Annexure V

# UNIVERSITY OF KERALA

## M.Phil Degree Course

## PHOTONICS

## Syllabus

## w.e.f. 2015 Admission onwards

**Duration of the Course**

As per M.Phil regulations, M.Phil Degree Courses in Photonics shall be for one calendar year with two semesters of six months.

**Course Structure**

| Course | Subject | Lecture/week | Total |
|---|---|---|---|
| | SEMESTER I | | |
| OPE 711 (Paper 1) | Photonics | 5 | 100 |
| OPE 712 (Paper 2) | Research methodology | 5 | 100 |
| Paper 3 | Elective | 5 | 100 |
| OPE 713 | Dissertation Work | 15 | Evaluation only at the end of second semester |
| Total | | 30 | 300 |
| | SEMESTER II | | |
| OPE 713 | Dissertation Work | 30 | 300 |
| | Viva-Voce Examination based on Dissertation work | | 100 |
| Total | | 30 | 400 |
| Grand Total | | | 700 |

The final results shall be graded as follows:

A grade 60% and above
B grade 50% and above but below 60%
Failure Below 50%

# Detailed Syllabus

## Core Papers

### OPE 711 Photonics

**Module I**

Laser fundamentals- Einstein's coefficients, gain coefficient, laser rate equations, optical resonator, Q-factor and stability of optical resonator- modes of laser resonator, Q-switching and mode locking. Properties of lasers- coherence, line width and divergence. Laser systems- Ruby laser, He-Ne laser, dye laser, Argon ion laser, free electron laser, Nd YAG, CO2 laser, Diode laser, Nitrogen laser, excimer laser, Ti Sapphire laser, Fibre laser.Laser applications- Material processing, holography, LIDAR, Bio medical applications, laser fusion, laser cooling and Bose- Einstein condensates.

**Module I**

Photo detectors and display devices, photodiodes, Photo transistor, APD, PMT, CCD, PIN photo diodes, liquid crystal display, Photo voltaic cells . Optical modulators- acousto-optics, electro-optics and magneto-optics. Physical origin of nonlinear optical coefficients, Second order optical nonlinearity, Propagation of EMW through NLO medium, optical second harmonic generation, phase matching conditions, Third order NLO, intensity dependent refractive index, Four wave mixing and optical phase conjugation.

**Module III**

Fibre Optics- classification of fibres- step index, graded index fibres, Numerical aperture, modes in optical fibre, single mode and multimode fibre, V- Parameter, evanescent modes, losses in fibres- bending and coupling losses, dispersion in fibres, Special fibres- polarization maintaining fibres,holey fibre, PC fibres, DC Flattened and dispersion shifted fibre.

Fibre optic sensors- advantages of FOS, intensity modulated sensors, interferometric sensors, rotation sensors, bio sensors. Optical communication – advantages, modulation, time division and wave length multiplexing

**References**

**Text Books:**

1. John M senior, Optical fiber communications PHI, 1992.
2. A.Ghatak & K. Thyagarajan, Lasers: Theory & Applications, Macmillan India LTD. 2003
3. A.Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 2004
4. Francis T.S Yu, Shizhuo Yin (Eds), Fiber Optic Sensors, Marcel Dekker Inc., New York,2002
5. Amon Yariv, Optical Electronics, Saunders College Publishing 1991

**Reference**

1. Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998
2. Orazio Svelto, Principles of Lasers, 4thEdn, Plenum Press, 1998
3. Koechner (Walter), Solid State Laser Engineering, Springer-Verlag, 1992
4. Bahaae A. Saleh and Malvin Carl Teich Fundamentals of Photonics, John Wiley & Sons, 1991
5. J Wilson and JFB Halkes Optoelectronics: an introduction PHI, l996.

6. Govind P Agrawal, Non Linear Optics, Academic Press, 1989
8. Emmanuel Rosencher and Borge Vinter, Optoelectronics, Cambridge University Press, 2002
9. Pal B.P, Fundamentals of fiber optics in telecommunication and sensor systems 1994, Wiley Eastern
10. Ben. G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, PHI, 2004
11. S.C. Gupta, Optoelectronic Devices and Systems, PHI, 2005
12. R P Khare, Fiber Optics and Optoelectronics, Oxford University Press, 2004
13. Gerd Keiser. Optical Fiber Communications, Mc Graw Hill, 2000
14. S.M. Sze. Physics of Semiconductor Devices II Edition, John Wiley 2005

## Core Course Paper II

## Research Methodology

### Module I

Research-Definition, Characteristics, objectives, research and scientific methods, Evolution of scientific enquiry, philosophy of science, scientific investigation, The real practice of science, ideas in science, meaning and importance of research, importance of R&D activity in science and Technology, Current trends in research: mono disciplinary research, trans disciplinary research, inter-disciplinary research, A bird's eye view of research and development activity in the field of photonics.

Research Methodology: An introduction, research process, basic overview, formulating the research problem, defining the research problem, research design-exploration, diagnosis, experimentation, Research methods: **Different types of inductive logical methods, research methods versus research methodology.**

### Module II

Literature review: review concepts and theories, formulation of hypothesis, sources, characteristics, role and tests of hypothesis, sources of data, primary, secondary, tertiary, Types of data: categorical, nominal, ordinal, Methods of collecting data, observations, field investigations. Interview method, Questionnaires, correlation analysis, inferential analysis, correlation analysis, statistics in research, generalization and interpretation, modelling. MATLAB, OPTSIM, COMSOL applications.

### Module III

Importance of effective communication, structure and components of scientific reports, layout, structure and language in scientific reports, illustration and tables, bibliography, referencing and footnotes, preparation of manuscripts for journals, seminars and conferences, application of research , research ethics. environmental impacts, ethical issues, ethical committees, commercialization, copyright, royalty, intellectual property right and patent law, reproduction of published material, plagiarism, reproducibility and accountability. Computer and internet: its role in research, threats and challenges to good research, criteria of good research, citation methods, citation rules-Blue Book, OSCOLA-MLA-APA, calculation of impact factor of journals, citation index, ISBN and ISSN

### Module IV

Principles and working of scientific instruments: XRD, SEM, AFM, TEM, STM, UV-Visible, IR (FTIR and ATRFTIR), Raman and NMR spectroscopic techniques, particle size analysis, vapour deposition techniques, Optical spectrum analyzer-OTDR.

**Text Books**


1. Hempel,C. (1966)Philosophy of Natural science Englewood Cliffs, N.J: Prentice Hall.
2. Burtt, E.A. (2003) The Metaphysical Foundations of Modern Science. London.
3. Latour, B. & Woolgar. (1986). Laboratory Life. The construction of scientific facts. 2ndEdition. Princeton: Princeton University Press.
4. Sundar Sarukkai (2008) Indian Philosophy and Philosophy of Science, Motilal Banarsidass Publishers Pvt.Ltd. New Delhi.
5. C R Kothari (1990),Research Methodology: Methods and techniques, (New Age International Publishers.
6. Garg.B.L., Karadia, R., Agarwal,F. and Agarwal, U.K., (2002). An introduction to Research Methodology, RBSA Publishers.
7. Trochim, W.M.K., (2005). Research Methods: the concise knowledge base, Atomic Dog Publishing. 270 p.
8. Dr.S.N.Yogish, (2007), Statistical Methods, Mangal deep Publications.
9. Gupta S.P., (2008). Statistical Methods. 37thed. (Rev) Sultan Chand and Sons. New Delhi. 1470 p.
10. Day RA (2012) How to write and publish a scientific paper. Cambridge University press. London
11. Arlene Fink (2010), Conducting research literature reviews from internet to paper- Sage Publications
12. Douglas A.Skoog, F.James Holler and Timothy A. Nieman, (1998) Principles of Instrumental Analysis, Harcourt College Publishers
13. Straughun and Walker, (1976) Spectroscopy, Vols I &II, Ed.
14. Wadehra, B.L. (2000). Law relating to patents, trade marks, copyright designs and geographical indications. Universal Law Publishing.


**References:**


1. Science (AAAS) Jounal –(Selected articles from archives)
2. Nature (Nature publishing group) Journal-(Selected articles from archives)
3. Nature Photonics (Nature publishing group) Journal-(Selected articles from archives)
4. Website : Web of Science - Science - Thomson Reuters,Website: Scopus (Elsevier Publications)
5. Ram Ahuja (2009) Research Methods, Rawat Publishers.
6. Sinha, S.C. and Dhiman, A.K., (2002). Research Methodology, Ess Ess Publications. 2 volumes.
7. Kozak A, Kozak R.A., Staudhammer C.L. and Watts S.B. (2008). Introductory probability and Statistics; Applications for forestry and Natural sciences.CAB International, UK.408p.
8. Walter T Federer, (1991), Statistics and Society-Data collection and interpretation. Marcel Dekker Inc
9. Harry Frank, Steven Althoen,. Statistics: Concepts and Applications. (1994) Cambridge University Press
10. P.J. Wheatly (1968), The Determination of Molecular Structure, , Oxford Press
11. Leon & Leon (2002). Internet for everyone, Vikas Publishing House.
12. Chandera A. and Sexena T.P. (2000) Style Manual, New Delhi, Metropolitan Book Comp. Ltd.
13. SPSS – Operating Manual and handbook – Latest version
14. Sinha P.K.(1992). Computer Fundamentals, BPB Publications, New Delhi.

## Elective Courses

### OPE 701 Nanophotonics

**Module I**

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

**Module II**

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

**Module III**

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

**Text Books:**

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

**Reference:**

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

### OPE 702 Image Processing

**Module I**

Introduction to digital image processing. image representation - gray scale and colour images introduction to two dimensional sequences , convolution correlation, separability etc. 2D-Fourier and Z- transform and its properties. 2D DFT and its properties. Convolution of two dimensional sequences,

convolutional filtering. Basics of 2D transform coding, 2D Discrete Cosine transform, Walsh transform. RGB color model, contrast, brightness, match-band effect etc., image formation model - perspective projection. Stereoscopic imaging - depth extraction and stereoscopic display.

**Module II**

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

**Module III**

Image restoration, system identification, DTF from degraded image spectrum, noise modeling. Image segmentation using region growing, region merging and watershed. Image compression -lossy and non- lossy compression. Introduction to JPEG and JPEG 2000.

**Text books**

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

**References:**

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

## OPE 703 Holography and Speckle Interferometry

**Module I**

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

**Module II**

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

**Module III**

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

**Text Books:**

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

**Reference:**

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

## OPE 704 Advanced Laser Technology

**Module I**

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

**Module II**

Q-switching, methods of Q-switching- methods, opto-mechanical methods of light- electro optic modulation- Pockels and Kerr modulators- magneto- optic modulators, acousto-optic modulators. Giant pulse lasers, mode locking in homogeneously and inhomogeneously broadened systems, passive and active mode locking beam diagnostics and characterization, thermal lensing effect.Descriptive and qualitative studies of laser applications in communication, remote sensing and interplanetary missions, laser gyro, laser Doppler aneometry (LDA). Applications of lasers in holography, material processing, pulsed laser ablation. Lasers in mechanical engineering and industry, metrology, defense and security, laser cooling, lasers for fusion, lasers for biology and medicine, satellite communications, LIDAR.

**Module III**

Working principle of Ruby laser, dye laser, argon ion laser, solid state lasers-fundamental and higher harmonic generation. 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, Ti:Saphire laser, rare earth doped and photonic crystal fiber based lasers. Super continuum generation in nonlinear photonic crystal fiber, soliton lasers. Chemical lasers, metal vapour lasers.

**Text Books**

1. Silfvast. W T., Laser Fundamentals, Cambridge University Press, New Delhi, 1998
2. Thyagarajan .K & Ghatak A K Lasers, Theory and Applications Macmillan, 1991
3. Orazio Svelto, Principles of Lasers, 4thEdn, Plenum Press, 1998
4. A.Ghatak & K. Thyagarajan, Lasers: Theory & Applications, Macmillan India LTD. 2003
5. A.Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 2004

**Reference**

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

## OPE705 Optical Sensor Technology

**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, Intensity modulated sensors, reflective concept, micro-bend concept, evanescent fiber sensors,. In-fiber Bragg grating based sensors – sensing principles – temperature and strain sensing, integration techniques, cross sensitivity, FBG multiplexing techniques. Long period fiber grating sensors-temperature and strain sensing, refractive index sensing, optical load sensors and optical bend sensors, Signal processing techniques for fiber optic sensor.

**Module II**

Interferometric sensors, Mach-Zehnder & Michelson interferometric sensors, theory-expression for fringe visibility, Fabry-Perot fiber optic sensor – theory and configurations, applications - temperature, pressure and strain measurements, Sagnac interferometers for rotation sensing Fiber gyroscope sensors. Faraday effect sensors, magneto-striction sensors, Lorentz force sensors.

**Module III**

Biomedical sensors, sensors for physical parameters, pressure, temperature, blood flow, humidity and radiation loss, sensors for chemical parameters. pH, oxygen, carbon dioxide, spectral sensors. Distributed fiber optic sensors - intrinsic distributed fiber optic sensor - optical time domain reflectometry

**Text Books**

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

**References**

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

## OPE 706: Optical Instrumentation

**Module I**

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

**Module II**

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

**Module III**

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

**Text Books**

1. Fowles G.R., Introduction to Modern Optics, 2nd Edition, Holt, Rienhart and Winston, 1975.

2. Bruce H &Walkar, Optical Engineering Fundamentals, PHI, 2003
3. Warren J. Smith, Modern Optical Engineering: The Design of Optical System, 2nd Edn, McGrew Hill, 1990
4. Douglas A. Skoog, F James Holler and Timothy A Nieman, Principles of Instrumental Analysis,5th Edn, Hartcourt Image Publishers, 1998

**References**

1. Rudolf Kingslake, Applied Optics and Optical Engineering, Vol: I-V, Academic Press, 1985
2. Daniel Malacara & Zacaria Malacara, Handbook of Optical Design, Marcel Dekker, 2004
3. Albert T Helfrack & William D Cooper, Modern Electronic Instrumentation and Measurement Techniques PHI, 1990
4. K. Lizuka, Engineering Optics, Springer-Verlag, 1983
5. Donald F. Jacob, Fundamentals of Opticals Engineering, Mc Grew Hill, 1943
6. Hank H. Karow, Fabrication Methods for Precision Optics, John Wiley and Sons, New York, 1993.
7. David Malacara, Optical Shop Testing, John Wiley and Sons, New York, 1992.

## OPE 707: Laser Remote Sensing

**Module 1**

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

**Module 1I**

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

**Module III**

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

**Text books:**

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

**References:**

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

## OPE 708: Nonlinear Optics

**Module I**

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

**Module II**

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

**Module III**

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

**Text Books:**

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

**Reference:**

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

## OPE 709 Solar Photovoltaics

**Module I**

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

**Module II**

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

**Module III**

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

**Text Books:**

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

**References:**

1. Semiconductors for Solar Cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
2. Thin-Film Crystalline Silicon Solar Cells: Physics and Technology, R. Brendel, Wiley-VCH, Weinheim, 2003.
3. Clean Electricity from Photovoltaics, M. D. Archer, R. Hill, Imperial College Press, 2001.
4. J. Nelson, The physics of Solar Cells, Imperial College Press, 2006.

5. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998 23
6. Solid State Electronic Devices, Ben G. Streetman, Prentice-Hall of India Pvt. Ltd.,1995.

## OPE 710 Biophotonics

### Module I

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

### Module II

Optical biosensors: fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, biosensors based on fibre optics, planar waveguides, evanescent waves, interferometry and surface plasmon resonance. Flow cytometry: basics, fluorochromes for flow cytometry, DNA analysis. Laser activated therapy: photodynamic therapy, photo-sensitizers for photodynamic therapy, applications of photodynamic therapy, two photon photodynamic therapy. Tissue engineering using light: contouring and restructuring of tissues using laser, laser tissue regeneration, femto-second laser surgery.

### Module III

Laser tweezers and laser scissors, design of laser tweezers and laser scissors, optical trapping using non Gaussian optical beam, manipulation of single DNA molecules, molecular motors, lasers for genomics and proteomics, semiconductor quantum dots for bio imaging, metallic nano-particles and nano-rods for bio-sensing. Photonics and biomaterials: bacteria as bio-synthesizers for photonic polymers.

**Text books:**

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

**References:**

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

## OPE 711 Laser Material Processing

### Module I

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

### Module II

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

### Module III

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

### Text books:

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

### Reference:

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

## OPE 712 Laser Spectroscopy

### Module I

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

**Module II**

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

**Module III**

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

**Text books:**

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

**References:**

1. F.T. Arecchi, " Laser Handbook", Vol.2,North Holland Publication, 1974.
2. R.E.Lidder, McGraw Hill, London, "Fundamental and Applied Laser Physics' John Wiley, New York, 1985.
3. W.W.Duley, " Laser Processing and Analysis of Materials", Plenum Press, New York, 1983.
4. William M. Steen," Laser Material Processing", Springer- Verlag, Berlin, Third Edn., 2005.

Annexure V

# UNIVERSITY OF KERALA

## M.Phil Degree Course

## PHOTONICS

## Syllabus

## w.e.f. 2015 Admission onwards