Integrated M.Tech-Ph.D. Programme

2+3 years Full-time residential
Integrated M.Tech-Ph.D. Programme

in

Advanced Material Physics & Engineering

PROGRAMME BROCHURE
2012

CSIR- NATIONAL PHYSICAL LABORATORY
Dr. K.S. Krishnan Marg, New Delhi - 110012
(www.nplindia.org)

The objective of this CSIR Integrated M.Tech-Ph.D. programme is to provide an in-depth exposure to the theoretical fundamentals and underlying physics of a variety of advanced materials & their properties, research methodology, materials processing technology, state-of-the-art material characterization techniques and technology for components & devices. This program would also provide hands-on experience in on-going national/international research & development projects in a variety of areas on advanced materials.

The CSIR Integrated M.Tech-Ph.D. programme would be of 2+3 years duration course, in which M.Tech course spread over four semesters (2 years), the remaining 3 years have to be spend by the candidate in completing his/her Ph.D. The M.Tech curriculum has a modular structure with the award of credits for successful completion of each module and the project dissertation. The first two semesters would consist of regular course work in which the students are expected to take-up course work, including a practical laboratory component. The third semester would consist of course work along with the introductory project dissertation work. The final semester would be entirely dedicated to dissertation work, which will be carried out under the supervision of scientists at NPL in frontiers areas of advanced materials.

The uniqueness of this programme is that the curriculum has been designed in such a way so as to provide an emphasis on both, the theoretical fundamentals of materials physics and engineering of materials for development of components & devices. The state-of-the-art laboratory facilities and research expertise of the scientists, acting as faculty and mentors, further adds to the programme's uniqueness.

NUMBER OF SEATS IN THE PROGRAMME : 10

ESSENTIAL QUALIFICATIONS : Engineering Graduate (Graduate in 2011/Graduating in 2012) with minimum 70% marks or 7.0 CGPA are eligible to apply. Age limit not exceeding 28 years as on July 01, 2012. For reserved category, age relaxation as per Govt. of India rules.

DESIRABLE QUALIFICATION : A valid GATE score will be an added advantage.

ADMISSION PROCESS
Please see the AcSIR website, http://www.acsir.res.in/, for announcement and on-line submission of the admission form and other details.

The position and selection of Trainee Scientists will be as per the reservation policy of CSIR. Trainee Scientists shall receive an amount of Rs. 34650/- approximate per month + allowances as applicable at CSIR .

After successful completion of the M.Tech programme with distinction, the Trainee Scientists may be considered by CSIR for absorption in CSIR as Scientists in Pay Band -3 of the Government of India (Scale Rs. 15600-39100, with Grade Pay of Rs. 6600/- plus other allowances as applicable). Selected candidates will be trained on exciting live projects o that they emerge as research ready scientists/engineers for taking up challenging position.

PROGRAMME FEE STRUCTURE

The course fee for first 4 semester during M.Tech. is Rs. 24000/- per semester subsequently, during Ph.D. course fee will be Rs. 1000/- per month.

The fee can be paid by a demand draft issued in favour of "Director NPL" payable at Delhi and post it by speed post or registered letter to Director, National Physical Laboratory, Dr. K.S. Krishnan Marg, New Delhi – 110012, with your name written in pencil on the reverse side of the demand draft.

IMPORTANT DATES

1. Last date for receipt of on-line application form on www.acsir.res.in : June 23, 2012.
2. Programme registration at CSIR-NPL, New Delhi : August 13, 2012.
3. Start of first semester at CSIR-NPL, New Delhi: August 14, 2012.

The detailed academic programme calendar will be made available before the start of each semester.

Please visit the AcSIR website at http://www.acsir.res.in for more information. You should also periodically visit NPL's website link for CSIR-M.Tech Ph.D-2012 at http://www.nplindia.org for updates and news about this programme.

NATIONAL PHYSICAL LABORATORY (CSIR), NEW DELHI

(Advanced Materials Physics & Engineering)

Coursework for M.Tech programs

National Physical Laboratory, New Delhi

SEMESTER I

Subject	*Code*	*Credits*
Fundamentals of Electronic Materials & Semiconductor Devices	Eng(NPL)-2-871	2-1-2-4
Physics & Technology of Thin Films	Eng(NPL)-2-872	2-1-2-4
Advanced Materials Characterization Techniques	Eng(NPL)-2-873	2-1-2-4
Nanostructured materials	Eng(NPL)-2-874	2-1-2-4

SEMESTER II

Subject	*Code*	*Credits*
Research Methodology, Technical Writing & Communication Skills	Eng(NPL)-1-001	1-1-0-2
Superconducting & Magnetic Materials	Eng(NPL)-3-871	2-1-2-4
Advanced Measurement Techniques & Metrology	Eng(NPL)-3-872	2-1-2-4
Advanced Computational Physics	Eng(NPL)-3-873	2-1-2-4

SEMESTER III

Subject	*Code*	*Credits*
Quantum Optics & Advanced Solid State Optical Devices	Eng(NPL)-3-874	2-1-2-4
Engineering Materials	Eng(NPL)-2-875	2-1-2-4
Dissertation Seminar - Initial Presentation	Eng(NPL)-4-871	0-0-16-8

SEMESTER IV

Subject	*Code*	*Credits*
Dissertation Seminar - Final Presentation & viva-voce	Eng(NPL)-4-872	0-0-16-8
Dissertation Report	Eng(NPL)-4-873	0-0-32-16

Total required credits for M Tech program = 68 (38 classroom/lab teaching, 32 thesis)

Detailed Curriculum for each course

Eng (NPL)-1-001 : Research Methodology, Technical Writing and Communication Skills : 2 Credits

Faculty : Senior Scientists

Introduction, Research terminology and scientific methods, different types and styles of research, role of serendipity, creativity and innovation; Scientific and critical reasoning skills, art of reading and understanding scientific papers, literature survey. Measurements in Research - primary and secondary data. Quantitative methods and data analysis, Qualitative analysis. Communicating Research results. Designing and implementing a research project. Professional ethics, Ethics in research, Plagiarism, Case studies. Laboratory safety issues – lab, workshop, electrical, health & fire safety, safe disposal of hazardous materials.

Role and importance of communication, Effective oral and written communication; Technical report writing, Technical/R&D proposals, Research paper writing,

Dissertation/Thesis writing; Letter writing and official correspondence; Oral communication in meetings, seminars, group discussions; Use of modern aids; Making technical presentations.

Eng (NPL)-2-871 : Fundamentals of Electronic Materials & Semiconductor Devices : 4 Credits

Faculty : Dr. Shilesh Sharma, Dr.Sanjay K. Srivastava & Dr.Pankaj Kumar

Crystal structure and reciprocal lattice, crystal binding, phonons & thermal conductivity, free electron Fermi gas, energy band diagrams and Fermi surfaces, semiconductor crystals, plasmons-polaritons-polarons, optical properties and excitons, nanocrystalline solids, phase change materials, ferroelectrics and dielectrics, basic equations of semiconductor device operation, p-n junction diode, metal-semiconductor contacts, MOSFETS, LEDs and semiconductor laser, solar cell.

Eng (NPL)-2-872 : Physics & Technology of Thin Films : 4 Credit

Faculty : Dr. K.M.K. Srivatsa, Dr. Sushil Kumar & Dr. Govind

Vacuum science & technology for thin film processing; thin films growth mechanisms, kinetic models of nucleation; thin film deposition techniques: physical vapor deposition (PVD): evaporation (resistive heating, flash, electron beam, ion beam and pulsed laser), sputtering (mechanisms and yield, dc and rf sputtering, bias sputtering, magnetron sputtering), hybrid and modified PVD, ion plating, ion beam assisted deposition, and vacuum arc deposition; chemical vapor deposition (CVD): reaction chemistry and thermodynamics of CVD, thermal CVD, atmospheric and low pressure CVD, plasma enhanced CVD (PECVD), MOCVD etc.; Chemical techniques: spray pyrolysis, electro deposition, sol-gel and Langmuir Blodgett techniques; types of thin films: metallic, dielectric & semiconducting; optical coating, thin film measurement & characterization, thickness measurements: Fizeau fringes, stylus measurement, ellipsometer etc.; ultra-high vacuum techniques and processes; electron-based techniques for examining surface and thin film processes. Surface processes in adsorption, surface processes in epitaxial growth, electronic structure and emission processes at metallic surfaces; semiconductor surfaces and interfaces; surface processes in thin film devices; in-situ characterization of epitaxial films. Defects in epitaxial films, epitaxial growth of nanostructures on silicon surfaces, graphene, III-V nitride quantum well structures for LED & Solar cells applications.

N Eng (NPL)-2-873 : Advanced Materials Characterization Techniques : 4 Credits

Faculty : Dr. G.Bhagavannarayana, Dr. Sukhbir Singh & Dr.Renu Pasricha

Fundamentals of X-rays - Bremsstrahlung and characteristic X-rays, Moseley's law, X-ray production (conventional X-ray tubes and synchrotron), X-ray absorption/K-absorption edge/filters ; X-ray crystallography, crystal systems and their corresponding Bravais lattices, space groups, reciprocal lattice, lattice planes and Miller indices, relation between lattice spacing and lattice constants, Bragg's Law, scattering of X-rays by an electron and an isolated atom and atomic structure factor, structure factor for unit cell, calculation of structure factor, X-ray scattering and systematic absences in a few crystal systems ; X-ray analysis for composition and trace elements or impurities - X-ray florescence spectroscopy, energy dispersive spectroscopy, X-ray photoelectron spectroscopy, Auger electron spectroscopy, CHN analyzer ; determination of crystal structures - X-ray Laue, single crystal X-ray and powder X-ray methods.

Characterization of crystalline perfection of single crystals & epitaxial films - crystal defects and lattice mismatch, theoretical aspects of X-ray diffraction, reflection and

scattering, high resolution X-ray Diffraction for Bragg and Laue cases, semi-kinematical theory for epitaxial layers for determination of thickness and composition, X-ray reflectometry for determination of density, thickness and interfacial roughness ; experimental aspects - monochromators, point and line focus configurations of X-ray beam, parabolic graded multilayer mirror, flow proportional and scintillation detectors, solid-state pixel detector ; high-resolution X-ray diffractometers - high-resolution X-ray diffraction curves, X-ray topography, X-ray reflectometry, grazing incidence X-ray diffractometry for in-plane diffraction, reciprocal space mapping.

Microscopy Techniques - basics of electron microscopy, electron scattering, electron atom interaction, electron emissions sources, vacuum conditions, scanning electron microscopy, different imaging modes, conventional transmission electron microscopy, high resolution transmission electron microscopy, reciprocal space, selected area electron diffraction, convergent beam electron diffraction, bright field and dark field imaging, scanning transmission electron microscopy, lattice scale imaging, interpretation of high resolution images, scanning tunneling microscopy, atomic force microscopy.

Spectroscopy techniques - Fourier transform infrared spectroscopy, Raman spectroscopy. secondary ion mass spectroscopy, electron paramagnetic resonance spectroscopy, cathodoluminescence, photoluminescence, defect structure analysis using microscopy and spectroscopy results; particle size analyzer.

Eng (NPL)-2-874 : Nanostructured Materials : 4 Credits

Faculty : Dr. A.K. Srivastava, Dr.H.K.Singh & Dr. D. Haranath

Introduction to nanomaterials, nanoparticles employing ball milling, gas condensation, laser ablation, thermal and ultrasonic decomposition, reduction methods, self-assembly, low-temperature plasma, thermal high-speed spray, sol gels, precipitation of quantum dots and other procedures; nanolayers by physical vapor deposition methods, PLD, sputtering, e-beam evaporation, MBE; Chemical Vapor Deposition (CVD); nanostructuring by nanopolishing, etching of nanostructures, lithography procedures like optical lithography, electron beam lithography, ion beam lithography, X-ray and synchrotron lithography, focused ion beams, nanoimprinting, atomic force, near-field optics. Characterization of nanomaterials for the structure, composition, defects, interfaces, grain boundaries. Generation, interpretation & application of nano-scaled defects. Physics at low dimensions, heterostructures, band engineering, quantum wires, quantum dots, effective mass approximation, quantum wells in heterostructures, square well of finite and infinite width, triangular and parabolic quantum wells, tunneling transport, potential step, T-matrices, current and conductance, resonant tunneling, tunneling in heterostructures, effects of electric and magnetic fields, density of states, conductivity and resistivity tensors, uniform magnetic field, Landau levels, S-D effect, quantum hall effect, Aharanov-Bohm effect, nanomagnetism, surface/interface magnetism, nanophotonics. Electronic devices based on nanostructures, high electron mobility transistors, resonant tunneling diode, quantum cascade laser, single electron transistor, carbon nanotube and graphene devices and spintronic devices.

Eng (NPL)-3-871 : Superconductivity and Magnetic Materials : 4 Credit

Faculty : Dr. Pushpa L. Upadhyay, Dr. Anurag Gupta & Dr. V.P.S. Awana

Introduction to superconductivity; thermodynamics of superconducting transition, two-fluid model London theory, flux-quantization, superconducting tunneling phenomena and energy gap, introduction to microscopic theory (Bardeen-Cooper-Schrieffer) of superconductivity. Type II superconductivity, mixed state and

Ginzburg-Landau theory, critical currents, flux-pinning and flux-flow. Magneto-thermal instabilities in type II superconductors. Applications of Superconductivity : materials requirement for superconducting devices, low current devices and superconducting electronics, superconducting thin films, SQUIDs and Josephson junction based devices, detectors and bolometers. High current applications, synthesis methods for wires and tape-conductors, superconducting magnets, energy storage, motors and generators. High Temperature superconductors : introduction & their unusual fundamental properties, electronic and power applications of high-temperature superconductors. Physical Properties of materials at low temperatures (specific heat, thermal conductivity, thermal expansion, electrical conductivity, magnetic and mechanical properties). Production of low temperatures, cryogenic fluids : their properties and storage, transfer devices, temperature control & measurement, production of very low temperatures, vacuum systems as applied to cryogenics.

Magnetic moments of a body, alignment of atomic magnetic moments in a solid, Ferromagnetism, Curie Point and the Exchange Integral, Magnetisation and magnetic domains, Temperature dependence of magnetization, Coercive force & hysteresis, coercivity in fine particles. Ferrimagnetism and Antiferromagnetic order, Neutron magnetic scattering Magnetism of transition metals (elements, alloys and compounds), Rare-earths and Special Oxides (Spinels, Garnets and Perovskites). Magneto-resistance, tunnel magnetoresistance, Spintronics.

Eng (NPL)-3-872: Advanced Measurement Techniques & Metrology : 4 Credits

Faculty : Dr. A.K. Bandopadhyay, Dr. K.P.Chaudhary & Dr. S.S. Rajput

Introduction of the measurement science, measurement terminology and vocabulary, basics of uncertainty in measurements, brief advance uncertainty analysis including uncorrelated and correlated measurand, accurate measurement techniques in basic and derived SI units like mass, temperature, length & dimension, pressure & vacuum, force, DC (voltage, resistance & current), AC (high voltage & current, power & energy), LF voltage & current, introduction to quantum SI, quantum definition of mass, e-mass by superconducting magnetic levitation, watt balance, I_2 stabilized He-Ne Laser, Michelson interferometer – principle theory and application, different kinds of interferometer and applications, primary laser and its importance in metrology as a standard, basics of radiometry, radiometric quantities, radiant quantities, realization of radiometry to SI, calibration for spectral irradiance responsivity, high temperature by radiation pyrometry, measurement of Boltzmann constant 'k', Josephson voltage standard, quantum hall effect, time and frequency standards, laser cooled cesium fountain, metrology instruments - standards and artifacts for key comparison, introduction to the international organizations BIPM, RMO (APMP, SIM, EORAMET etc.), OIML, ILAC, international data base – key comparison data base (KCDB), calibration measurement capabilities (CMCs), ISO/IEC 17025: 2005 quality system and conformity assessment and their use in support of technical regulations.

Eng (NPL)-3-873: Advanced Computational Physics : 4 Credits

Faculty : Dr. Ravi Mehrotra, Dr. Sumit K. Mishra & Dr. J.Pulikkotil

Introduction to computer problem solving techniques, design and anatomy of a computer program, programming in C.

Modeling of Data : least square methods, finite difference methods, numerical differentiation and integration, interpolation and extrapolation, statistical analysis

Numerical Methods : root finding, eigen systems, FFT, ordinary differential equations and boundary value problems, Runge-Kutta and predictor corrector methods, partial differential equations

Simulations : molecular dynamics and Monte Carlo methods.

Eng (NPL)-2-875 : Engineering Materials : 4 Credit

Faculty : Dr. Ajay Dhar, Dr. T.D. Senguttuvan & Mr. B. Sivaiah

Classification of engineering materials, material properties, selection of material, advanced and futuristic materials, smart materials, nanomaterials; phase diagram, equilibrium & kinetics, stable & metastable phases, nucleation and growth, metals, alloys and solid-solutions; ceramics, polymers, composites; crystal imperfections, defects, dislocations; elastic and plastic deformation, stress-strain curves, work hardening & dynamic recovery, strengthening mechanisms; solidification and crystallization, recovery, recrystallization and grain growth; creep, fatigue, fracture, oxidation and corrosion; materials processing techniques : liquid metallurgy, powder metallurgy, spray forming; secondary processing techniques : extrusion, forging, rolling; mechanical and metallurgical characterization, structure-property correlations; light weight materials, metal matrix composites, polymer matrix composites, ceramic matrix composites, carbon-based composites, nanocomposites, super-hard materials, dielectric, ferroelectric and piezoelectric materials, magnetic materials

Eng (NPL)-2-874: Quantum Optics & Advanced Solid State Optical Devices : 4 Credits

Faculty : Dr. A. Sengupta & Dr. H.C. Kandpal

Introduction to quantum mechanics - quantum theory and wave nature of matter, complementarity, wave function and its interpretation, wave packets and free particle motion, principle of superposition, wave packets and uncertainty relation, spreading of wavepackets ; wave equations and solutions - linear harmonic oscillator, eigen value and eigen functions, motion of wave packets, double oscillator ; different types of potentials - normalization of free particle wave function, potential steps, rectangular potential barrier, periodic potential, potential square well ; coherence theory - classical coherence, quantum coherence ; semiconductor photon sources and detectors - light emitting diodes, laser amplifiers and injection lasers, photodetectors, photoconductors, photodiodes and avalanche photodiodes, single photon detectors ; theory of photoelectric detection of light - differential photodetection probability, joint probability of multiple photodetection, integral detection probabilities, photoelectric detection in a fluctuating field – photoelectric bunching, photoelectric counting statistics of a fluctuating field, photoelectric current fluctuations, Hanburry Brown – Twiss effect – photon antibunching.

Introduction to time and frequency standards including historical perspectives. Basic concepts of frequency standards, macroscopic frequency sources. Basics of laser frequency standards. Characterization of noise processes – amplitude and phase noise. Statistical characterization of the noise processes. Measurement techniques of phase and frequency noise. Introduction to atomic frequency standards, primary and secondary frequency standards. Microwave atomic frequency standards such as H-maser, Rb cell standards, cesium beam standards. Sources of frequency biases and their evaluation. Physics of cold atoms – laser cooling and trapping. Optical Molasses and magneto optic traps. Polarization gradient cooling. Bose Einstein condensation. Atomic Fountain frequency standards based on cold atoms. Cesium fountain frequency standard. Evaluation of sources of frequency biases. Ion trap frequency standards. Realization of different types of traps. Microwave & optical frequency standards based on trapped ions. Synthesis and translation of optical frequencies including femto-second comb, applications of precision frequency standards.

AMENITIES AT THE NPL CAMPUS

Hostels
Separate hostel accommodation with Wi-Fi connectivity for male and female students will be made available very close to the laboratory premises. The students are required to abide by the rules and regulations of the hostel in force.

Recreation
The staff club of laboratory has a recreational room with facilities for indoor and a few outdoor games. The staff club of the laboratory also organizes various sports and games related activities for its members. It also organizes various sports events in coordination with the CSIR Sports Promotion Board.

Canteen/Cafeteria
The laboratory canteen facility in the campus is available for breakfast and lunch at nominal rates. Apart from the regular canteen, the laboratory also has a tea/coffee/snacks cafe, which is open till late, beyond office hours.

Medical Facilities
There are medical facilities available within the laboratory premises. A full-time nurse and part-time doctors are available for medical consultation during office hours.

Auditorium/Seminar Hall/Lecture Hall/Conference Room
The laboratory campus houses an auditorium, seminar halls, conference & meeting rooms, lecture halls with projection systems and audio-visual facilities.

IT Infrastructure
A campus LAN (Local Area Network) has been setup which connects approximately 850 computers spread over the NPL campus. The network utilizes a mixture of optical fibre, UTP cables and switches.

Internet Connectivity
The internet access is provided through a gateway to the external world via a 2 Mbps ERNET radio link, 2 Mbps ERNET leased line and 8 Mbps Airtel leased line. Redundancy against failures is provided using three separate links based on different technologies such as Fiber Optics based leased line, Copper based leased line and Radio link based last mile connectivity. Email and Internet services are thus brought to the user's desktops.

Intranet
NPL intranet website provides one single stop location for various laboratory-related information, such as, circulars, soft copy of essential forms; telephone directory; essential pointers/links to webmail, various online journals etc; web based interface to online stores, online complaint system etc.

E-mail Facility
An in-house mailing facility with web based interface is provided to the staff of the Laboratory.

Information Security
Internal network has been divided in various zones, which are protected by Unified Threat Machine (UTM). Enterprise Antivirus with centralized control is installed on the computers in the laboratory.

Video Conferencing Facility
State-of-the-art video conferencing has been setup for video based interaction between remote locations, especially the CSIR labs.

Web-Server
A Linux based web server hosting the various websites related to NPL functionalities, including its main website, is deployed in-house. Open-source Database backend solutions viz. PostgreSQL and MySQL are deployed.

Electronic Attendance Facility
Electronic card based attendance system has been established to facilitate marking of attendance of staff using units at various locations in the campus. A central attendance server stores data using LAN and generates various reports.

Knowledge Resource Centre (Library)
NPL Knowledge Resource Center (KRC) provides library and information support for laboratory's R & D pursuits. Over the years, it has developed a rich collection of scholarly books and journals for this purpose, especially in the field of physics and related sciences.

During the current year, KRC subscribed to 87 scholarly journals *(65 foreign journals and 22 Indian journals*) having an approximate collection of 44,381 S & T books 1,336 Hindi books and 73,369 back volumes of journals (*as on March 2010*). KRC also serves the NPL community with services like Reprographic service, Electronic Document Delivery service, Inter Library Loan service, Reference service, Literature Search service etc.

NPL KRC offers online access to more than 6000+ full text journals under the e-consortium project of CSIR. The project facilitates access to electronic content from various publishers such as Elsevier, Springer, AIP (American Institute of Physics), APS (American Physical Society), Wiley - Blackwell, Oxford University Press, Royal Society of Chemistry, American Chemical Society etc as well as the archives of few publishers on concession rates.

KRC also provides access to intranet edition of Indian Standards and online access to its e-content and access to Science Direct (Elsevier) group of journals. It also offers Wi-Fi connectivity within the KRC thereby offering freedom to the users to use their personal laptops in the KRC premise and thus helps in optimizing the use of e-resources.

KRC maintains its site on the NPL intranet to provide latest information on its activities such as additions to its collection, current subscribed journals, new journals received during the week, links to electronic libraries, publishing houses, papers published by NPL scientists and latest news related to CSIR. NPL KRC also maintains NPKL website (http://www.nplindia.org) on Internet proving information about various activities of NPL, such as, its role towards the society; thrust area of research, facilities, services and achievements.