OPTICAL SPECTROSCOPY AND MICROSCOPY: FUNDAMENTALS OF OPTICAL MEASUREMENTS AND INSTRUMENTATION

PROF. BALAJI JAYAPRAKASH
Department of Biological Sciences & Bioengineering
IISc Bangalore

INTENDED AUDIENCE : Life Science, Photonics, Instrumentation

INDUSTRIES APPLICABLE TO : Carl Zeiss, Leica, DSS Image Tech, Olympus, Nikkon, Optica, Holmarc

COURSE OUTLINE :

Optical spectroscopy and microscopy plays a very vital role in modern day research. Due to extensive commercialization and the cost associated with usage of these instruments most often these instruments are bought and used as turn key systems. While this has served the academic as well as industrial usage very effectively, it is very limiting when it comes to understanding the inner workings of these equipment. Specifically, understanding the inner working would help the user to push the boundaries of technical capability and perhaps come up with new technology. In this course I am planning to teach the foundations of spectroscopy from the viewpoint of light matter interaction and demonstrate the working of these instruments in a lab setting through teach them how to build some of these systems. It is unique course in which I am planning to give theoretical foundation as well as practical aspects of the building a scientific equipment from ground up.

ABOUT INSTRUCTOR :

Prof. Balaji Jayaprakash is Assistant Professor, Centre for Neuroscience, Indian Institute of Science Research: Learning and Memory Post Doctoral Fellow with Prof. Silva, Department of Neurobiology, UCLA, Los Angeles, July 2007- Dec 2011 Post Doctoral Fellow with Prof. Ryan, Department of Biochemistry, Weil Medical College of Cornell University, New York, NY - 10021. USA, 2005 - 2007 Tata Institute of Fundamental Research, Visiting Fellow, 2004 - 2005 Tata Institute of Fundamental Research, Ph.D. (Chemistry), 2004

COURSE PLAN :

Week 1: Essential Quantum Mechanics: Uncertainity Principle, Probabilistic nature of measurement, postulates of qmech, Stern Gerlach equivalent in light, Photon picture (PMT response), Linear Vector Space.

Week 2: Time dependent perturbation theory, Fermi Golden Rule, Transition probability in light matter interaction, Beer Lambert relation, Einestin's phenomenolgical treatment, A and B coefficients, Spontaneous emission, Origins of fluorescence

Week 3: Nature of Fluorescence, Emisson spectrum, Absorption spectrum, Anisotropy, Life time, FRET

Week 4: Second quantaisation, creation and anhilation operators, Fock states, light matter interaction in Feynman digrams

Week 5: Spontaneous emission orgin, Stimulated Emission origin dependence through Fock states

Week 6: Laser emission, two state, three state and four state laser systems

Week 7: Real world lasers, Charecteristics of laser emission, thershold behavior, Laser gain equation, CW operation, Pulsed lasers, Qswitching, mode locking, Saturable absorber

Week 8: Laser induced fluorescence, optical components (lenses, mirrors, gratings, prisms) and their working principles, Interference filters, dichroic filters, efficiency calculations for SNR improvement, aligning an optical equipment.

Week 9: Intro to optical hardware, common opto-mechanical assemblies, setting up a simple laser based spectrometer using gratings in lab, calibration and acqusition of fluorescein spectra.

Week 10: Principles of photo detection, QE, Dynamic range shot noise, photodetectors – PMTs, photodiodes, photo resistors, understanding common metrics and specs. Detection electronics – preamps, A2Ds

Week 11: Area detectors, CCDs, emCCDs, sCMOS, comparison, read noise, speed and other sensor charecteristics. Theory of Image formations – widefiled microscopy, bright field, phase contrast, DIC and fluorescence microscopy

Week 12: Scanning system: Principles of scanning system, Gaussian light progation and focussing, optical resolution, deinition in xy and z. Measurement and charecetrisation in lab. Scanning as time averaged focus, optical hinges, imaging of hinges, Confocal microscope