVD-nanochemistry-XRD- Raman-IR- XPS-SEM- TEM- SPM.

### **Module III**

Organic quantum confined structures- carbon nanotubes-gaphene- characterization, properties and applications. Concept of photonic band gap – photonic crystals - theoretical modeling - features-optical circuitry-photonic crystal in optical communication-nonlinear photonic crystal-applications. Current at the nanoscale-nanoelectronic devices-introduction-single electron transistor. Basic ideas of nanolithography and biomaterials-nanophotonics for biotechnology and nanomedicine-nanophotonics and the market place.

### **Text Books:**

1. Paras N. Prasad, Nanophotonics, Wiley Interscience ,2004
2. Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge University Press, 2006
3. J.M. Martinez-Duart,R.J. Martin Palma,F. Agulle Rueda Nanotechnology for Microelectronics and Optoelectronics , Elsevier,2006.

### **Reference:**

1. Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Juan Ariel Levenson, Nanophotonics, ISTE Publishing Company, 2006.
2. Surface Plasmon Nanophotonics, Mark L. Brongersma, Pieter G. Kik, Springer -Verlag, 2006.
3. Photonic Crystals, by John D. Joannopoulos, Robert D. Meade, Joshua N. Winn Prienceton University Press.

## **OPE 6012: Integrated Optics**

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Objectives: To provide information regarding principle of optical amplifiers, wave guides, construction and working of integrated circuits.

### **Module I**

Optical amplifiers: principles of optical amplification, semiconductor optical amplifier, applications, merits and demerits, photonic switching principles. Theory of planar (2-D), channel (3- D) and coupled waveguides, step index 2-D, graded Index 2- D, 3-D optical waveguides step index and graded index 3 D waveguide devices, general theory of mode coupling, gratings. Guide-wave control- electro optic acousto-optic magneto optic and nonlinear optic. Recent trends in optical integrated circuits.

### **Module II**

Materials and fabrication techniques of optical waveguides, guided wave excitation and wavelength evaluation, passive waveguide devices, functional optical waveguide devices, fabrication techniques of optical integrated circuits, patterning and processing techniques, fabrication of 3-D waveguides. Waveguide evaluation, propagation constant waveguide parameters, transmission losses, scattering.

### **Module III**

Design of directional couplers, phase, interferometric travelling wave, balanced bridge, Bragg type, switches, electro optic, magneto optic and thermo optic bistable integrated optical devices, multiplexers, demultiplexers, integrated diode laser structures, integrated optical detectors, integrated quantum well detectors. System design using photonic circuits, application DIC in telecommunication, switching, sensing, signal processing and computing, integrated optic sensors.

### **Text books:**

1. Nishihara. H, Haruna M. and Suhara T, Optical Integrated Circuits, McGraw Hill, New York, 1989.
2. Hunsperger R.G, Integrated Optics Theory and Technology, 3<sup>rd</sup>Edn, Springer Verlag, New York. 1991
3. Marcel Dekker, Integrated Opto Circuits, 1982.

### **References:**

1. D.K. Mynbaev and L.L. Scheiner, "Fiber-optic Communications Technology", Pearson Education, New Delhi, 2001.
2. B.E.A. Saleh and M.C. Teich., "Fundamentals of Photonics", John Wiley, New York, 1991.
3. G. Keiser, "Optical Fiber Communications", McGraw Hill, New Delhi, 1983.
4. P. Bhattacharya, "Semiconductor optoelectronic devices", Prentice-Hall India., New Delhi, 1998.
5. A. Ghatak and K. Thyagarajan, "Optical electronics", Cambridge Univ. Press, New Delhi, 2002.

## **OPE 6013 Solar Photovoltaics**

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Objectives: To provide knowledge in the field of solar cell developments.

### **Module I**

Solar cell materials and their properties. Solar cell research: technology (silicon, organic, Dye sensitized, perovskites), applications and limitations. Device fabrication: semiconductor junctions: Schottky barriers, MIS, P-N junction, P-I-N junction and its properties homo & hetero junction solar cells, multi-junction solar cells- fabrication techniques: diffusion, thin film technology- physical vapour deposition (PVD)- electro-deposition- metal organic chemical vapour deposition (MOCVD)- plasma enhanced chemical vapour deposition (PECVD).

### **Module II**

Characterization and analysis: ideal cell under illumination- solar cell parameters ,optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, internal quantum yield measurements – effects of series and parallel resistance and temperature - loss analysis.

### **Module III**

PV modules: solar PV modules from solar cells, series and parallel connections, design and structure of PV modules, power output, batteries for PV systems, DC-DC converters, DC-AC converters, PV system configurations, Hybrid PV systems

### **Text Books:**

1. Solar Photovoltaic: Fundamentals, Technologies and Applications, Chetan Singh Solanki, PHI, Newdelhi, 2011.
2. Solar Cells: Operating principles, Technology and System Applications, by Martin A. Green, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981
3. Thin Film Solar Cell: Fabrication, Characterizations and Applications, Poortmans J and Arkhipov V, John Wiley & Sons, England 2006
4. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.

### **References:**

1. Semiconductors for Solar Cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
2. Thin-Film Crystalline Silicon Solar Cells: Physics and Technology, R. Brendel, Wiley-VCH, Weinheim, 2003.
3. Clean Electricity from Photovoltaics, M. D. Archer, R. Hill, Imperial College Press, 2001.
4. J. Nelson, The physics of Solar Cells, Imperial College Press, 2006.
5. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998 23
6. Solid State Electronic Devices, Ben G. Streetman, Prentice-Hall of India Pvt. Ltd.,1995.

## **OPE 6014 Satellite & Mobile Communication**

L T P C  
3 1 0 3

### **Objective:**

- To understand how mission dictates orbit.
- To use and understanding of link budget equations to provide sufficient margin for performance.
- To take a practical look at the engineering impact of the various satellite components on performance.
- To impart the fundamentals concepts of mobile communication systems.
- To introduce various technologies and protocols involved in mobile communication.

### **Module I**

Communication satellite- orbits & launching methods-Kepler's law-inclined orbits-geostationary orbits, effect of orbital inclination, azimuth and elevation, coverage angle and slant range, eclipse, satellite placement. space segment subsystems & description, earth station- antenna, high power amplifiers, up converter, down converters, monitoring and control. satellite link- basic link and interference analysis.

### **Module II**

Cellular concept: hand off strategies, interference and system capacity: cell splitting, sectoring, repeaters, micro-cells. Link budget based on path loss models. propagation models(outdoor):- Longely-Rice model, Okumura model. Mobile propagation- fading and Doppler shift, impulse response model of multipath channel, parameters of multipath channel. Fading effect due to multipath time delay spread and Doppler shift. Multiple Access- TDMA overlaid on FDMA, SDMA, FHMA.

### **Module III**

GSM: architecture, radio subsystem, channel types, frame structure. introduction to ultra wideband communication system. direct sequence modulation, spreading codes, the advantage of CDMA for wireless, code synchronization, channel estimation, power control- the near-far problem, FEC coding and CDMA, multiuser detection, CDMA in cellular environment. space division multiple access and smart antennas.

### **Text books**

1. Dennis Roody, Satellite Communication, 2/e, McGraw Hill.
2. Theodore S. Rappaport, Wireless Communication Principles and Practice, 2/e, Pearson Education.
3. William C Y Lee, Mobile Cellular Telecommunications,2/e, McGraw Hill.
4. Madhavendar Richharia, Mobile Satellite Communications: Principles and Trends, Pearson Education, 2004

### **References:**

1. Simon Haykin & Michael Mohar, Modern Wireless Communication, Pearson Education, 2008.
2. Tri. T. Ha, Digital Satellite Communication, 2/e, Mcgraw Hill.
3. M. Ghavami, L. D. Michael & K Rohino, Ultra-Wide Band Signals in Communication Engineering, Wiley Inc.
4. William Stallings, Wireless Communication and Networks, Pearson Education, 2006.

## **OPE 6015 Digital Systems Design**

L T P C  
3 1 0 3

### **Objectives:**

- To provide the student with a working knowledge of different methods for logic representation, manipulation, and optimization, for both combinational and sequential logic.
- To implement digital building blocks such as memory chips, processing elements, arithmetic circuits etc.
- To know about designing complex, high speed digital systems.

### **Module I**

Introduction to combinational modules and modular networks. Standard combinational modules, design of arithmetic modules. Implementation of combinational systems with ROM's and PLA's. Comparison with other approaches. Implementation of multi-module combinational systems – decoder networks, Multiplexer trees, demultiplexer network, encoder network, shifter network and barrel shifters.

### **Module II**

Canonical implementation – analysis and synthesis of networks in the canonical implementation. Flip flop modules and networks. Modular sequential networks. Standard sequential modules. Registers – shift register. Counters – RAM – content addressable memories and programmable sequential arrays (PSA) – Design of sequential systems with small number of standard modules – state register and combinational networks – RAM and combinational networks – SR and combinational networks. Multi-module implementation of sequential systems – multi-module registers – shift registers and RAMs – multi-module counters.

### **Module III**

Introduction to synchronous digital systems: state diagram, state tables, state reduction methods, state assignments, Mealy and Moore machines. Time behaviour of synchronous sequential systems. minimization of number of states. Specification of various types of sequential system, sequential circuit design. Asynchronous sequential circuits: derivation of excitation table, race conditions and cycles.

### **Text books:**

1. Milos D. Ercegovac, Tomas Lang: Digital Systems and Hardware / Firmware Algorithm, John Wiley
2. William I Fletcher: An Engineering Approach to Digital Design, Prentice Hall.

### **References :**

1. Hayes: Digital System Design and Microprocessors, McGraw Hill.
2. John B Peatman: Digital Hardware Design, McGraw Hill.
3. Charles H. Roth, Jr., Fundamentals of Digital Design, PWS Pub.Co. 1998.
4. Kenneth J Breeding, Digital Design Fundamentals, Prentice Hall, Englewood Cliffs, New Jersey,1989.
5. James E. Palmer, Introduction to Digital Design, David E. Perlman, Tata McGraw Hill, 1996.
6. John F. Wakerly, Digital Design Principles and Practices, Prentice Hall, 4th Edition, 2001

## **OPE 6016 Communication Networks and Telecommunication System Engineering**

L T P C  
3 1 0 3

Objective: To provide basic knowledge in communication networks and telecommunication system.

### **Module I**

Internet Architecture: Architectural concepts in ISO's ,OSI layered model, layering in the internet, TCP/ICP protocol stack, transport layer-TCP and UDP, network layer- IP routing, internet working, data link layer-ARQ schemes, LANs, Broadband services and QOS issues- quality of service issues in networks-integrated service architecture-queuing disciplines-weighted fair queuing-random early detection-differentiated services-protocols for -QOS support-resource reservation-RSVP-Multi protocol label switching- real time transport protocol. Introduction to queuing theory: Markow chain- discrete time and continuous time Markov chains-poisson process-queuing models for data gram network- Little's theorem-M/M/I queuing systems-M/M/m/m queuing models-M/G/I queue-Mean value analysis.

### **Module II**

Statistical multiplexing in communication network: multiplexing, network performance and source characterization, stream sessions in packet networks-deterministic analysis, stochastic analysis, circuit multiplexed networks, elastic transfers in packet networks. Optical fiber network: data buses, LAN systems, network configuration, FDDI network, SONET and SDH network, ISDN and BISDN, high speed networks, industrial network, public network applications.

### **Module III**

Close network, recursive construction of switches, strictly non-blocking, rearrangeable by non-blocking, Close theorem, Slepiau Duguid theorem, Paull's theorem, Paull's matrix, Cantor network, network traffic arrival and service characterization, Erlang formulae, mathematical modeling, blocking models ( Lee's approximation), Karnaugh's method for blocking probability estimate, stored program control (SPC) exchange, space, time switch implementation, super multiplexing, operating system architecture for switching system, overload control mechanisms, user to network signaling, pulse, tone signaling, common channel signaling, SS7 architecture and protocol stack, IP telephony, IP network architecture, generic architecture, banyan networks, delta networks, Shuft I enet as delta network, buffered banyan network, input vs output queuing, discussion of various packet switching architectures.

### **Textbooks:**

- 1 . Anurag Kumar, D.Manjunath and Joy Kuri,Communication Networking: An Analytical Approach- Morgan Kaufman publishers,2004.
2. Bertsekas and R.Gallager, Data Networks, PHI 2000

***M.Tech in Electronics and Communication (Optoelectronics and Optical communication)***

3. S.Keshav , An Engineering Approach to Computer Networking, Addison Wesley Ist Ed.1997.
- 4 . Joseph Y. Hui. Switching and Traffic theory for Integrated Broadband Networks, Kluwer Academic Press
- 5 . M. Schwartz, Telecommunication Networks: Protocols, Modeling and Analysis, Addison-Wesley Longman Publishing company, Boston,1986.

**References:**

1. Peterson L.L & Davis B.S.Computer Networks: A System Approach. Morgan Kaufman Publishers. 2007.
2. I Suematsu and Iga, Introduction to Optical Fiber Communication, John Wiley, 1982
3. H.Johnson Chao, Broadband Packet Switching Technology-A Practical Guide to ATM Switches and IP routers, John Wiley and Sons Inc.
- 4.T.Viswanathan, EM Telecommunication Switching Systems and Networks. Prentice Hall of India, 1992.
5. R.L Freeman, Telecommunication System Engineering, John Wiley and Sons

## **OPE 6017 Optical Metrology**

L T P C  
3 1 0 3

Objectives : To provide better understanding in optical measurement techniques.

### **Module I**

General image-forming system, lens aberrations, computer lens design , imaging and lens formula, standard optical systems, afocal systems, telescope, simple magnifier, microscope, laser Doppler velocimetry (LDV), physical optics description of image formation, interferometry, dual-frequency Michelson interferometer, diffraction from a grating, grating equation, amplitude transmittance , spatial frequency spectrum, phase-modulated sinusoidal grating

### **Module II**

Radiometry, photometry, lambertian surface , blackbody radiator with examples, holographic interferometry , double-exposure interferometry , real-time interferometry, analysis of interferograms, localization of interference fringes, Moire methods, triangulation, sinusoidal gratings, Moire between two angularly displaced gratings measurement of in-plane deformation and strains, methods for increasing the sensitivity, measurement of out-of-plane deformations, contouring shadow, Moire projected fringes ,vibration analysis, Moire technique by means of digital image processing, reflection Moire, triangulation

### **Module III**

Speckle effect, speckle size, speckle photography, Fourier fringe method ,Young fringe method, photoelasticity , plane polariscope, circular polariscope, detection of isochromatics of fractional order, compensation ,holographic photoelasticity. Fringe analysis , intensity-based analysis methods, fringe tracking and thinning, fringe location by sub-pixel accuracy, principles of TPMI, means of phase modulation, different techniques, errors in TPMI measurements, phase-unwrapping techniques , path-dependent methods, path-independent methods ,temporal phase unwrapping.

### **Text Books:**

- 1.Gasvik, K.J. Optical Metrology. 3rd ed. Chichester: John Wiley & Sons, 2002.
- 2.Malacara, D. (ed.). Optical Shop Testing. 3rd ed. New York: John Wiley & Sons, 2007.

### **References:**

- 1.Cielo, P.G. Optical Techniques for Industrial Inspection. Boston: Academic Press, 1988.
- 2.Rastogi, P.K. (ed.). Optical Measurement Techniques and Applications. Boston: Artech House, 1997.

## **OPE 6018 Mathematical Physics**

L T P C

3 1 0 3

Objectives: To give awareness in the applications of mathematics in physics and engineering.

### **Module I**

Ordinary differential equations, 1<sup>st</sup>-order, nth- order linear differential equations, application of linear differential equations, differential equations of other types, separation of variables, boundary value problems in physics, eigen values and eigen functions, Sturm-Liouville problem.

### **Module II**

Fourier series, Fourier transformation, properties of the Fourier transformations, Fourier transformation of the delta function, z- transformation, Laplace transformation, FT applications: Parseval's theorem- Dirac delta function-unit step function-two dimensional signals-Fresnel & Fraunhofer diffraction-examples FT by lens- point source-single slit, double slit-circular aperture-cosine grating- coherent optical filtering-holographic filters-discrete Fourier transform- Fourier transformation in optics, convolution and correlation. 2-DFT.

### **Module III**

Partial differential equations, classification-methods of solving linear ODE and PDEs- separation of variables. Wave equation, Laplace equation- nonlinear PDEs-approximation methods for nonlinear differential equations- Painleve analysis for PDEs- AKNS, bilinear and BT methods- applications, n dimensional wave equations, heat flow and diffusion, PDE.

### **Text Books:**

1. G.B. Arfken, H J Weber, Mathematical Methods for Physicist, 4<sup>th</sup> ed. Academic Press,1995.
2. P.M. Morse and H. Feshbach, Methods of Theoretical Physics ( Volume, I,II,1953).
3. Mary Boas, Mathematical Methods in Physical Sciences, Wiley.
4. S. Hassani, Mathematical Physics: A Modern Introduction to its Foundations ( 1998,99).
5. MATLAB Programming for Engineers, Stephen J. Chapman, Thomson Press (2007).

### **References:**

1. Dr. B.S. Grewal, Higher Engineering Mathematics.
2. Jon Mathews, Robert L. Walker Mathematical Methods of Physics, University of Cambridge, 1970
3. Applied Mathematics for Scientists and Engineers 2.Edition - January 2006.
4. Hassani, Sadri, Mathematical Methods of Physics and Related Fields2nd ed., 2009.
5. Kreyszig, Erwin, Advance Engineering Mathematics, Loyola Marymount University,10th Edition, 2012.

## **OPE 6019 Biophotonics**

L T P C  
3 1 0 3

Objectives: To give an idea about the developments in Biophotonics.

### **Module I**

Photobiology: interaction of light with cells and tissues, photo-processes in biopolymers, human eye and vision, photosynthesis. photo-excitation: free space propagation, optical fiber delivery system, articulated arm delivery, hollow tube wave-guides. Optical coherence tomography, special and time-resolved imaging, fluorescence resonance energy transfer(FRET) imaging, nonlinear optical imaging. Bio-imaging: transmission microscopy, Kohler illumination, microscopy based on phase contrast, dark-field and differential interference contract microscopy, fluorescence, confocal and multi-photon microscopy. Applications of bio-imaging: bio-imaging probes and fluorophores, imaging of microbes, cellular imaging and tissue imaging.

### **Module II**

Optical biosensors: fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, biosensors based on fibre optics, planar waveguides, evanescent waves, interferometry and surface plasmon resonance. Flow cytometry: basics, 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 III**

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, lasers for genomics and proteomics, semiconductor quantum dots for bio imaging, metallic nano-particles and nano-rods for bio-sensing. Photonics and biomaterials: bacteria as bio-synthesizers for photonic polymers.

### **Text books:**

1. Introduction to Biophotonics-V N Prasad (Wiley-Interscience April 2003)
2. Biomedical Photonics: A Handbook-Tu Vo Dinh (CRC Press, Boca Raton, FL 2003)

### **References:**

1. A Handbook of Optical Biomedical diagnostics, SPIE press monograph vol pm 107
2. Biomedical Optics-Principles and Imaging -Lihong V and Hsin-IWU, Wiley Interscience 1sted, 2007)
3. Optical Coherence Tomography-Principles and Applications –Mark E.Brezinski, (Academis Press 1<sup>st</sup>ed 2006)
4. Biophysics –An Introduction-Rodney Cotterill, (John Wiley Student edition)

## **OPE 6020 Optical Networks**

| L | T | P | C |
|---|---|---|---|
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Objective:

- To study the Optical network components for Optical Network communication.
- To study various Network architecture and topologies for optical networks.
- To study the network design and operation for wavelength routing in optical networks.

### **Module I**

SONET & SDH : brief history of SONET & SDH, multiplexing hierarchy, multiplexing structure – functional components, problem detection, virtual tributaries & containers, concatenation. Architecture of OTN: digital wrapper, control planes, control signaling, multiplexing hierarchies, current digital hierarchy, revised hierarchies, optical & digital transport hierarchies, functionality stacks, encapsulation & decapsulation, GFP, WDM, DWDM topologies : relationship with SONET / SDH, EDF, WDM amplifiers, multiplexers, WADM I/P & O/P ports, spanloss & chromatic, dispersion, tunable DWDM lasers, network topologies & protection schemes : non-negotiable requirements of robust networks, line & path protection switching, type of topologies, optical channel concatenation, meshed topologies, PON's, optical ethernet, wide area backbones, metro optical networking.

### **Module II**

MPLS & optical networks : label switching, FEC, scalability & granularity: labels & wavelength, MPLS nodes, distribution & binding methods, MPLS support of virtual private networks, traffic engineering, MPLS, relationships of OXC, MPLS operation, MPLS & optical traffic engineering, similarities. Control & data planes interworking, architecture of IP & MPLS based optical transport networks : IP, MPLS & optical control planes- interworking, three control planes, framework for IP Vs. Optical networks, generalized MPLS use in optical networks, bidirectional LSP's in optical network, next horizon of GMPLS, ODVK general communication channels, traffic parameters.

### **Module III**

Link management protocol ( LMP):data bearing links, basic function of LMP, LMP messages, LMP message header, TLW's control channel management, LPC, LCV, fault management, extending LMP operations to optical links optical routers management: switching in optical internets: state of art in optical switching, clarification of key terms, evolution of switching technologies, speeds of electronics & photonics, optical routers, control element, switching technologies MEMS, OSP, setting up protection paths between nodes H, G & J, expanding the role of nodes G & I, node failure, coupling, decoupling, node to node wavelengths, approach to problem of LSP & OSP interworking, thermo-optic switches, bubble switch. Optical compilers: building blocks, serial binary adder with carry delay, fiber delay line memory loop, bit serial, optical counter design, lumped delay design, distributed delay design, time multiplex multiprocessor, time slot interchange with  $2 \log_2 (N-1)$  switch, Hatch design support system.

### **Text Books:**

1. Rajiv Ramaswami, Kumar N. Sivarajan, Optical Networks 2<sup>nd</sup> Edn.,Morgan Kaufmann Publishers, Elsevier.
2. Biswanath Mukherjee, Optical WDM Networks, Springer.
3. Thomas E.Stern, Georgios Ellinas, Krishna Bala, Architectures, Design and Control, 2<sup>nd</sup> Edn. Cambridge University Press.

### **References:**

1. Achyut K. Dutta, Niloy K. Dutta, Masahiko Fujiwara WDM Technologies, Optical Networks, Academic Press, Elsevier.

## **OPE 6021 Micro Electro Mechanical Systems (MEMS)**

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| L | T | P | C |
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### **Objective:**

- To teach different methods of micromachining and how these methods can be used to produce a variety of MEMS, including microstructures, microsensors, and microactuators.
- Expose the students to design, simulation and analysis softwares.
- In addition to this the course covers the various applications of MEMS in different fields.
- Learning Outcomes:
- Design of MEMS based systems.

### **Module I**

Introduction to MEMS: historical background of micro electro mechanical systems, role of MEMS in improved efficiency, smart materials and structures, materials processing synthesis, multifunctional polymers. material processing and device fabrication: lithography, ion implantation, etching, wafer bonding, integrated processes, bulk silicon micromachining, surface micro machining, CVD oxide process. Enhanced CVD, physical vapor deposition, DRIE.

### **Module II**

Micro sensors - micro actuators -micro opto electro mechanical systems, micromechanical components - springs bearings, gears and connectors, high temperature sensors, capacitive pressure sensor, bulk micro-machined accelerometer, surface micro-machined microspectrometer. micro opto electro mechanical systems (MOEMS), optical MEMS components, micro mirrors, micro lenses, optical sources and detectors for optical MEMS applications, design and simulation of micro sensors, micro actuators and MOEMS- micro fluidic devices, micro fluidic devices using photonic crystal fiber.

### **Module III**

Applications of MEMS: blood pressure monitoring transducers, disposable blood pressure monitoring transducers. MEMS devices - infusion pumps, kidney dialysis, respirators, active noise and vibration control, intelligent structures, micro -robots, smart structures for aircraft, automotive requirements, automobile, satellite, buildings and manufacturing systems. Simulation of microstructures and component modeling: general overview of basic processes (planar-CMOS, bulk-Si, LIGA), physical-chemical determined simulation of selected process steps. Systematic of MEMS components, layout support, examples of element modeling (DAE, FEM).

### **Textbooks:**

1. Tai-Ran Hsu, 'MEMS & Microsystem, Design and Manufacture', McGraw Hill, 2002
2. Banks H.T. Smith R.C. and Wang Y.Smart, 'Material Structures - Modeling, Estimation and Control', John Wiley & Sons, New York, 1996.

### **Reference:**

1. Massood Tabib - Arar, 'Microactuators - Electrical, Magnetic Thermal, Optical, Mechanical, Chemical and Smart structures', Klumer Academic publishers, New York 1997.
2. M.Eluenspoek, R.Wiegerink, "Mechanical Microsensors", Springer, 2001. Mode of evaluation: Written examination, Seminar, Assignments

## **OPE 6022 Laser Material Processing**

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Objective: To give basic understanding of the various laser surface treatment processes and to explain the laser welding process and its advantages over conventional process.

### **Module I**

Models of laser heating- choice of laser for material processing-laser welding, drilling, machine and cutting- laser surface treatment-laser vapour deposition- thin film application, depth of penetration with respect to laser energy density- reflectivity of metals with respect to wavelength- rate of heating and cooling- maximum temperature rise and depth of hardened layer- different gases used using laser materials processing- operational parameters in laser materials processing-key hole effect.

### **Module II**

Surface treatment: surface modification-surface cladding-surface alloying – hard facing- shock hardening- laser parameters for surface alloying- process variables- beam profiles- different methods to obtain desired penetration depths-experimental set up.

### **Module III**

Laser welding: different modes of laser beam welding- comparison between laser beam and electron beam welding-influence of different parameters-absorptivity-welding speed-focussing conditions-advantages and limitations of laser welding-laser welding of industrial materials-recent developments in laser welding techniques, laser cutting and drilling: laser energy density for cutting and drilling-melt flash mechanism-various assisting gases and their importance-advantages of laser cutting-laser instrumentation for cutting and drilling-factors affecting cutting rates- effect of laser pulse energy on diameter and depth of drilled hole.

### **Text books:**

1. Ian. W.Boyd,” Laser Processing of Thin films and Microstructures”,Springer-Verlag,1987.
2. W.W.Duley, “ Laser Processing and Analysis of Materials”, Plenum Press, New York, 1983

### **Reference:**

1. Rykalni, A.Ugloo and A.Kokona, “Laser and Electron Beam Material Processing Hand Book”,, MIR Publishers,1987.
2. J. Wilson & J.F.B.Hawkes,” Optoelectronics- An Introduction”,Prentice Hall of India Pvt.Ltd.,New Delhi,1 1996.
3. J.F.Reddy,” High Power Laser Applications”,Academic Press, 1977.
4. William M. Steen,” Laser Material Processing”, Springer- Verlag, Berlin, Third Edn.,2005

## **OPE 6023 Laser Spectroscopy**

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|---|---|---|---|
| L | T | P | C |
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Objective: To provide knowledge of the fundamentals of spectroscopy and about different types of spectroscopy and applications of laser spectroscopy in various fields.

### **Module I**

Basic principles: comparison between conventional light sources and lasers –saturation excitation methods: single step excitation –multistep excitation-multi-photon absorption-detection methods: fluorescence-photo ionization-collisional ionization-field ionization – laser wavelength setting, Doppler limited techniques: absorption measurements- intra-cavity absorption measurements-absorption measurements on excited states- level labeling-two-photon absorption measurements-opto-galvanic spectroscopy-single atom detection-opto-acoustic spectroscopy-optical double resonance and level-crossing experiments with laser excitation.

### **Module II**

Time resolved spectroscopy: generation of short optical pulses-generation of ultra short optical pulses-measurement techniques for optical transients: transient- digitizer-boxcar-delayed coincidence-streak camera and pump-probe techniques, basics of life time measurements –methods of measuring radiative properties- line width measurements- ODR and LC-beam foil techniques- beam shift method and emission method- the hook method- quantum-beat spectroscopy.

### **Module III**

Applications of laser-spectroscopy: photochemical reactions-steady and excited state techniques-comparison of one photon and multi-photon effect and its applications-photo ionization-photo isomerism-isotope separation-laser fusion-laser trapping of atoms and cooling, diagnostics of combustion processes-background-laser induced fluorescence and related techniques-Raman spectroscopy-coherent anti-stokes Raman scattering-velocity measurements-laser induced fluorescence and Raman spectroscopy in liquids and solids- hydrospheric remote sensing-monitoring of surface layers-laser induced chemical processes: laser induced chemistry-laser isotope separation-spectroscopy aspects of lasers in medicine- laser remote sensing LIDAR techniques.

#### **Textbooks:**

- 1 . S.Svanberg, “ Atomic and Molecular Spectroscopy”. Springer Verlag,Germany,1992.
- 2 . J.R. Lakowicz, “ Principles of Flourescence Spectroscopy”, Kluwer Academic/ Plenum Publishers,New York,1999.
- 3 . Z.Wang and H.Xia,” Molecular and Laser Spectroscopy “ Springer series in chemical physics, Vol.50,1991.

#### **References:**

- 1 . F.T. Arecchi, “ Laser Handbook”, Vol.2,North Holland Publication, 1974.
- 2 . R.E.Lidder, McGraw Hill, London, “ Fundamental and Applied Laser Physics””John Wiley, New York, 1985.
- 3 . W.W.Duley, “ Laser Processing and Analysis of Materials”, Plenum Press, New York, 1983.
- 4 . William M. Steen,” Laser Material Processing”, Springer- Verlag, Berlin, Third Edn.,2005.