



From the Director's Desk...



I am delighted to present the Annual Report of CSIR-National Physical Laboratory (NPL) for the year 2012-13. CSIR-NPL is one of the leading laboratories of the Council of Scientific & Industrial Research (CSIR) in addition to being the National Metrology Institute (NMI) of India. It promotes R&D in various innovative research fields related to energy, nanotechnology, advanced materials, quantum condensed matter, radio & atmospheric sciences, quantum metrology and development of advanced standards of measurements. All along since its inception, NPL has been supporting Indian industries and contributing to society by providing them knowledge-based technologies and continuous advancement in knowledge.

It is now globally recognized that to realize a sustainable society and to address many environmental issues emanating from massive industrial growth, integrated implementation of science, technology, and innovation is highly essential. In this context public research institutes like CSIR-NPL have to play a very significant role. The National Physical Laboratory is fully conscious of this responsibility and is playing a defining role in this direction, and contributing significantly towards India's global competitiveness in all sectors development. To meet its objectives, NPL has been steadily and continuously undergoing transformation to be a frontline and globally recognized laboratory in physical sciences. During the Year 2012-13, this process continued and further additions were made to the already existing world class research infrastructure of the laboratory. In terms of human resource, which is the backbone of any organization, the laboratory continued to move towards a favourable mix of young as well as experienced scientific work force. All these efforts culminated into enhanced and important R&D accomplishments during the year. Two of our scientists, Dr. Poonam Arora and Dr. Priyanka H. Maheshwari with their exceptional contributions bagged the coveted CSIR Young Scientist Award, 2012 in the areas of Physical Sciences and Engineering Sciences respectively.

Outstanding research was carried out in all the seven distinguished and theme-dedicated divisions, namely, Physics of Energy Harvesting; Materials Physics and Engineering; Radio & Atmospheric Sciences; Time & Frequency; Apex Level Standards & Industrial Metrology; Quantum Phenomenon & Applications



and Sophisticated & Analytical Instruments. Based on the excellent fundamental and applied research in these areas, several papers were published in journals with high impact factor as well as some national and international patents were filed on important inventions.

Physics of Energy Harvesting Division reported Polymer Solar Cells (PSCs) with a modified and innovative PTB7:PC60BM light absorbing active layer. This has the potential of giving cost effective, efficient, flexible and stable polymer solar cells with power conversion efficiency (PCE) of $> 6\%$. The invention, internationally certified, is being patented. In the area of silicon solar cells, a 'Proof of Concept' of black silicon solar cells was developed which has the potential to reduce the cost of these devices. Other important contributions included : synthesis of graphene from a-C films, ZT value of 1.1 at 470K for $\text{Bi}_2\text{Te}_3 + \text{BiTe}$ (8 mol %) sample, fabrication of unipolar OFET on optimized SiO_2 dielectric materials, growth of epitaxial GaN on sapphire, amorphous & microcrystalline silicon thin film deposition for solar cells using VHF PECVD and improved quality of CIGS absorber layer. Some new facilities were also created and made operational in the division such as polymer solar cell device fabrication facility using glove box integrated with evaporator and encapsulation system, atomic layer deposition system, ultra-fast femto-second laser spectroscopy and ultra high vacuum pulsed laser deposition (UHV-PLD) system.

The Division of Materials Physics and Engineering also emphasized on both basic and applied research. The mechanism of electrically modulated photoluminescence in ferroelectric liquid crystal (FLC) was studied and reported in a high impact journal. Two important and commercially viable carbon components for fuel cell, namely, porous conducting carbon paper and composite bipolar plate were developed. In the area of biomedical sensors, extensive research continued for the measurement of cholesterol level and detection of cardiac biomarkers using micro fluidic techniques. The important engineering materials, which were investigated and characterized, included p-type of thermoelectric material, Cu_2Se , with a very high figure-of-merit and rare earth free permanent magnetic materials. Another achievement was development of nanophosphors for solar cell and synthesis of doped nanocrystals and quantum dots with enhanced luminescence for display devices. Novel nanophosphors for LEDs and luminomagnetic nanophosphors for bio-related applications were other thrusts areas of development.

Radio and Atmospheric Sciences Division participated in the 31st Indian Scientific Expedition to Antarctica and successfully carried out scientific experiments in the field of space weather and climate changes. Electromagnetic macro modeling, with an objective of predicting the path loss exponent of propagation, in mobile wireless communication was carried out in collaboration with Syracuse University. Idea was to find out a suitable propagation model required for future network planning. The ionospheric F2-region variability recently linked to sudden stratospheric warming (SSWs) was established. Assessment of Energy Generation Potentials of Municipal Solid Waste (MSW) in Delhi under Different Technological Options was carried out. An updated inventory of greenhouse gas emissions from the energy sector in India comprising of emissions from thermal power plants, road transport, railways, aviation and marine transport were prepared for the period of 2001-02 to 2009-10. Work on the 12th plan network project to characterize the changing atmosphere and its impacts were initiated. Detailed chemical, physical and isotopic characterization of atmospheric aerosols over India was done using different state-of-the art analytical facilities available at NPL. Studies on the altitude distribution of lower tropospheric Aerosols and Clouds over New Delhi using Lidar was also carried out.

Time and Frequency Division is actively involved in research on microwave frequency standards, optical frequency standards and precise timing systems. Major scientific achievements included: continual



operation of the first Cs fountain frequency standard and preliminary evaluation of its frequency; design and development of second Cs fountain; indigenous development of rubidium cells and bulbs for space clocks for ISRO's IRNSS (Indian Regional Navigation Satellite System); initial work on the project on development of single trapped ytterbium ion optical frequency standard; creation of NTP (Network Time Protocol) internet time service and contribution of all atomic clocks in the division to the international atomic time. CSIR-NPL has recently started comparing the accuracy of its clocks with other precision clocks around the world with an uncertainty of 0.3 ns. This precise, regulated and automated inter comparison of clocks using satellite links has resulted in the NPL's cesium clocks and a hydrogen maser contributing to the International Atomic Time Scale, TAI. Weightage to these Indian clocks have been assigned by Bureau International des Poids et Mesures (BIPM, Paris) for the first time.

Apex Level Standards and Industrial Metrology Division consisting of twelve groups continued to participate very keenly in the various assigned activities. In view of the importance to meet the continually increasing demand of accuracy and improved uncertainties, two major milestones achieved were: (1) Extension of the 11th Five year Plan project "Advances in Metrology – CSIR/NWP-45" up to 31st March, 2014 with additional fund and (2) Approval of a new project under 12th Five year Plan entitled "Measurement Innovation in Science & Technology (MIST) under SFC/CSIR funding. A poster containing the divisional activities was selected as one of the 70 posters of CSIR and presented at the CSIR foundation day on 26th September, 2012. Some of the important R&D contributions of the division included: (1) Measurement of external diameter of cylindrical shaped artifacts using a Length Measuring Machine, (2) High temperature primary standards by realizing silver and copper fixed points by metal-in-graphite blackbody cavities using Photo-electric linear pyrometer, (3) Elaborate studies on spectral switching based information processing (SSBIP), and (4) development of New Rice Husk Material as an Absorber. The division could establish: (1) A new Triple Raman Spectrometer with low temperature attachment, (2) High Temperature Primary Standards, (3) Installation of Multiferroic Tester, (4) Set-up for 24 h Noise Monitoring System for Road Traffic Noise and Airport Noise Measurements (5) An automatic Water Flow Calibration Standard of size DN100, and (6) Establishment of automated Power Ratio Technique for the calibration of lower value attenuators (0.1dB to 10 dB).

In the Quantum Phenomenon & Applications Division, wide range of thin film and device fabrication techniques such as Pulsed Laser Deposition, DC and RF Magnetron Sputtering, Thermal Evaporation, Photo-lithography, Argon Ion Milling and Focused Ion Beam were employed to produce transition metal oxide heterostructures, spintronic materials, superconductor/ferromagnet heterostructures, magnetic nanorings and graphene/tungsten based junctions. A "SQUID based 7 Tesla Magnetometer" was installed and made functional to characterize magnetization, ac susceptibility and resistivity of various thin film based samples. To understand novel quantum phenomena in advanced samples of oxide interfaces, nano-wires and junctions at very low temperatures in presence of high magnetic fields, a facility of 10 mK dilution refrigerator coupled with a 14 Tesla magnet has been planned. Besides, a new activity of pulsed magnet was initiated with an aim to establish ~ ms pulse of 50 Tesla magnetic field systems at low temperatures. Superconducting materials group continued to contribute in BiS₂, pnictides and MgB₂ superconductors. The Programmable Josephson Voltage Standard was further characterized to operate the system consistently with better stability and reproducibility. A facility based on the phenomena of SPDC for measurement of absolute quantum efficiency of photo-detectors and basic quantum optical studies for their application in quantum information processing was established. Fourier transform infrared spectroscopic technique is being tried to delineate the interaction mechanism of anticancer drugs with DNA and different oligonucleotides.





Sophisticated Analytical Instruments Division comprising of four groups namely: X-ray Analysis, Electron & Ion Microscopy, EPR & IR Spectroscopy and Analytical Chemistry remained dedicated to the basic characterization of materials regarding different aspects, namely, chemical composition, purity, structure (including defects) and crystallographic perfection. The division houses high quality and state-of-the-art characterization facilities.

The progress made by X-ray Analysis group, devoted to the growth of technologically important crystals like pure and/or doped LN, KDP, BMZ, ZTS, LA, LAP, LAM, GPI, ninhydrin etc. and their characterization, was admirable. The characterization of important semiconducting GaN based LED devices for solid state lighting and development of powder XRD Certified Reference Materials (CRMs) were its additional significant contributions. In the electron and ion microscopy, the microstructural interpretation of materials even at atomic scale in real and reciprocal space was accomplished. The Microscopy group was also dedicated to the growth of various nanostructured materials (ZnO, TiO₂, SnO₂, CuO, Al₂O₃, Graphene, Gold, etc.) and energy efficient thermoelectric materials like Bi₂Te₃ nano composites reinforced with graphene and MWCNTs and their thin films. It was recently involved in a new activity focused on biological applications (safety, health and environment) of nanomaterials and their respective standardization. The thematic areas of the activity included targeted drug delivery, imaging, cancer therapy, nanotoxicology, and theranostics. EPR and magnetic fluid activities encompassed the characterization of materials of interest including various spin resonance sensitive materials and ferrofluids. Nanomagnetic particles of mixed ferrites doped with rare earth e.g. Gd, Pr etc., were investigated for their physical properties like structural, morphological, rheological and magnetic properties. The metrology in chemistry and certified reference materials were the two most important assignments carried out by Analytical Chemistry group. The development of new methods to determine trace level of As⁵⁺, Cr³⁺ and Cr⁶⁺ by Ion Chromatography (IC) system and their validation according to the IUPAC and EURACHEM approaches was noteworthy.

During the year, several conferences and seminars were organized by the laboratory. Among the prominent ones, under TAPSUN, the first conference on “Advances in Futuristic Solar Energy Technologies” was organized during December 4-5, 2012. The brain storming sessions throughout the conference helped in forming innovative ideas towards a new paradigm of materials, devices, storage and distribution of solar energy. The conference was inaugurated by Dr. Farooq Abdullah, Hon'ble Minister, MNRE. Prof. Michael Gratzel of Swiss Federal Institute of Technology and pioneer of Dye Sensitized Solar Cells motivated the participants with his key note address entitled “Nano-structured Photo-systems for the generation of Fuels and Electricity from sunlight”. Hon'ble Minister of Science & Technology, Earth Sciences and Vice President, CSIR, Shri Jaipal Reddy, also graced the occasion.

A five-day international conference on magnetic fluids (ICMF-13) with keynote and plenary addresses, invited talks and oral presentations focusing on specific tenets of magnetic fluids along with poster sessions was held during January 7-11, 2013. It provided a platform for interaction between academicians, technology experts and industrialists and covered detailed fundamental and practical knowledge in the field of physical, chemical, mechanical, rheological and biological properties of magnetic fluids.

The International Conference “Advances in Metrology”, AdMet – 2013, (8th conference in AdMet series) was jointly organized by CSIR-NPL and Metrology Society of India (MSI) during February 21-23, 2013 along with one day workshop in Chemical Metrology on February 20, 2013. It is one of the major scientific events held every three years in the area of Metrology. Four hundred registered participants attended the conference from 15 countries including 6 NMI's and various institutes across the globe. Prof. V.



S. Ramamurthy Director, NIAS, Bengaluru, inaugurated the conference as Chief Guest and Prof. J. H. Ullrich President, PTB Germany, delivered the Keynote Address.

To discuss all the key issues concerning nanoscience such as need for international and national standards, nanometrology, nanomaterial synthesis and characterization, toxicity, and nano-optics, 1st National Seminar on Standardization for Nanoscience and Nanotechnology was held during February 25-26, 2013. Several national experts on the subject participated in the two day deliberations. It was supported by Mission on Nano science and Technology, DST. In addition, a workshop on Nano-Metrology was held on 27th September, 2012 and a national conference on “Various aspects of Radio and Atmospheric Sciences” was organized in Hindi by Raj Bhasha Unit during November 7-8, 2012.

CSIR-NPL provided training to students, pursuing M.Sc./M.Tech./MCA, from different educational institutions spread all across the country. During the year, about 96 students underwent short and long term training. Under the Academy of Scientific and Innovative Research (AcSIR), for Post Graduate Research Programme in Engineering (PGRPE) in “Advanced Materials Physics & Engineering“, ten students were admitted. Twenty six fresh research fellows joined during the year, making a total strength of 97. Under AcSIR, thirty four students are registered for Ph.D. in Physical and Chemical Sciences. Sixty three students are already registered for Ph.D. at other universities such as IITs, Delhi University, Delhi Technological University and JNU etc.

Organization of institutional visits involving students, teachers, faculty members from schools, colleges, universities, technical institutes, S&T organizations is an important activity of the CSIR-NPL. Six of such institutional visits took place during the year. Industrial training was also organized in the area of Metrology, Quality Management System, Materials Characterization Techniques as well as other specialized topics including Intellectual Property Rights (IPR). Nine of such courses were organized and were attended by the personnel belonging to various industries, testing & calibration laboratories and other various national and international S&T organizations.

During the year, a total of 350 scientific and technical papers were published in SCI Journals. Six patents were filed in India and three patents were filed abroad. Seventeen international patents and three Indian patents filed in previous years were granted during 2012-13. Seventeen new projects (sponsored and consultancy) were undertaken and 2355 calibration reports were issued, which contributed to generation of an ECF of about 470 lakhs.

Prof Anil K. Gupta, IIM, Ahmedabad, delivered key note address entitled “Coping with Climatic Risks Creatively” on “World Metrology Day” which was celebrated on May 21, 2012 together with “National Technology Day”. The theme of “World Metrology Day”, as decided by BIPM, was *Metrology-We measure for your safety*. Prof. Gupta described the role of innovation and creativity in coping with climatic risks. On the occasion, NPL released five certified Reference Materials (CRM) of mono-elemental aqueous solutions of Pb (two), Ca, Cr and sulfate. To mark the National Technology Day, the teams of innovators from NPL were awarded for their patents, software copyrights and technology transfers.

The 70th CSIR’s Foundation Day was celebrated on 26th September, 2012. Prof. Sushant Duttgupta, Vice Chancellor, Vishva Bharati, Shanti Niketan, delivered Foundation Day lecture entitled “Inclusive Education, The Tagore model and the Higgs Particle”. As a part of celebrations, the CSIR-NPL Open-Day was held on 28th September, 2012 The Open-Day is once a year opportunity for direct interaction between scientists





and the public to know about research activities of the laboratory. Around 2000 visitors turned up on the occasion.

As a tribute to Sir C.V. Raman, the National Science Day 2012 was celebrated on 28th Feb, 2012. Prof. S.D. Mahanti, University of Michigan, USA, delivered the Science Day Lecture. A Poster Presentation Event was also organized where the work of all research fellows of CSIR-NPL was exhibited. Out of these, five best posters were selected for awards.

It was an honour for NPL to hold the XXXIV Krishnan Memorial Lecture which was delivered by a world renowned researcher, Dr. Stuart S.P. Parkin*, an IBM Fellow, on March 11, 2013. The lecture entitled “Spin on Electronics! Science and Technology of Spin Currents in Nano-science and Nano-Technology” was very informative and fascinating. Prof. S. K. Joshi, Vikram Sarabhai Professor, JNCASR, Bangalore, presided over the function.

Along with the academics, NPL also participated in Pusa Horticulture Show held at IARI, Delhi, during March 4-5, 2013, and bagged largest number of prizes in the show. In 14 categories, it won 37 first prizes, 24 second prizes, 14 third prizes and 15 Challenge Cups/Shields. The effort was quite commendable on the part of our Horticulture Section.

I earnestly appreciate the unconditional support and sincere contributions of each and every member of CSIR-NPL staff including young researchers towards the progress of the laboratory. It is important to emphasize that without their wholehearted and dedicated cooperation, much of our accomplishment would not have been possible. I also wish to acknowledge the valuable guidance and support provided by the CSIR Head Quarters, our Research Council and Management Council in achieving our aims. The visits of national and international experts to the laboratory and interaction with our researchers had been most rewarding and motivational.

Finally, I wish to acknowledge the contribution of the Publication Committee under the leadership of Dr. Virendra Shanker in bringing out this report. The cooperation and special efforts of Sh. T. Raghavendra, Dr. T.D. Senguttuvan, Sh. V. D. Arora, Sh Prem Chand, Ms Anita Sharma, Ms Saroj Upadhyay and Sh Subhash Chandra are also appreciated.

(R. C. Budhani)
Director

* Parkin's discoveries in magneto-resistive thin film structures enabled a 1000 fold increase in the storage capacity of magnetic disk drives in little more than a decade. Most recently, Parkin is working on a novel storage class memory device, “Racetrack Memory”, which could replace both hard disk drives and many forms of conventional solid state memory.