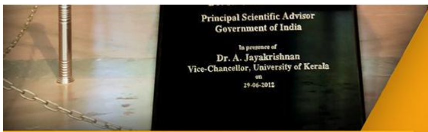
Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme



DEPARTMENT OF OPTOELECTRONICS

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UNIVERSITY OF KERALA
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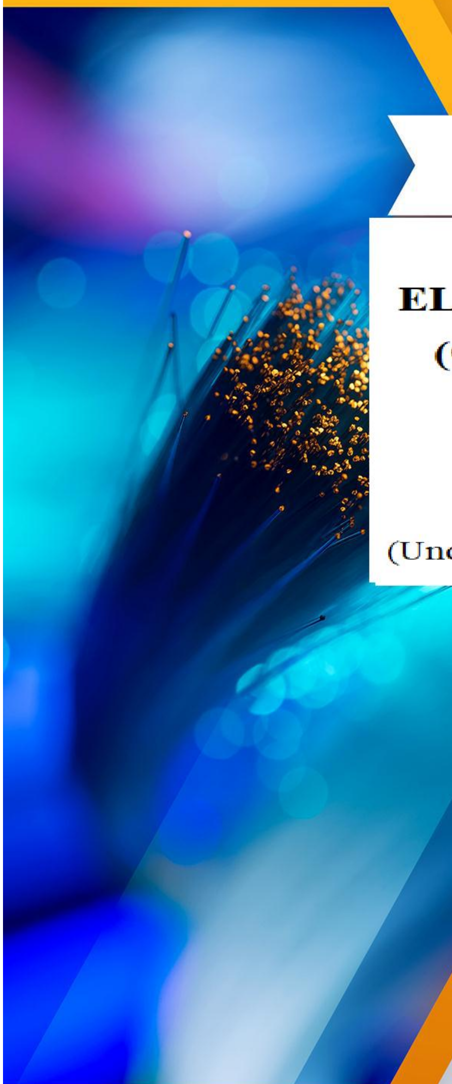

M.TECH PROGRAMME IN ELECTRONICS & COMMUNICATION (OPTOELECTRONICS & OPTICAL COMMUNICATION)

SYLLABUS

(Under Credit & Semester System w.e.f 2020 Admission)

DEPARTMENT OF OPTO ELECTRONICS

UNIVERSITY OF KERALA

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, defence and industrial applications. Optical communication plays a vital role in today's communication technology. This intellectually challenging subject underpins the core technologies of the 21st 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 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

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

Sem. No.	Course code	Name of the course	Credits	Total Credit per Semester
I	**Core Courses (CC)**			
	OPE-CC-611	Modern Optics	3	**19**
	OPE-CC-612	Lasers	3	
	OPE-CC-613	Optoelectronic Devices	3	
	OPE-CC-614	Fiber Optics Technology	3	
	OPE-CC-615	General Optoelectronics Lab	4	
	Discipline-Specific Electives (DE)			
		Elective – I*	3	
II	**Core Courses (CC)**			
	OPE-CC-621	Fiber Optic Sensors and Applications	3	**23**
	OPE-CC-622	Optical Fiber Communication Systems	3	
	OPE-CC-623	Research Methodology	3	
	OPE-CC-624	Data Analysis and Image Processing Lab	4	
	OPE-CC-625	Photonic Design, Communication and Digital Signal Processing Lab	4	
	Discipline-Specific Electives (DE)			
		Elective – II*	3	
		Elective – III*	3	
III	**Core Courses (CC)**			
	OPE-CC-631	Seminar	2	**15**
	OPE-CC-632	Mini Project I (Design and Development)	2	
	OPE-CC-633	Study on Current Advanced Research	3	
	OPE-D-634	Dissertation Phase I	8	
IV	OPE-D-641	Dissertation Phase II	16	**16**
Generic Courses (GC)				
I		Open Elective I	2	**4**
II		Open Elective II	2	
	Total Credits		**77**	

*The students will have to select Elective subject from list of Discipline-Specific Electives provided in each semester as given below:

Course Code	Discipline-Specific Electives (DE)	Credits
OPE-DE-601	Digital Communication	3
OPE-DE-602	Advanced Digital Signal Processing	3
OPE-DE-603	Holography and Speckle Interferometry	3
OPE-DE-604	Integrated Optics	3
OPE-DE-605	Satellite and Mobile Communications	3
OPE-DE-606	Laser Material Processing	3
OPE-DE-607	Image Processing	3
OPE-DE-608	Pattern Recognition	3
OPE-DE-609	Optical Instrumentation	3
OPE-DE-610	Digital System Design	3
OPE-DE-611	Optical Signal Processing	3
OPE-DE-612	Artificial Neural Networks	3
OPE-DE-613	Nonlinear Optics	3
OPE-DE-614	Nanophotonics	3
OPE-DE-615	Solar Photovoltaics	3
OPE-DE-616	Engineering Mathematics	3
OPE-DE-617	Laser Remote Sensing	3
OPE-DE-618	Communication Networks and Telecommunication System Engineering	3
OPE-DE-619	Optical Networks	3
OPE-DE-620	Micro Electro Mechanical Systems	3
OPE-DE-621	Laser Spectroscopy	3
OPE-DE-622	Nanobiophotonics	3

Programme Outcomes (POs)

PO1	Students become capable to carry out research and development work independently
PO2	Achieve the ability to prepare and present a substantial technical report
PO3	Improve skills in solving scientific problems and designing devices.
PO4	Students will become able to demonstrate a degree of mastery over the area as per the specialization of the program.

Programme Specific Outcomes (PSOs)

PSO1	Understand the principles and theoretical concepts in the fabrication of Optoelectronic materials and devices.
PSO2	Develop skills in designing optoelectronic devices and optical communication systems which are in tune with current technology and adaptable for future changes.
PSO3	Create an environment such that students develop a passion for hardware and software design.
PSO4	Act as the part of the electronic design industry to become leaders in indigenous product development.
PSO5	Get mathematical background for theoretical analysis

Course Outcomes

Semester: I	Course Code: OPE-CC-611
Course Title: MODERN OPTICS	**Credits: 3**

Prerequisite : Knowledge in optics.

Objective : To develop a thorough understanding of the underlying physical principles of various modern optical phenomena and their applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Define phase velocity and group velocity.
CO2	Understand the behaviour of Gaussian beams in a homogeneous medium.
CO3	Use Gaussian beam focussing.
CO4	Discuss the propagation of light in isotropic dielectric medium and crystals.
CO5	Compare Fraunhofer and Fresnel diffraction.
CO6	Classify the Fraunhofer and Fresnel diffraction patterns in different aperture.
CO7	Evaluate Fourier transforms in optics.
CO8	Develop a hologram.
CO9	Apply the concept of coherence and non-linear optics.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Define phase velocity and group velocity.	PSO1	R	F, C
CO2	Understand the behaviour of Gaussian beams in a homogeneous medium.	PSO1	U	C
CO3	Use Gaussian beam focussing.	PO3/ PSO2	Ap	P

CO4	Discuss the propagation of light in isotropic dielectric medium and crystals.	PSO1	U	P
CO5	Compare Fraunhofer and Fresnel diffraction.	PSO2	An	C
CO6	Classify the Fraunhofer and Fresnel diffraction patterns in different aperture.	PO4/ PSO4	Ap	M
CO7	Evaluate Fourier transforms in optics.	PSO3	E	P
CO8	Develop a hologram.	PO3/ PSO3	Cr	M
CO9	Apply the concept of coherence and non-linear optics.	PO3/ PSO2	Ap	C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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.

MODULE III: Propagation of light in isotropic dielectric medium, dispersion, Sellmeier's formula, propagation of light in crystals, wave-vector surface, Ray-velocity surface.

MODULE IV: 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.

MODULE V: 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 analyser.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

- Joseph N Goodman, Introduction to Fourier optics, McGraw Hill, 1996.
- Stark H, (Ed.), Applications of Optical Fourier Transforms, Academic Press, 1982.

Semester: I	Course Code: OPE-CC-612
Course Title: LASERS	**Credits: 3**

Prerequisite : Knowledge in Electromagnetic Theory, Optics.

Objective : To introduce the fundamental theories and technological aspects of Lasers and its applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts in Lasers.
CO2	Understand the principles and design of laser cavities and population inversion techniques
CO3	Understand different types of laser systems and their working
CO4	Analyse Laser cavity parameters, line broadening mechanisms
CO5	Design mode locked and Q switched lasers and various optical modulation techniques.
CO6	Applications of Laser systems in various fields of Science and Technology
CO7	Design aspects and working of various Laser systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts in Lasers.	PSO1	R	F and C
CO2	Understand the principles and design of laser cavities and population inversion techniques	PSO1	U	C

CO3	Understand different types of laser systems and their working	PSO1	U	C
CO4	Analyse Laser cavity parameters, line broadening mechanisms	PO2	An	M
CO5	Design mode locked and Q switched lasers and various optical modulation techniques.	PO4/PSO3	Cr	M
CO6	Applications of Laser systems in various fields of Science and Technology	PO1/PSO2	Ap	P
CO7	Design aspects and working of various Laser systems.	PO4/PSO3	Cr	M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Black body radiation, Planck's law, spontaneous and induced transitions- Einstein's coefficients, gain coefficient, Coherence – Spatial and Temporal coherence- Line broadening mechanisms- homogenous and inhomogeneous broadened systems-

.

MODULE II: Laser oscillation conditions - population inversion - three and four level systems - rate equations Optical resonators, rectangular cavity- open planar resonators- spherical resonators, modes and mode stability criteria, losses in optical resonators-quality factor, unstable optical resonators.

MODULE III: Q-switching, methods of Q-switching- methods, optomechanical methods of light- electro optic modulation- Pockel 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.

MODULE IV: Laser applications- thermal lensing effects – photothermal – photoacoustics – techniques and applications- Descriptive and qualitative studies of laser applications in communication, remote sensing – Lasers in speckles and holography (introductory ideas), Laser material processing - Pulsed laser ablation.

MODULE V: Lasers in mechanical Engineering and industry, metrology, defense and security, laser cooling, lasers in biology and medicine, satellite communications, LIDAR. Working principle of Ruby laser, dye laser, Argon ion laser, Tunable solid state lasers.

MODULE VI: Working principle and detailed study of semiconductor lasers Nd: YAG laser- flash lamp pumped and diode pumped lasers- -He-Ne laser, CO2 laser, Excimer laser, Nitrogen laser, free electron laser, Fiber laser. Frequency convertors and Parametric Oscillators.

REFERENCES

- Orazio Svelto, Principles of Lasers, 4thEdn, Plenum Press, 1998.
- Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998
- Thyagarajan .K&Ghatak A K Lasers, Theory and Applications Macmillan, 1991
- Yariv A, Optical Electronics, 4thEdn, Holt, Rinehart and Winston, 1991.

ADDITIONAL REFERENCES

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

Semester: I	Course Code: OPE-CC-613
Course Title: OPTOELECTRONIC DEVICES	**Credits: 3**

Prerequisite : Knowledge in Condensed Matter Physics.

Objective : To introduce the theories and to understand the fabrication, integration, working and applications of optoelectronic devices.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember band theory of solids.
CO2	Understand electronic and optical properties of materials.
CO3	Analyse the characteristics, parameters and performance of diodes and lasers
CO4	Differentiate electro, magnetic and acousto optic effects
CO5	Design phase, amplitude, transverse electro optic modulators and travelling wave modulators
CO6	Fabricate photo – detectors - conductors - resistors
CO7	Measure quantum yield and efficiency in solar cell technology

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember band theory of solids.	PSO1	R	F
CO2	Understand electronic and optical properties of materials.	PSO1	U	C
CO3	Analyse the characteristics, parameters and performance of diodes and lasers	PO2	An	M

CO4	Differentiate electro, magnetic and acousto optic effects	PO3	Ap	M
CO5	Design phase, amplitude, transverse electro optic modulators and travelling wave modulators	PO4/PSO3	Ap	M
CO6	Fabricate photo-detectors, conductors and resistors	PSO4	Cr	P
CO7	Measure quantum yield and efficiency in solar cell technology	PO3	E	P

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Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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, Blue LED, White light.

MODULE III: Laser diodes – basic concepts, heterojunction and injection lasers, output characteristics. Quantum well lasers, VCSEL, DFB and DBR lasers.

MODULE IV: 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 V: 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.

MODULE VI: 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.

REFERENCES

- AmnonYariv, Optical Electronics, Holt Rine hart & Winston, Philadelphia, 1991
- Ben G. Streetmann& Sanjay Banerjee, Solid State Electronic Devices, 5thEdn, 2000.
- Bhattacharya P., Semiconductor Optoelectronic Devices, PHI, New Delhi.1995
- Martin A. Green, Solar Cells: Operating principles, Technology and System Applications, Prentice-Hall Inc, Englewood Cliffs, NJ, USA, 1981.
- Poortmans J and Arkhipov V Thin Film Solar Cell: Fabrication, Characterizations and Applications, John Wiley & Sons, England 2006

ADDITIONAL REFERENCES

- AmnonYariv & PochiYeh, Optical Waves in Crystals, Wiley & Sons, 2003
- Bahaa E. A Saleh & Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, 1991
- Ghatak A. and Thyagarajan K., Optical Electronics, Cambridge University Press, NewDelhi, 1994.
- Joachim Piprek, Semiconductor Optoelectronic Devices, Academic Press, 2003

- R. P. Khare, Fiber Optics and Optoelectronics, Oxford University Press, 2004
- Rampal V.V., Photonics Elements and Devices, Wheeler, Allahabad,1992.

Semester: I	**Course Code: OPE-CC-614**
Course Title: FIBER OPTICS TECHNOLOGY	**Credits: 3**

Prerequisite : Knowledge in optics.

Objective : To familiarize students on fiber optics technology and make them knowledgeable about the present communication technology.

Learning Outcomes : On completion of the course the student will be able to

CO No.	**CO Statement**
CO1	Understand the important fiber parameters and fiber drawing techniques
CO2	Analyse various transmission characteristics and V-parameter
CO3	Discuss passive optical components and jointing techniques
CO4	Apply active components used in optical fiber communication
CO5	Evaluate important fiber parametric measurements
CO6	Measure attenuation using OTDR and spectrum analysis.

Tagging Course Outcomes

CO	**CO Statement**	**PO/ PSO**	**CL**	**KC**
CO1	Understand the important fiber parameters and fiber drawing techniques	PSO1	R	F, C
CO2	Analyse various transmission characteristics and V-parameter	PSO1	An	C, P
CO3	Discuss passive optical components and jointing techniques	PO3/ PSO2	Ap	P
CO4	Apply active components used in optical fiber communication	PSO2	Ap	P

CO5	Evaluate important fiber parametric measurements	PSO3	An	P, M
CO6	Measure attenuation using OTDR and spectrum analysis.	PO4/ PSO4	E, Cr	P, M

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Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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. Fiber drawing and fabrication methods: - Modified chemical vapor deposition (MCVD)and VAD techniques.

MODULE II: 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 III: LED and LD modulators. Coupling of light sources to fibers- (LED and LD) – Derivations. Theory and applications of Passive optical components: Connectors, couplers, splices, Directional couplers, gratings: FBGs and AWGs, reflecting stars: optical add drop multiplexers and SLMs.

MODULE IV: Active components: Optical Amplifiers (OAs) - Comparative study of OAs-SLA, FRA, FBA EDFA and PDFA based on signal gain, pump efficiency, Noise figure, insertion loss and bandwidth. Design and Characterization of forward pumped EDFA.

MODULE V: 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.

MODULE VI: OTDR- working principle and applications. OSA- basic block schematic and applications in measurements. Fibers for specific applications: Polarization maintaining fibers (PMF), dispersion shifted and dispersion flattened fibers, doped fibers. Photonic crystal fibers, Holly fibers.

REFERENCES

- Allen H Cherin, "An introduction to Optical Fibers", McGraw Hill Inc., Tokyo, 1995.
- Gerd Keiser, Optical Fiber Communications, McGraw Hill, 2000
- Govind P.Agrwal, "Fiber Optic Communication systems", John Wiley & Sons Inc., New York, 1997.
- John M senior, Optical Fiber Communications, PHI, 1992
- Maynbav, Optical Fiber Technology, Pearson Education, 2001.

ADDITIONAL REFERENCES

- Ajoy Ghatak and K. Thyagarajan. Introduction to Fiber optics: Cambridge University press, 1999.
- David Bailey and Edwin Wright, Practical Fiber Optics, Elsevier, 2003.
- Dennis Derikson, Fiber optic test and measurement, Prentice Hall, 1998.
- Franz and Jain, Optical Fiber Communication systems: Systems and Components, Narosa Publishers, 2004
- Joseph C Palais, Optical fiber Communications, Pearson Education.1998.

Semester: I	Course Code: OPE-CC-615
Course Title: GENERAL OPTOELECTRONICS LAB	**Credits: 4**

Prerequisite : Basic knowledge in Optoelectronics and Lasers.

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

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Understand the characteristics of optical sources and detectors.
CO2	Analyse the diffraction pattern through various optical devices.
CO3	Evaluate refractive index of substances.
CO4	Verify Malu's law

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the characteristics of optical sources and detectors.	PSO1	U	P
CO2	Analyse the diffraction pattern through various optical devices.	PO4/PSO2	An, Ap	P
CO3	Evaluate refractive index of substances.	PSO1	E	P
CO4	Verify Malu's law	PO3/PSO2	Cr, E	P, M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	

Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

Laser

1. Measurement of beam characteristics of lasers
2. Characteristics of laser diode
3. Diffraction through Single slit and Double slit
4. Diffraction through circular aperture
5. Diffraction - reflection grating
6. Diffraction - transmission grating
7. Refractive index of mirror and liquid
8. Acoustic grating – Compressibility of liquids
9. Goniometer – Angle of contact
10. Determination of Brewster's angle
11. Mach – Zehnder interferometer
12. Determination of Stefan's constant
13. Pull – Frich refractometer

Sensors and Detectors

14. Characteristics of LED and LDR
15. Characteristics of photodiodes and phototransistors
16. Characteristics of opto-coupler
17. Malu's law
18. Characteristics of solar cell

Semiconductors

19. Energy bandgap of Silicon
20. Fermi energy of Copper and fermi temperature
21. Determination of Planck's constant using LED
22. Hall effect

(At least 10 experiments should be provided)

Semester: II	Course Code: OPE-CC-621
Course Title: FIBER OPTIC SENSORS AND APPLICATIONS	**Credits: 3**

Prerequisite : Knowledge in fibre optics.

Objective : To familiarize the applications of fiber optics in various fields such as civil structures, aircrafts, nuclear power plants, chemical and petroleum industries and biomedical applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concept of fiber optic sensors and types
CO2	Understand the Fiber Bragg Grating based sensors and their commercial applications
CO3	Design interferometry sensors
CO4	Design and develop fiber optic gyroscopes
CO5	Analyse biomedical sensors and spectral sensors.
CO6	Fabricate distributed fiber optic sensors.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concept of fiber optic sensors and types	PSO1	R	F, C
CO2	Understand the Fiber Bragg Grating based sensors and their commercial applications	PSO1	U, Ap	C, P
CO3	Design interferometry sensors	PO3/ PSO2	Ap, Cr	P
CO4	Design and develop fiber optic gyroscopes	PSO2	E, Cr	P, M

CO5	Analyse biomedical sensors and spectral sensors.	PSO2	An	M
CO6	Fabricate distributed fiber optic sensors.	PO4/ PSO4	Ap, Cr	P, M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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.

MODULE IV: 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. Magnetostriction sensors. Lorentz force sensors.

MODULE V: Biomedical sensors, sensors for physical parameters, pressure, temperature, blood flow, humidity and radiation loss, sensors for chemical parameters. pH, oxygen, carbon dioxide, spectral sensors.

MODULE VI: 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.

REFERENCES

- Allen Dakin J and Culshow B., (Ed), Optical fiber sensors, Vol I, II, III, Artech House, 1998.
- Francis T.S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors,Marcel Dekker Inc., New York,2002.
- Pal B. P, Fundamentals of fiber optics in telecommunication and sensor systems, 14, Wiley Eastern, 1994.

ADDITIONAL REFERENCES

- Anna Grazia Mignani and Francesco Baldini, Bio-medical sensors using optical fibers, Report on Progress in Physics Vol 59.1, 1996.
- B.D Gupta, Fiber optic sensors: Principles and applications, New India Publishing Agency, New Delhi., 2006.
- Eric Udd (Ed), Fiber optic sensors: An introduction for engineers and scientists, John Wiley and Sons Ltd., 1991.
- Jose Miguel Lopez-Higuera (Ed), Handbook of optical fiber sensing technology, John Wiley and Sons Ltd., 2001.

Semester: II	Course Code: OPE-CC-622
Course Title: OPTICAL FIBER COMMUNICATION SYSTEMS	Credits: 3

Prerequisite : Basic knowledge in optical fiber.

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

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optical fiber.
CO2	Discuss nonlinear effects in optical fiber.
CO3	Discuss the soliton wave generation and its application.
CO4	Design Erbium doped fiber amplifier (EDFA)
CO5	Construct dense wavelength division multiplexing (DWDM).
CO6	Design power budget and rise time budget.
CO7	Apply software practice for designing of optical fiber communication systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optical fiber.	PSO1	R	C
CO2	Discuss nonlinear effects in optical fiber.	PO1	U	F
CO3	Discuss the soliton wave generation and its application.	PO1/PSO2	Ap,Cr	C
CO4	Design Erbium doped fiber amplifier (EDFA)	PO2/PSO3	Cr	M
CO5	Construct dense wavelength division multiplexing (DWDM).	PSO4	Cr	P
CO6	Design power budget and rise time budget.	PO4/ PSO4	Ap	M

CO7	Apply software practice for designing of optical fiber communication systems.	PO3/PSO2	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Classification of light wave systems, need for fiber based and all-optical systems. Nonlinear 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.

MODULE II: 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 III: 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.

MODULE IV: 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 V: 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.

MODULE VI: 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 GEPON.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester: II	Course Code: OPE-CC-623
Course Title: RESEARCH METHODOLOGY	Credits: 3

Prerequisite : None.

Objective : To familiarize students with basics of research and the research process and conducting research work and formulating research synopsis and report

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand objectives of doing research.
CO2	Formulate the research problem.
CO3	Distinguish appropriate research designs and techniques.
CO4	Identify methods of data collection and analysis strategies.
CO5	Develop enhanced writing skills to prepare technical reports.
CO6	Analyse a qualitative research report according to the evaluation criteria.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand objectives of doing research.	PSO1	R, U	F, C
CO2	Formulate the research problem.	PO1/PSO2	Ap	M
CO3	Distinguish appropriate research designs and techniques.	PO3/ PSO3	Cr	P
CO4	Identify methods of data collection and analysis strategies.	PSO3	U	C

CO5	Develop enhanced writing skills to prepare technical reports.	PO2/PSO4	Ap	P
CO6	Analyse qualitative research report according to the evaluation criteria.	PO4/ PSO4	An	M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

<u>COURSE CONTENT</u>

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.

MODULE II: 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 III: 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.

MODULE IV: 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 V: 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.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

- Day R A, How to Write and Publish a Scientific Paper, Cambridge University Press, 1989.
- Donald Cooper, Business Research Methods, Tata McGraw Hill, New Delhi, 2013.
- J.W Bames, Statistical Analysis for Engineers and Scientists, McGraw Hill, New York, 1994.
- Leedy P D, Practical Research: Planning and Design, MacMillan Publishing Co, 2001.
- Manna, Chakraborti, Values and Ethics in Business Profession, Prentice Hall of India, New Delhi, 2012.
- Sople, Managing Intellectual Property: The Strategic Imperative, Prentice Hall of India, New Delhi, 2012.

Semester: II	Course Code: OPE-CC-624
Course Title: DATA ANALYSIS AND IMAGE PROCESSING LAB	**Credits: 4**

Prerequisite : Knowledge in Programming

Objective : To provide programming skills for data analysis and image processing.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Identify the morphological and structural parameters of a compound.
CO2	Analyse the biomedical signals.
CO3	Apply histogram analysis and edge detection using image processing

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Identify the morphological and structural parameters of a compound.	PO3/PSO3	Ap, An, Cr, E	P, M
CO2	Analyse the biomedical signals.	PO3/PSO3	Ap, An, Cr, E	P, M
CO3	Apply histogram analysis and edge detection using image processing	PO3/PSO3	Ap, An, Cr, E	P, M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10

Create	10	10	10	10

COURSE CONTENT (List of Experiments)

Data Analysis

1. Determination of band gap from UV
2. Determination of a compound and its crystalline size from XRD
3. Determination of morphological and structural parameters of a compound from XRD
4. FFT and wavelet analysis of biomedical signals
5. Determination of CIE coordinates and colour parity from PL
6. Curve fitting

Image Processing

7. Electronic speckle pattern
8. Dynamic speckle pattern
9. Radon transforms
10. Histogram analysis of image
11. Image compression and resizing
12. Edge detection
13. Filtering of images
14. Image encryption and decryption using transforms
15. Image coding using ANN
16. Pattern classification using ANN
17. Loss measurements in image compression

(At least 10 experiments should be provided)

Semester: II	Course Code: OPE-CC-625
Course Title: PHOTONIC DESIGN, COMMUNICATION AND DIGITAL SIGNAL PROCESSING LAB	**Credits: 4**

Prerequisite : Knowledge in Programming

Objective : 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. Also, to perform the measurements of losses, Numerical aperture and dispersion in optical fibers.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Generate elementary waveforms in signal processing.
CO2	Simulate systems related to Digital Signal Processing
CO3	Design optical systems and optical fibers
CO4	Determine the losses and dispersion in optical fiber

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Generate elementary waveforms in signal processing.	PO3/PSO3	Cr	M
CO2	Simulate systems related to Digital Signal Processing	PO3/PSO3	Cr	M
CO3	Design optical systems and optical fibers	PO3/PSO3	Cr	M
CO4	Determine the losses and dispersion in optical fiber	PO4/PSO3	Ap, An, E	P, M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT (List of Experiments)

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

Digital Signal Processing Lab (using MATLAB)

6. DFT & IDFT
7. Convolution (with & without conv)
8. Scaling & Shifting
9. Digital Butterworth filters
10. Digital Chebyshev filters
11. Digital filters using FIR

Designing of Optical Systems and Optical Fibers

12. Design and analysis of various FBGs using OPTIGRATING
13. Design and analysis of different types of optical fibers using OPTIFIBER
14. Design and performance analysis of optical communication systems using OPTISYSTEM and OPTSIM

15. Design and performance analysis of various optical networks using OPTISYSTEM and OPTSIM
16. Design and analysis of various types of photonic crystal fibers using COMSOL MultiPhysics

Optical Communication

17. Measurement of losses- attenuation, bending in optical fibers.
18. Measurement of numerical aperture
19. Measurement of power gain using Erbium Doped fiber amplifier
20. Study of dispersion in optical fibers
21. Wave length division multiplexing of signals
22. Characterization of FBG and circulator
23. Analog and digital fiber optic links
24. Time division multiplexing of digital signals
25. WDM fiber optic link
26. Optical amplification in a WDM link
27. Adding and dropping of optical channels in a WDM link
28. Testing and analysis of OTDR
29. Testing and analysis of bit error rate & eye pattern analysis
30. Testing and analysis of power budgeting

(At least 10 experiments should be provided)

Semester: III	**Course Code: OPE-CC-631**
Course Title: SEMINAR	**Credits: 2**

Prerequisite **:** None.

Objective **:** To perform a seminar relevant to the field of optoelectronics and optical communication.

Learning Outcomes **:** To carry out a seminar presentation relevant to the field of optoelectronics and optical communication. The students have to submit a report, exhibit (if any) and have to make a presentation before the expert committee.

Semester: III	Course Code: OPE-CC-632
Course Title: MINI PROJECT (DESIGN AND DEVELOPMENT)	**Credits: 2**

Prerequisite : None.

Objective : To perform a project relevant to the field of optoelectronics and optical communication.

Learning Outcomes : To carry out a project relevant to the field of optoelectronics and optical communication. The students have to submit a report, exhibit (if any) and have to make a presentation before the expert committee.

Semester: III	Course Code: OPE-CC-633
Course Title: STUDY ON CURRENT ADVANCED RESEARCH	**Credits: 3**

Prerequisite : None.

Objective : To introduce students to recent developments in Photonics and technologies of Photonics for solving real life problems.

Learning Outcomes : Students have to select a technologically important relevant topic for this investigation. They have to submit a detailed report on this investigation.

Semester: III	Course Code: OPE-D-634
Course Title: DISSERTATION PHASE I	**Credits: 8**

Prerequisite **:** None.

Objective **:** To enable students to develop deep knowledge, understanding, capabilities and attitudes in Photonics. It should improve their subject knowledge level, experimental and report making skills. It should also enhance aptitude for research and assist career growth.

Learning Outcomes **:** Each student has to submit a first level of report of the M.Tech project that they are undergoing at the end of the 3rd semester.

Semester: IV	Course Code: OPE-D-641
Course Title: DISSERTATION PHASE II	Credits: 16

Prerequisite : None.

Objective : To enable the students to develop deep knowledge, understanding, capabilities and attitudes in Photonics. It should improve their subject knowledge level, experimental and report making skills. It should also enhance aptitude for research and assist career growth.

Learning Outcomes : At the end of 4^{th} semester, each student has to submit a dissertation consisting of the work they have done and findings obtained during their project.

DISCIPLINE SPECIFIC ELECTIVES

Semester:	Course Code: OPE-DE-601
Course Title: DIGITAL COMMUNICATION	Credits: 3

Prerequisite : Knowledge in signal processing.

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

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in signal processing.
CO2	Design of different modulation techniques.
CO3	Evaluate the bit error rate for different modulation techniques.
CO4	Discuss multiple access techniques.
CO5	Construct of source coding.
CO6	Apply MATLAB for designing of various communication systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in signal processing.	PSO1	R	C
CO2	Design of different modulation techniques.	PO2/PSO2	Ap, Cr	M
CO3	Evaluate the bit error rate for different modulation techniques.	PO3	E	P
CO4	Discuss multiple access techniques.	PSO2	U	C

CO5	Construct of source coding.	PO1/PSO2	Cr	P
CO6	Apply MATLAB for designing of various communication systems.	PO4/ PSO4	Ap	M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: Pulse modulation – Sampling process – PAM – Quantization – PCM – Noise in PCM system - TDM – Digital multiplexers – Modifications of PCM – Delta modulation – DPCM – ADPCM – ADM. Base band 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 III: Application of pass band 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.

MODULE IV: 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 V: 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.

MODULE VI: 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 theorem.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-602
Course Title: ADVANCED DIGITAL SIGNAL PROCESSING	**Credits: 3**

Prerequisite : Knowledge of handling digital signals.

Objective : To learn the principles of advanced digital signal processing techniques.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Comprehend characteristics of Multi-dimensional discrete signals and systems.
CO2	Analyze and process signals using various transform techniques.
CO3	Apply Multi rate signal processing of signals through systems.
CO4	Design and Implementation of Finite Impulse Response (FIR)
CO5	Design of Adaptive Filter.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Comprehend characteristics of Multi-dimensional discrete signals and systems.	PSO4	R	F, C
CO2	Analyze and process signals using various transform techniques.	PSO4	U	C
CO3	Apply Multi rate signal processing of signals through systems.	PSO4	Ap	P

CO4	Design and Implementation of Finite Impulse Response (FIR)	PO3/ PSO4	Ap	P
CO5	Design of Adaptive Filter.	PO3/ PSO4	An	P

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: Discrete Fourier analysis of multi-dimensional signals: discrete Fourier series representation of rectangular 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 III: 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.

MODULE IV: Decimation and interpolation, identities, cascading, sampling-rate alteration devices, poly-phase decomposition, multi-stage systems.

MODULE V: 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.

MODULE VI: Adaptive filters: introduction to LMS adaptive FIR filters, basic Wiener theory and LMS algorithm.

REFERENCES

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

ADDITIONAL REFERENCES

- J S Lim, Two-dimensional Signal and Image Processing, Prentice Hall, 1990.
- Li Tan & Jean Jiang, Digital Signal Processing, Academic Press, Elsevier Inc., 2013.
- R.E. Crochiere, Multirate Digital Signal Processing, Prentice Hall. Inc., 1983.
- Tamal Bose, Digital Signal and Image Processing, John Wiley publishers, 2004.

Semester:	Course Code: OPE-DE-603
Course Title: HOLOGRAPHY AND SPECKLE INTERFEROMETRY	**Credits: 3**

Prerequisite : Knowledge in optics.

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

Learning Outcomes: To provide theoretical fundamentals and conditions for realization of Holographic and Speckle Interferometric techniques.

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optics.
CO2	Development of construction and recording of holographic image.
CO3	Evaluate the quantitative measurement of holographic image quality.
CO4	Discuss about Speckle pattern and its application.
CO5	Construction of speckle pattern.
CO6	Apply the technique of speckle interferometry in different research area.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optics.	PSO1	R	C
CO2	Development of construction and recording of holographic image.	Po2/PSO2	Ap, Cr	M
CO3	Evaluate the qualitative measurement of holographic image .	PSO3	E	P

CO4	Discuss about Speckle pattern and its application.	PSO1	U	P
CO5	Construction of speckle pattern.	PO1/PSO2	Cr	P
CO6	Apply the technique of speckle interferometry in different research area.	PO1/ PSO4	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Optical Holography: basic principle, recording and reconstruction, types of holograms: transmission hologram, reflection hologram, phase holograms, rainbow hologram (qualitative analysis only).

MODULE II: Experimental techniques, detectors and recording materials, holographic optical elements, holographic scanners, application of holography: pattern recognition, information storage.

MODULE III: 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.

MODULE IV: Loading methods, holographic contouring/shape measurement, dual wavelength method, dual refractive index method, digital holography, holographic photoelasticity, optical coherence tomography.

MODULE V: Speckle Metrology: speckle phenomena, statistics of speckle pattern, classification, objective speckle pattern, subjective speckle pattern, speckle techniques: speckle photography, speckle interferometry, speckle shear interferometry.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-604
Course Title: INTEGRATED OPTICS	**Credits: 3**

Prerequisite : Knowledge in Optics.

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

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand the principle of optical amplification.
CO2	Discuss the theory of optical waveguides and mode coupling.
CO3	Apply fabrication techniques for optical waveguides.
CO4	Fabricate optical integrated circuits.
CO5	Develop integrated optical detectors.
CO6	Design photonic circuits for optical sensing.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the principle of optical amplification.	PSO1	R,U	F, C
CO2	Discuss the theory of optical waveguides and mode coupling.	PO1/PSO3	Ap, E	P
CO3	Apply fabrication techniques for optical waveguides.	PO3/ PSO2	Ap, Cr	P, M

CO4	Fabricate optical integrated circuits.	PO4/PSO3	Ap	M
CO5	Develop integrated optical detectors.	PO1/PSO3	Ap, Cr	P, M
CO6	Design photonic circuits for optical sensing.	PO4/ PSO4	An	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Optical amplifiers: principles of optical amplification, semiconductor optical amplifier, applications, merits and demerits, photonic switching principles.

MODULE II: 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. Guided-wave control-electro optic, acousto-optic magneto-optic and nonlinear optics. Recent trends in optical integrated circuits.

MODULE III: Materials and fabrication techniques of optical waveguides, guided wave excitation and wavelength evaluation, passive waveguide devices, functional optical waveguide devices.

MODULE IV: 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 V: 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.

MODULE VI: System design using photonic circuits, application DIC in telecommunication, switching, sensing, signal processing and computing, integrated optic sensors.

REFERENCES

- Nishihara. H, Haruna M. and Suhara T, Optical Integrated Circuits, McGraw Hill, New York, 1989.
- Hunsperger R.G, Integrated Optics Theory and Technology, 3rdEdn, Springer Verlag, New York. 1991.
- Marcel Dekker, Integrated Opto Circuits, 1982.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-605
Course Title: SATELLITE AND MOBILE COMMUNICATIONS	**Credits: 3**

Prerequisite : Knowledge in basic communication.

Objective : **(i)** To understand the engineering impact of the various satellite components and its performance.

(ii) To impart the fundamentals concepts of mobile communication systems.

(iii) To introduce various technologies and protocols involved in mobile communication.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand about satellite orbits and launching methods.
CO2	Discuss the satellite links.
CO3	Understand the cellular concepts.
CO4	Apply the multiple access techniques in cellular communication.
CO5	Design a GSM.
CO6	Create CDMA in cellular environment.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand about satellite orbits and launching methods.	PSO1	R,U	F, C
CO2	Discuss the satellite links.	PO1/PSO3	Ap	P

CO3	Understand the cellular concepts.	PO3/ PSO2	U	C
CO4	Apply the multiple access techniques in cellular communication.	PO4/PSO3	Ap, Cr	P, M
CO5	Design a GSM.	PO1/PSO3	Ap, Cr	P, M
CO6	Create CDMA in cellular environment.	PO4/ PSO4	An, E	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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.

MODULE IV: 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 V: 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.

MODULE VI: FEC coding and CDMA, multiuser detection, CDMA in cellular environment. space division multiple access and smart antennas.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-606
Course Title: LASER MATERIAL PROCESSING	**Credits: 3**

Prerequisite : Knowledge in Differential Equation, Fourier Series, Integral transforms and Vector spaces.

Objective : To provide fundamental exposure to students in understanding application of lasers in material processing

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts in Lasers.
CO2	Understand the principles of laser cavities and population inversion techniques.
CO3	Discuss different methods of high-power generation in laser systems
CO4	Apply laser systems for material characterisation.
CO5	Apply lasers for welding in industry.
CO6	Design laser systems in various fields of Science and Technology.
CO7	Apply lasers for cutting in industry.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts in Lasers.	PSO5	R	F and C
CO2	Understand the principles of laser cavities and population inversion techniques.	PSO5	U	C
CO3	Discuss different methods of high-power generation in laser systems	PO3/PSO5	Ap	P

CO4	Apply laser systems for material characterisation.	PO3/PSO5	Ap, E	P, M
CO5	Apply lasers for welding in industry.	PO2/PSO5	Ap, Cr	M
CO6	Design laser systems in various fields of Science and Technology.	PO2/PSO5	Cr, E	M
CO7	Apply lasers for cutting in industry.	PO3/PSO5	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Characteristics of Lasers - spontaneous and induced transitions, Einstein's coefficients, homogenous population inversion, three and four level systems, rate equations.

MODULE II: Q-switching, methods of Q-switching- methods, - electro optic modulation- Mode locking- Different types of lasers – Nd YAG, He-Ne, Fibre lasers

MODULE III: Laser assisted synthesis of nanomaterials- Laser assisted thin film deposition – Methods – experimental techniques – Laser applications, Models of laser heating- choice of laser for material processing-laser welding, drilling, machine and cutting.

MODULE IV: Laser assisted material characterizations – applications to study the thermal and optical property of materials-Photothermal and Photoacoustics- Defects in materials – photothermal imaging – Photoacoustic imaging.

MODULE V: Laser welding: different modes of laser beam welding- comparison between laser beam and electron beam welding-influence of different parameters-absorptivity-welding speed-focusing conditions-advantages and limitations of laser welding-laser welding of industrial materials-recent developments in laser welding techniques.

MODULE VI: 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.

REFERENCES

- Ian. W.Boyd," Laser Processing of Thin films and Microstructures",Springer-Verlag,1987.
- W.W.Duley, " Laser Processing and Analysis of Materials", Plenum Press, New York, 1983.
- D. P Almond and P.M Patel, Photothermal Science and Techniques, Chapman and Hall, 1996.
- Jeffrey A. Sell, Photothermal Investigations of Solids and fluids, Academic Press, Inc, 1989.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-607
Course Title: IMAGE PROCESSING	**Credits: 3**

Prerequisite : Basic knowledge in digital image processing.

Objective : To provide basic of digital image representation and processing techniques.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in signal processing.
CO2	Discuss about various transforms of two-dimensional sequences.
CO3	Discuss about the two-dimensional transform coding.
CO4	Design and development of spatial filtering
CO5	Design and development of wiener filtering
CO6	Apply software practice for designing of image compression technique.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in signal processing.	PSO1	R	C
CO2	Discuss about various transforms of two-dimensional sequences.	PO1	U	F
CO3	Discuss about the two-dimensional transform coding.	PO1/PSO2	Ap,Cr	C

CO4	Design and development of spatial filtering	PSO3	Cr	M
CO5	Design and development of wiener filtering	PSO4	Cr	P
CO6	Apply software practice for designing of image compression technique.	PO3/PSO2	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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.

MODULE IV: 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 V: Image restoration, system identification, DTF from degraded image spectrum, noise modeling. Wiener filtering - derivation of filter transfer function - pseudo and inverse psuedo filtering.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-608
Course Title: PATTERN RECOGNITION	Credits: 3

Prerequisite : Basic knowledge in digital image processing.

Objective : To provide an idea about pattern recognition.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in signal processing.
CO2	Discuss about the image enhancement technique.
CO3	Discuss about the shape analysis.
CO4	Design and development of Hough transform.
CO5	Apply software practice for designing of pattern recognition.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in signal processing.	PSO1	R	C
CO2	Discuss about the image enhancement technique.	PO1	U	F
CO3	Discuss about the shape analysis.	PO1/PSO2	Ap, Cr	C
CO4	Design and development of Hough transform.	PSO2/PSO3	Cr	M
CO5	Apply software practice for designing of pattern recognition.	PSO1	R	C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: Basics of image processing - sampling, 2 dimensional transforms, image enhancement, smoothening, sharpening, edge detection, image segmentation, boundary extraction.

MODULE III: 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.

MODULE IV: 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 V: 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

MODULE VI: 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 arrangement, measurements, more features description and classification of arrangements.

REFERENCES

- Daisheng Luo, Pattern Recognition and Image Processing, Horwood Publishing, England, 1998.
- Milam Sonka, Vaclav HLAVAC, Roger Boyle, Image Processing, Analysis and Machine Vision, 2ndEdn, Thomson Learning, 2001.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-609
Course Title: OPTICAL INSTRUMENTATION	**Credits: 3**

Prerequisite : Basic knowledge in geometrical optics and optical phenomena.

Objective : To learn the basic concepts, theories and applications of optical instruments.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles and concepts of optical phenomena and optometry
CO2	Understand the theories in optical instrumentation
CO3	Analyze optical devices and materials
CO4	Design optical components and interferometers
CO5	Apply interferometry and ellipsometry in research
CO6	Fabricate opto-medical instruments, lenses, camera and projector

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles and concepts of optical phenomena and optometry	PSO1	R	F and C
CO2	Understand the theories in optical instrumentation	PSO1	U	C
CO3	Analyze optical devices and materials	PO2	An	M
CO4	Design optical components and interferometers	PO2	E	M
CO5	Apply interferometry and ellipsometry in research	PO1/PSO2	Ap	P

CO6	Fabricate opto-medical instruments, lenses, camera and projector	PO4/PSO3	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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.

MODULE IV: Lens design optimization, opto-medical instruments, optical coherence tomography, infrared instrumentation; holographic camera; IR telescopes; Moire self- imaging and speckle metrology.

MODULE V: 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.

MODULE VI: Photometry, projection systems and refractometers -different sources for optical experiments – lasers – basic laws of photometry, Abbe and Kohler illuminations – episcope, epi-dioscope, slide and overhead projectors – computer-based projection systems – polarizing instruments. Ellipsometry and applications in materials research.

REFERENCES

- Fowles G.R., Introduction to Modern Optics, 2nd Edition, Holt, Rienhart and Winston, 1975.
- Bruce H &Walkar, Optical Engineering Fundamentals, PHI, 2003
- Warren J. Smith, Modern Optical Engineering: The Design of Optical System, 2nd Edn, Mc Grew Hill, 1990
- Douglas A. Skoog, F James Holler and Timothy A Nieman, Principles of Instrumental Analysis, 5th Edn, Hartcourt Image Publishers, 1998
- Donald F. Jacob, Fundamentals of Opticals Engineering, Mc Grew Hill, 1943
- Hank H. Karow, Fabrication Methods for Precision Optics, John Wiley and Sons, New York, 1993.
- David Malacara, Optical Shop Testing, John Wiley and Sons, New York, 1992.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-610
Course Title: DIGITAL SYSTEM DESIGN	**Credits: 3**

Prerequisite : Knowledge in designing complex, high speed digital systems.

Objective : To expertise students on different methods for logic representation, manipulation and optimization for both combinational and sequential logic.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand the concepts of digital design by using combinational and sequential modules.
CO2	Analysis of combinational systems implementation with ROM's and PLA's.
CO3	Analysis of multi-module implementation of combinational and sequential systems.
CO4	Analysis of networks in the canonical implementation.
CO5	Discuss different sequential and combinational modular networks.
CO6	Discuss Synchronous and Asynchronous sequential circuits

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the concepts of digital design by using combinational and sequential modules.	PSO1	U	F,C

CO2	Analysis of combinational systems implementation with ROM's and PLA's.	PO3/PSO2	An,Ap	P
CO3	Analysis of multi-module implementation of combinational and sequential systems.	PO3/ PSO2	An,Ap	P
CO4	Analysis of networks in the canonical implementation.	PO3/PSO2	An,Ap	P
CO5	Discuss different sequential and combinational modular networks.	PO4/PSO1	U	F, C
CO6	Discuss Synchronous and Asynchronous sequential circuits	PO2/ PSO1	U	F,C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: Implementation of multi-module combinational systems – decoder networks, Multiplexer trees, demultiplexer network, encoder network, shifter network and barrel shifters.

MODULE III: 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.

MODULE IV: 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.

MODULE V: Multi-module implementation of sequential systems – multi-module registers – shift registers and RAMs – multi-module counters. Introduction to synchronous digital systems: state diagram, state tables, state reduction methods, state assignments, Mealy and Moore machines.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-611
Course Title: OPTICAL SIGNAL PROCESSING	**Credits: 3**

Prerequisite : None.

Objective : To expertise students on the fundamentals of optical signal processing and its design considerations.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in optical signal processing.
CO2	Design and development of a soliton based optical clock generator
CO3	Evaluate Fourier transforms in optics.
CO4	Discuss about optical spectrum analyzer (OSA).
CO5	Design and fabricate photo detector arrays.
CO6	Apply optical computing based on optical polarizations

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in optical signal processing.	PSO1	R	F, C
CO2	Design and development of a soliton based optical clock generator	PO1/PSO2	Ap, Cr	M
CO3	Evaluate Fourier transforms in optics.	PO3/ PSO2	E	P
CO4	Discuss about optical spectrum analyzer (OSA).	PSO3	U	C

CO5	Design and fabricate photo detector arrays.	PO1/PSO2	Cr	P
CO6	Apply optical computing based on optical polarizations	PO4/ PSO4	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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).

MODULE II: Optical clock generation, design of a soliton based optical clock generator, optical bistability, applications- optical gates.

MODULE III: 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.

MODULE IV: 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 V: Ideal photo detector, noise in detection. CCD arrays: fabrication and layout, specifications, challenges faced in fabrication and design of photo detector arrays.

MODULE VI: Optical computing based on optical polarizations. Encoding and decoding of binary data using polarization states. Design of decoding and encoding systems.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-612
Course Title: ARTIFICIAL NEURAL NETWORKS	Credits: 3

Prerequisite : Knowledge in computing.

Objective : To familiarize the concept of biological neural network and implementation of neural networking for problem solving in real life.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Deals with the principle and working of biological neural network, adaptation of various paradigms and learning principles.
CO2	Describes fundamental theorems and their applications
CO3	Deals with Radial basis function network for modelling applications, multilayer perceptrons and associative learning rules
CO4	Deals with Self organized maps with unsupervised learning, winner networks and adaptive resonance theory for computational applications
CO5	Deals with self-organizing maps and issues regarding linearly separable and non-linearly separable patterns.
CO6	Deals with Hopfield network, Boltzmann machine and applications.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Deals with the principle and working of biological neural network, adaptation of various paradigms and learning principles.	PSO1	R, U	F, C
CO2	Describes fundamental theorems and their applications	PSO1	Ap, E	C, P

CO3	Deals with Radial basis function network for modelling applications, multilayer perceptrons and associative learning rules	PO3/ PSO2	Ap, Cr	P
CO4	Deals with Self organized maps with unsupervised learning, winner networks and adaptive resonance theory for computational applications	PSO2	E, Cr	P, M
CO5	Deals with self-organizing maps and issues regarding linearly separable and non-linearly separable patterns.	PSO2	Cr, An	M
CO6	Deals with Hopfield network, Boltzmann machine and applications.	PO4/ PSO4	Ap, Cr	P, M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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) – Backpropagation algorithm.

MODULE III: RBF networks- Cover's theorem on separability of patterns, comparison of RBF networks and MLPs. Associative learning- Unsupervised Hebb rule, Instar and outstar rules.

MODULE IV: Competitive learning- Winner –Take-All networks, Learning Vector Quantizers, Counter propagation networks, Adaptive Resonance Theory (ART) - ART1 clustering algorithm, ART1 network architecture.

MODULE V: Self-organizing maps (SOM), Support vector machines: optical hyperplane for linearly separable and non-separable patterns, design of support vector machines. Principal component analysis (PCA) networks.

MODULE VI: 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.

REFERENCES

- Martin T. Hagan, Howard B. Demuth & Mark Beale, Neural Network Design,Vikas Thomson learning, 2014.
- Mohamad H. Hassoun, Fundamentals of Artificial Neural Networks, 1995.
- Simon Haykin,Neural Networks,A Comprehensive Foundation, Pearson Education, 1999.

ADDITIONAL REFERENCES

- Bose &Liang,Neural Network Fundamentals, McGraw Hill, 1995.
- James A Freeman, David M. Skapura,Neural Networks, Algorithms, Applications and Programming Techniques,Pearson Education, 1991.
- KishanMehrotra, Chilukuri K. Mohan, Sanjay Ranka: Elements of Artificial Neural Networks, Penram International Publishing (India), 2009.

Semester:	Course Code: OPE-DE-613
Course Title: NONLINEAR OPTICS	**Credits: 3**

Prerequisite **:** Basic concepts in optics.

Objective **:** To introduce the theory of Nonlinear Optics and its impact on technological applications.

Learning Outcomes **:** On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts and quantities in nonlinear optics
CO2	Understand theories of nonlinear optical phenomena and propagation of electromagnetic wave
CO3	Analyse nonlinear optical coefficients
CO4	Formulate nonlinear interactions and parametric amplification
CO5	Apply degenerate four wave mixing and Z-scan
CO6	Fabricate experimental set up for optical harmonic generation and frequency tuning

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts and quantities in nonlinear optics	PSO1	R	F and C
CO2	Understand theories of nonlinear optical phenomena and propagation of electromagnetic wave	PSO1	U	C
CO3	Analyse nonlinear optical coefficients	PO2	An	M

CO4	Formulate nonlinear interactions and parametric amplification	PO2	E	M
CO5	Apply degenerate four wave mixing and Z-scan	PO1/PSO2	Ap	P
CO6	Fabricate experimental set up for optical harmonic generation and frequency tuning	PO4/PSO3	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Nonlinear optical susceptibility tensor, on the physical origins of the nonlinear optical coefficients, electromagnetic formulation of nonlinear interactions- harmonic generation, sum and difference frequency generation. Optical second harmonic generation- experimental set up.

MODULE II: Parametric generation of light, Basic equations of parametric amplification, parametric oscillation, frequency tuning, experimental arrangement, frequency up and down conversion.

MODULE III: Third order optical nonlinearities: nonlinear absorption- Saturable and reverse saturable absorption, two photon absorption, optical limiting, nonlinear refractive index - intensity dependent refractive index, self-focusing and defocusing, optical bi-stability- absorptive and dispersive, optical switching.

MODULE IV: Stimulated Raman Scattering, Stimulated Brillouin scattering. Nonlinear optical materials: growth and characterization- Degenerate four wave mixing and Z-scan technique.

MODULE V: 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.

MODULE VI: Beam coupling and phase conjugation by photorefractive effect, self- induced transparency, self- phase modulation.

REFERENCES

- Ammon Yariv, Quantum Electronics 3rdEdn, John Wiley, New York, 1989.
- Govind P. Agrawal, Nonlinear Fiber Optics, 3rdEdn, Academic Press, New Delhi, 2001.
- Pochi Yeh, Introduction to Photorefractive Nonlinear Optics, John Wiley & Sons, New York, 1993

ADDITIONAL REFERENCES

- Fischer R.A (Ed), Optical Phase Conjugation, Academic Press, San Diego, 1983.
- R.D. Guenther, Modern Optics, John Wiley & Sons, 1990.
- Rampal V.V, Photonics, Elements and Devices, Wheeler, Allahabad, 1992.
- Richard L. Sutherland, Handbook of NonLinear Optics, Marcal Dekker, 1996.
- Robert W Boyd, NonLinear Optics, 2ndEdn, Academic Press, 2003.
- Singh N.B, Growth and characterization of Nonlinear Optical Materials, Pergamon, 1990.

Semester:	Course Code: OPE-DE-614
Course Title: NANOPHOTONICS	**Credits: 3**

Prerequisite **:** Basic knowledge in nanoscience.

Objective **:** To learn fundamentals of nanotechnology and its applications in Photonics.

Learning Outcomes **:** On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of nanoscale interactions, photonic band gap, nanolithography and biomaterials
CO2	Understand the nature and properties of nanophotonic materials
CO3	Differentiate quantum - wells, wires, dots, rings, confinements and cutting
CO4	Analyse XRD, Raman, IR, XPS, SEM, TEM and SPM.
CO5	Fabricate nanostructures, photonic crystals, nanophores and carbon nanotubes
CO6	Apply nanophotonics in biotechnology and nanomedicine
CO7	Develop thin films using MBE, PLD and CVD

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts of nanoscale interactions, photonic band gap, nanolithography and biomaterials	PSO1	R	C
CO2	Understand the nature and properties of nanophotonic materials	PSO1	U	C

CO3	Differentiate quantum - wells, wires, dots, rings, confinements and cutting	PO3	Ap	M
CO4	Analyse XRD, Raman, IR, XPS, SEM, TEM and SPM.	PO2	An	M
CO5	Fabricate nanostructures, photonic crystals, nanophores and carbon nanotubes	PO1/PSO2	Ap	P
CO6	Apply nanophotonics in biotechnology and nanomedicine	PO4/PSO3	Cr	P
CO7	Develop thin films using MBE, PLD and CVD	PSO4	Cr	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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.

MODULE IV: Growth and characterization of nanomaterials- epitaxial growth-MBE-PLDCVD- nanochemistry-XRD- Raman-IR-XPS-SEM- TEM- SPM.

MODULE V: Organic quantum confined structures- carbon nanotubes-graphene characterization, properties and applications. Concept of photonic band gap – photonic crystals-theoretical modelling-features-optical circuitry-photonic crystal in optical communication nonlinear photonic crystal-applications.

MODULE VI: 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.

REFERNCES

- Colm Durkan, Current at the Nanoscale, Imperial College Press, 2007.
- J.M. Martinez-Duart,R.J. Martin Palma,F. Agulle Rueda, Nanotechnology for Microelectronics and Optoelectronics , Elsevier,2006.
- Lukas Novotny and Bert Hecht, Principles of Nano-Optics, Cambridge University Press, 2006.
- Paras N. Prasad, Nanophotonics, Wiley Interscience,2004.

ADDITIONAL REFERENCES

- Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Juan Ariel Levenson,Nanophotonics, ISTE Publishing Company, 2006.
- John D. Joannopoulo, Robert D. Meade and Joshua N. Winn, Photonic Crystals, Prienceton University Press, 2008.
- Mark L. Brongersma and Pieter G. Kik, Surface Plasmon Nanophotonics, Springer – Verlag, 2006.

Semester:	**Course Code: OPE-DE-615**
Course Title: SOLAR PHOTOVOLTAICS	**Credits: 3**

Prerequisite : Basic Knowledge in semiconductor Physics.

Objective : To introduce the fundamental theories and technological aspects of power generation using solar photovoltaic technology.

Learning Outcomes : On completion of the course the student will be able to

CO No.	**CO Statement**
CO1	Remember the principles and concepts in solar photovoltaic field.
CO2	Understand different types of photovoltaic materials and their properties
CO3	Apply the fabrication techniques of thin film technology
CO4	Analyse solar cell parameters
CO5	Design solar cells and PV modules
CO6	Develop materials for solar photovoltaic applications
CO7	Measure losses and quantum efficiency in a solar cell

Tagging Course Outcomes

CO	**CO Statement**	**PO/ PSO**	**CL**	**KC**
CO1	Remember the principles and concepts in solar photovoltaic field.	PSO1	R	F and C
CO2	Understand photovoltaic materials and their properties	PSO1	U	C
CO3	Apply the fabrication techniques of thin film technology	PO1/PSO2	Ap	P

CO4	Analyse solar cell parameters	PO2	An	M
CO5	Design solar cells and PV modules	PO4/PSO3	Ap	M
CO6	Develop materials for solar photovoltaic applications	PSO4	Cr	P
CO7	Measure losses and quantum efficiency in a solar cell	PO3	E	P

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Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Solar cell materials and their properties. Solar cell research: technology (silicon, organic, Dye sensitized, perovskites), applications and limitations. Device fabrication: Semiconductor junctions: P-N junction, P-I-N junction and its properties. Solar cell structures: homo & hetero junction solar cells, single & multi-junction solar cells. Substrate and Superstrate configuration.

MODULE II: Fabrication techniques: Diffusion, Electrodeposition, Thin film technology: physical vapour deposition (PVD) techniques, chemical vapour deposition (CVD) techniques- MOCVD and PECVD.

MODULE III: Solar cell parameters, Losses in a solar cell: optical losses and electrical losses. Effects of series & parallel resistance, solar radiation and temperature on efficiency. Minimization of optical losses and recombination.

MODULE IV: Design of solar cells: high Isc, high Voc, high FF. Characterization of solar cells: Measurements of solar cell parameters, Solar Simulator- I-V measurement, L-I-V characteristics, quantum efficiency measurement.

MODULE V: PV Modules: solar PV modules from solar cells, series and parallel connections, design and structure of PV modules, power output, batteries for PV systems.

MODULE VI: DC-DC converters, DC-AC converters, PV system configurations, Hybrid PV systems. Photovoltaic system design and applications.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-616
Course Title: ENGINEERING MATHEMATICS	**Credits: 3**

Prerequisite : Knowledge in Differential Equation, Fourier Series, Integral transforms and Vector spaces.

Objective : To provide fundamental exposure to students in understanding theories in Optoelectronics and Laser Technology and its applications.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the principles of Fourier series, infinite series, transformations and integrals.
CO2	Understand Fourier transform, integral transform and Wavelet transform methods,
CO3	Understand and Apply Laplace and Z transform techniques to Physical and Optical systems
CO4	Apply integral transform methods, linear transformation and β,γ, and δ functions.
CO5	Understand and Apply Fractal and multi fractal analysis to electronics
CO6	Analyze theoretically the differential equations and Special functions
CO7	Apply differential equations and Special functions

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the principles of Fourier series, infinite series, transformations and integrals.	PSO5	R	F and C
CO2	Understand Fourier transform, integral transform methods, linear transformation, Wavelets and wavelet transforms	PSO5	U	C

CO3	Understand and Apply Laplace transform techniques to Physical and Optical systems	PO3/PSO5	Ap	P
CO4	Apply integral transform methods, linear transformation and β,γ, and δ functions.	PO3/PSO5	An	P
CO5	Understand and Apply Fractal analysis	PO2/PSO5	Cr	M
CO6	Analyze theoretically the differential equations and Special functions	PO2/PSO5	Cr	M
CO7	Apply differential equations and Special functions	PO3/PSO5	Ap	P

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Fourier series – Dirichlet's conditions – Fourier series of even and odd functions– Complex form of Fourier series – Fourier integral and it's complex form – Applications –Square wave, full wave rectifier, wave equation.

MODULE II: Fourier transforms – Fourier sine and cosine transforms – Convolution theorem and Parseval's identity– Applications –FT by lens, FT of Gaussian function, FT of derivatives. Introduction to Wavelets- Types of wavelets –Wavelet transform- Continuous and Discrete – Applications.

MODULE III: Laplace transform of elementary functions – Inverse Laplace transforms – Methods of finding Inverse Laplace transforms – Solutions of simple differential equations– Applications. Z Transform- Applications

MODULE IV: Linear Transformations – change of bases – matrix representation of linear transformation. Eigen values – Eigen vectors – Hermitian and unitary matrices(transformation) β, γ, δ Functions: Properties and applications of each.

MODULE V: Introduction to fractals – Characteristics - Classification of fractals - geometric fractals- Fractal dimension- Box counting and Power spectral dimensions - Multifractals - Applications of Fractals in electronics

MODULE VI: Special functions: LEGENDRE-Frobenius method for solving second order ordinary differential equations with variable coefficients. Bessel, Legendre, Recurrence relations, generating functions and Rodrigues formulae for the Bessel functions.

REFERENCES

- G.B. Arfken, H J Weber, Mathematical Methods for Physicist, 4th ed. Academic Press, 1995.
- Mary Boas, Mathematical Methods in Physical Sciences, Wiley, 2005.
- P.M. Morse and H. Feshbach, Methods of Theoretical Physics, 1953.
- S. Hassani, Mathematical Physics: A Modern Introduction to its Foundations, 1998.
- Stephen J. Chapman, MATLAB Programming for Engineers, Thomson Press, 2007.
- K.P. Soman and K.I. Ramachandran, Insight into Wavelets, Prentice Hall of India, 2004
- George Bachman, Lawrence Narici, and Edward Beckenstein, Fourier and Wavelet analysis, Springer-Verlag New York, Inc, 2000.
- Paul S Addison, Fractals and chaos, IOP publishing, 2001.

ADDITIONAL REFERENCES

- Dr. B.S. Grewal, Higher Engineering Mathematics, 2005.
- Hassani**,** Sadri, Mathematical Methods of Physics and Related Fields2nd ed., 2009.
- Jon Mathews and Robert L. Walker, Mathematical Methods of Physics, University of Cambridge, 1970.
- Kreyszig, Erwin, Advance Engineering Mathematics, Loyola Marymount University, 10^{th}Edition, 2012.

- Qian Tao, Vai Mang I, and Xu Yuesheng Wavelet analysis and applications, Part of Springer Science, Birkhäuser Verlag, Switzerland 2007.

Semester:	Course Code: OPE-DE-617
Course Title: LASER REMOTE SENSING	**Credits: 3**

Prerequisite **:** Knowledge in lasers.

Objective **:** To expertise students on the fundamentals of laser remote sensing and its design considerations.

Learning Outcomes **:** On completion of the course, the student will be able to

CO No.	CO Statement
CO1	Understand the structure and composition of Earth's atmosphere.
CO2	Discuss about different types of clouds and its properties.
CO3	Explain laser remote sensing methods.
CO4	Apply lidar inversion methods for atmospheric measurements.
CO5	Design lidar system components.
CO6	Analyse airborne and space borne (satellite) lidar systems.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Understand the structure and composition of Earth's atmosphere.	PSO1	R	F, C
CO2	Discuss about different types of clouds and its properties.	PO1/PSO3	U	P
CO3	Explain laser remote sensing methods.	PO3/ PSO2	Ap, Cr	C
CO4	Apply lidar inversion methods for atmospheric measurements.	PO4/PSO3	Ap	M

CO5	Design lidar system components.	PO1/PSO3	Ap, E	P, M
CO6	Analyse airborne and space borne (satellite) lidar systems.	PO4/ PSO4	An	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create, **KC- Knowledge Category**: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: 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.

MODULE II: 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 III: 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.

MODULE IV: 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 V: 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.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

- Raymond M. Measures (Ed) Laser Remote Chemical Analysis, John Wiley & Sons, 1988.
- 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.
- P. Caagani and S. S Sandroni (Editor)Optional Remote Sensing of the Air Pollution, Elsevier science Publisher B. V, pp. 123-142, 1984.
- 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.
- Winker, M.D., Couch, R.H., and McCormick, M.P., Proc. IEEE, 84, pp. 164-180, 1996.
- 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.

Semester:	**Course Code: OPE-DE-618**
Course Title: COMMUNICATION NETWORKS AND TELECOMMUNICATION SYSTEM ENGINEERING	**Credits: 3**

Prerequisite : Knowledge in communication networks and telecommunication.

Objective : To introduce the concepts of communication networking, its functioning and network design.

Learning Outcomes : On completion of the course, the student will be able to

CO No.	**CO Statement**
CO1	Understand the concepts in Internet Architecture.
CO2	Understand the mechanisms in Quality of Service in networking.
CO3	Discuss queuing theory and different queuing models.
CO4	Explain Statistical multiplexing in communication network.
CO5	Discuss Network traffic and traffic models.
CO6	Discuss Operating system architecture for switching system.
CO7	Discuss different Interconnection networks.

Tagging Course Outcomes

CO	**CO Statement**	**PO/ PSO**	**CL**	**KC**
CO1	Understand the concepts in Internet Architecture.	PO2/PSO1	U	F,C
CO2	Understand the mechanisms in Quality of Service in networking.	PSO1	U	F, C

CO3	Discuss queuing theory and different queuing models.	PO2/ PSO2	U, An	F, C
CO4	Explain Statistical multiplexing in communication network.	PO1/PSO2	U	F, C
CO5	Discuss Network traffic and traffic models.	PO1/PSO2	U,An	F, C
CO6	Discuss Operating system architecture for switching system.	PO2/ PSO2	U	F,C
CO7	Discuss different Interconnection networks.	PSO2	U, An	F, C

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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.

MODULE III: 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 IV: 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 V: Point-to-Point Multi-Stage Circuit Switching: Close network, recursive construction of switches, strictly non-blocking, rearrangable 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.

MODULE VI: 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 l enet as delta network, buffered banyan network, input vs output queuing, discussion of various packet switching architectures.

REFERENCES

- Anurag Kumar, D.Manjunath and Joy Kuri,Communication Networking: An Analytical
  Approach- Morgan Kaufman publishers,2004.
- Bertsekas and R.Gallager, Data Networks, PHI 2000.
- S.Keshav , An Engineering Approach to Computer Networking, Addison Wesley Ist Ed.1997.
- Joseph Y. Hui. Switching and Traffic theory for Integrated Broadband Networks, Kluwer
  Academic Press

- M. Schwartz, Telecommunication Networks: Protocols, Modeling and Analysis, Addision-
  Wesley Longman Publishing company, Boston,1986.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-619
Course Title: OPTICAL NETWORKS	**Credits: 3**

Prerequisite : Basic knowledge about optical devices and electronic circuits.

Objective : To learn the components, architecture, topologies, design and operations in optical network communication.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of optical networking.
CO2	Understand the optical network architecture and topologies
CO3	Differentiate the types of optical networking systems
CO4	Design optical network for wavelength routing
CO5	Detect the problems and faults in the devices used in optical network communication
CO6	Fabricate the components of optical networks

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the basic concepts of optical networking.	PSO1	R	F and C
CO2	Understand the optical network architecture and topologies	PSO1	U	C
CO3	Differentiate the types of optical networking systems	PO2	An	M
CO4	Detect the problems and faults in the devices used in optical network communication	PO1/PSO2	Ap	P

CO5	Design optical network for wavelength routing	PO1/PSO2	Ap	P
CO6	Fabricate the components optical networks	PO4/PSO3	Cr	P

(**CL- Cognitive Level:** R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, C- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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, PONs, optical ethernets, wide area backbones, metro optical networking.

MODULE III: MPLS & optical networks: label switching, FEC, scalability & granuility: 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.

MODULE IV: 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 V: 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.

MODULE VI: 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.

REFERENCES

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

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-620
Course Title: MICRO ELECTRO MECHANICAL SYSTEMS	**Credits: 3**

Prerequisite : Basic knowledge in smart materials and structures.

Objective : To provide basic of different methods of micromachining and how these methods can be used to produce a variety of MEMS, including microstructures, microsensors, and microactuators.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals and concepts in smart materials and structures.
CO2	Discuss about material processing and device fabrication.
CO3	Discuss about the micro sensors.
CO4	Design and development of micro sensors.
CO5	Design and development of MEMS devices for different application.
CO6	Apply software practice for designing of microstructures and component modelling.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals and concepts in smart materials and structures.	PSO1	R	C
CO2	Discuss about material processing and device fabrication.	PO1	U	F
CO3	Discuss about the micro sensors.	PO1/PSO2	Ap,Cr	C
CO4	Design and development of micro sensors.	PSO2/PSO3	Cr	M

CO5	Design and development of MEMS devices for different application.	PSO4	Cr	P
CO6	Apply software practice for designing of microstructures and component modelling.	PO3/PSO2	Ap	M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

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.

MODULE II: 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 III: 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 micro-spectrometer.

MODULE IV: 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 V: 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.

MODULE VI: Simulation of microstructures and component modeling: general overview of basic processes (planar-CMOS, bulk-Si,LIGA), physical-chemical determinated simulation of selected process steps. Systematic of MEMS components, layout support, examples of element modeling (DAE, FEM).

REFERENCES

- Tai-Ran Hsu, "MEMS & Microsystem, Design and Manufacture", McGraw Hill, 2002.
- Banks H.T. Smith R.C. and Wang Y.Smart, "Material Structures - Modeling, Estimation and Control", John Wiley & Sons, New York, 1996.

ADDITIONAL REFERENCES

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

Semester:	Course Code: OPE-DE-621
Course Title: LASER SPECTROSCOPY	**Credits: 3**

Prerequisite : Knowledge in Lasers, Electromagnetic Theory

Objective : To provide knowledge of the fundamentals of spectroscopy and about different types of spectroscopy and applications of laser spectroscopy in various fields

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the characteristics of laser.
CO2	Understand the different laser level systems.
CO3	Discuss nonlinear spectroscopy.
CO4	Analyse laser Raman and fluorescence spectroscopy.
CO5	Illustrate time resolved spectroscopy
CO6	Design spectroscopy aspects of lasers in various fields of Science and Technology.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the characteristics of laser.	PSO5	R	F and C
CO2	Understand the different laser level systems.	PSO5	U	C
CO3	Discuss nonlinear spectroscopy.	PO3/PSO5	Ap	P
CO4	Analyse laser Raman and fluorescence spectroscopy.	PO3/PSO5	An	P, M

CO5	Illustrate time resolved spectroscopy	PO2/PSO5	Ap, Cr	M
CO6	Design spectroscopy aspects of lasers in various fields of Science and Technology.	PO2/PSO5	Cr	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

Module I: Laser Fundamentals-Characteristics of Lasers - spontaneous and induced transitions, Einstein's coefficients, homogenous population inversion, three and four level systems, rate equations.

MODULE II: Nonlinear Spectroscopy-Linear and nonlinear absorption- Harmonic generation- saturation, polarization and multiphoton spectroscopy.

MODULE III: Laser Raman and Fluorescence Spectroscopy-Luminescence- Fluorescence and Phosphorescence- Lifetime measurements- Raman effect – Classical and Quantum theory of Raman effect – Raman spectrometer – applications – Fundamentals of SERS, CARS and PARS- Applications of Raman Spectroscopy in Medicine

MODULE IV: Photothermal spectroscopy-Photothermal (PT) generation- Different photothermal phenomena- Thermal lensing- beam deflection- photoacoustics-theory and application.

MODULE V: Time resolved spectroscopy-Q-switching, Mode locking -Time resolved spectroscopy: generation of short optical pulses-generation of ultra short optical pulsesmeasurement techniques for optical transients – Measurement of ultra short pulses- Pump-and-Probe Spectroscopy of Collisional Relaxation in Liquids

MODULE VI: New Developments in Laser Spectroscopy-Optical Cooling and Trapping of Atoms- Atom Laser- Squeezing- Laser-Induced Breakdown Spectroscopy (LIBS) - Measurements of Flow Velocities in Gases and Liquids - Spectroscopic Detection of Water Pollution- Optogalvanic spectroscopy, spectroscopy aspects of lasers in medicine- laser remote sensing LIDAR techniques.

REFERENCES

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

ADDITIONAL REFERENCES

- F.T. Arecchi, "Laser Handbook", Vol.2, North Holland Publication, 1974.
- R. E. Lidder, McGraw Hill, London, "Fundamental and Applied Laser Physics", John Wiley, New York, 1985.
- W. W. Duley, "Laser Processing and Analysis of Materials", Plenum Press, New York, 1983.
- William M. Steen, "Laser Material Processing", Springer-Verlag, Berlin, Third Edn., 2005.
- Wolfgang Demtröder, Laser, Spectroscopy- Vol. 1- Basic Principles, Springer, Fourth edition, 2014.
- Wolfgang Demtröder, Laser, Spectroscopy- Vol. 2 Experimental Techniques, Springer, Fourth edition, 2014.
- B.B. Laud, Lasers and Nonlinear Optics, New Age International Publishers, 3rd Edition, 2011.

Semester:	Course Code: OPE-DE-622
Course Title: NANOBIOPHOTONICS	**Credits: 3**

Prerequisite : Basic knowledge in nanoscience.

Objective : To learn fundamentals of nanotechnology and its applications in Photonics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the concepts of nanoscale interactions, photonics.
CO2	Understand about the interaction of light with cells and tissues.
CO3	Discuss the different bio-imaging techniques.
CO4	Understand the concepts of optical biosensors.
CO5	Analyse the laser activated therapy.
CO6	Develop photonics for bio-imaging.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the concepts of nanoscale interactions, photonics.	PSO1	R	C
CO2	Understand about the interaction of light with cells and tissues.	PSO1	U	F, C
CO3	Discuss the different bio-imaging techniques.	PO1/PSO3	Ap	P
CO4	Understand the concepts of optical biosensors.	PO3/ PSO2	U	C
CO5	Analyse the laser activated therapy.	PO4/PSO3	An, Cr	P, M

CO6	Develop photonics for bio-imaging.	PO1/PSO3	Ap, Cr	M

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KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Introduction to Nanoscience and Nanotechnology- classification of nanomaterials – Fundamentals of Nanobiophotonics.

MODULE II: 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,

MODULE III: Application of nanoparticles in imaging **-**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 IV: 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.

MODULE V: 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 VI: 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.

REFERENCES

- Introduction to Biophotonics-V N Prasad (Wiley-Interscience April 2003)
- Biomedical Photonics: A Handbook-Tu Vo Dinh (CRC Press, Boca Raton, FL 2003)
- Understanding Biophotonics, Ed. Kevin K Tsla, Pan Stanford Publishing, 2015
- A Handbook of Optical Biomedical diagnostics, SPIE press monograph vol pm 107
- Biomedical Optics-Principles and Imaging -Lihong V and Hsin-IWU, Wiley Interscience 1st ed, 2007
- Optical Coherence Tomography-Principles and Applications –Mark E.Brezinski, (Academis Press 1sted 2006)
- Biophysics –An Introduction-Rodney Cotterill, (John Wiley Student edition)
- P.N. Prasad, “Nanophotonics”, John Wiley & Sons, New York (2004).
- P.N. Prasad, “Introduction to Biophotonics”, John Wiley & Sons, New York (2003).
- M. Bruchez, Jr., M. Moronne, P. Gin, S. Weiss, and A.P. Alivisatos, Science 281, (1998) 2013-2016
- Photon-based Nanoscience and Nanobiotechnology, Ed. Jan J. Dubowski and Stoyan Tanev, Springer, 2005.
- Colm Durkan, Current at the Nanoscale, Imperial College Press, 2007.
- J.M. Martinez-Duart,R.J. Martin Palma,F. Agulle Rueda, Nanotechnology forMicroelectronics and Optoelectronics , Elsevier,2006.

ADDITIONAL REFERENCES

- Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Juan ArielLevenson, Nanophotonics, ISTE Publishing Company, 2006.
- John D. Joannopoulo, Robert D. Meade and Joshua N. Winn, Photonic Crystals,Prienceton University Press, 2008.

- Mark L. Brongersma and Pieter G. Kik, Surface Plasmon Nanophotonics, Springer – Verlag, 2006.

Extra Departmental Elective Courses

Semester:	Course Code: OPE-GC-611
Course Title: INTRODUCTION TO PHOTONICS	Credits: 2

Prerequisite : Knowledge in optics and lasers.

Objective : To learn the fundamentals of Lasers and its applications, optical fiber technology, holography and nanophotonics.

Learning Outcomes : On completion of the course the student will be able to

CO No.	CO Statement
CO1	Remember the fundamentals of laser.
CO2	Discuss different laser systems.
CO3	Apply the applications of laser in the industrial and medical fields.
CO4	Discuss optical communication through optical fibers.
CO5	Evaluate the characteristics of optical devices.
CO6	Apply the technique of nanophotonics in different research area.

Tagging Course Outcomes

CO	CO Statement	PO/ PSO	CL	KC
CO1	Remember the fundamentals of laser.	PSO1	R	C
CO2	Discuss different laser systems.	PO2/PSO2	Ap, Cr	M
CO3	Apply the applications of laser in the industrial and medical fields.	PSO3	E	P
CO4	Discuss optical communication through optical fibers.	PSO1	U	P

CO5	Evaluate the characteristics of optical devices.	PO1/PSO2	Cr	P
CO6	Apply the technique of nanophotonics in different research area.	PO1/ PSO4	Ap	M

(**CL- Cognitive Level**: R-remember, U-understand, Ap- Apply, An- analyses, E- evaluate, Cr- create,
KC- Knowledge Category: F-Factual, C- Conceptual, P-Procedural, M- Metacognitive)

Assessment Pattern (Internal & External)

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	15	15	15	15
Understand	15	15	15	15
Apply	35	35	35	35
Analyse	15	15	15	15
Evaluate	10	10	10	10
Create	10	10	10	10

COURSE CONTENT

MODULE I: Laser Fundamentals: Fundamentals of Interference – superposition principle – Coherence – spatial and temporal coherence. Einstein's coefficients – population inversion and optical pumping.

MODULE II: Laser Systems: Threshold condition – Optical Resonator – quality factor- Two - Three level –Four level systems. Ruby – He-Ne - Nd:YAG – CO2 – Dye Laser systems.

MODULE III: Industrial and Medical applications of Lasers- Holography – principle – special features of Holograms – Applications.

MODULE IV: 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 - Introduction to Optical Communication systems.

MODULE V: Solid state devices: Principle and working of - Photodiodes – Phototransistors – Solar cell – LEDs -Semiconductor lasers.

MODULE VI: Nanophotonics: Semiconductor nanoparticles-low dimensional structures-metal nanoparticles- Gold nanoparticles-plasmons- Carbon nanotubes- Graphene- properties and applications.

REFERENCES

- Gerd Keiser- Optical Fiber Communications- McGraw Hill, 2013
- H. J. Caulfield, Handbook of Optical Holography, Academic Press. 1979
- Paras N. Prasad, Nanophotonics, Wiley Interscience,2004
- Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998.

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