



From the Director's Desk...



The Annual Report of CSIR-National Physical Laboratory (NPL) for the year 2011-12 is placed before you. It was a pleasure preparing the same.

CSIR-NPL is a premier physics laboratory as well as the National Metrology Institute of India. It is actively pursuing frontier areas of research in Physical Sciences and Metrology. The year, 2011-12, had been very creative, exciting as well as inspiring for us. The process of reorientation and transformation continued for achieving greater external visibility in forefront areas of advance research. One could feel the steady increase in the volume and quality of work as CSIR-NPL kept evolving into an ever more internationally oriented institute.

Efforts continued during the year to develop and establish the state-of-the-art characterization facilities and best-in-class experimentation setup in priority areas of research. A focused ion beam (FIB) microscope, X&Q band EPR spectrometer with low temperature ($\geq 3.5\text{K}$) attachment and UV illumination facility and SQUID based magnetometer were installed while the commissioning of Riber Molecular Beam Epitaxy (MBE) System was completed. A new Pulsed Laser Deposition laboratory was set up. Cesium (Cs) atomic fountain became fully operational as a primary frequency standard (India-CsF1). A programmable Josephson Voltage Standard at 10 V level was installed with the support of NIST, USA. A number of other primary and secondary standards were established for the parameters of length, hardness, vibration, sound and power. Our plan to grow and nurture high quality young researchers continued and 15 new scientists were recruited.



The Annual Report highlights the progress and achievements made under different research programmes and also summarize other information that provides an overview of the institute during the year 2011-12. It also outlines the research priorities of XII Five Year Plan.

Focused R&D was done under various constituent divisions of the laboratory. The seven newly structured theme-wise Divisions are recognized as (1) Physics of Energy Harvesting, (2) Materials Physics and Engineering, (3) Radio & Atmospheric Sciences, (4) Time & Frequency (5) Apex Level Standards & Industrial Metrology and (6) Quantum Phenomena & Applications. For Materials Characterization, Sophisticated & Analytical Instruments Division has been put in place as a support unit.

Newly created, Division of Physics of Energy Harvesting showed significant progress on the development of novel anti reflection and surface passivation processes for single crystal and multi-crystalline solar cells. Use of luminous graphene quantum dots and soluble functionalized fullerenes for advanced organic photovoltaic devices were investigated. Progress was achieved in the development of low dimensional bismuth telluride alloys for advanced thermoelectric devices. Improved plasma assisted deposition processes for tribological coatings and thin film solar cells were developed.

The Division of Materials Physics and Engineering initiated two new activities, under the CSIR Network Project - Technologies and Products for Solar-energy Utilization through Networks (TAP-SUN), namely, “Development of novel thermoelectric materials and devices for harnessing solar energy and waste heat” and “Lithium ion and light weight lead-acid battery”. Work was started to develop novel thermoelectric materials such as, SiGe, Mg_2Si , half-Heusler and others with enhanced figure-of-merit. A well-equipped thermoelectric laboratory was established to work on the design, synthesis, characterization and thermoelectric property evaluation of nanostructures. Under an MoU between CSIR-NPL and Bhabha Atomic Research Center (BARC), the capability to develop carbon-carbon (C/C) composite fuel tubes for the application in Compact High Temperature Nuclear Reactor being proposed by BARC was demonstrated. Carbon-Carbon (C/C) composites were found to be more suitable materials due to their superior thermo – mechanical properties such as high thermal conductivity, low coefficient of thermal expansion, high thermal shock resistance, high strength and chemical inertness. Four numbers of C/C composite tubes as specified in the MoU, were handed over to the scientists of BARC for field trials and post irradiation evaluation.

In the area of Luminescence, tunable photoluminescence from hydrophobic silica gel nanoparticles, core-shell upconversion nanophosphors and optical bifunctional nanophosphors were developed for displays, enhancement of solar cell efficiency and biomedical applications. During the year, while some new biosensors were developed, performance enhancement of the existing ones was achieved. The DNA Sequence specific to Leukemia had been identified and a biosensor, very sensitive to leukemia (Blood cancer) was fabricated. The sensor is being validated with clinical patient samples from Army hospital (R&R). Cholesterol biosensor detection range (linear range) was improved to the range of 50 mg/dl to 300mg/dl. A new process of electrochemical polymerization onto paper strips was developed, for cost effective biosensor fabrication. Biocompatible dendrimer based biosensor was fabricated for e-coli (water borne disease) detection. Carboxyl functionalized ZnS, Au and Pt nanoparticles of 5-10 nm size were synthesized for modifying ITO-glass electrodes used as electrochemical sensors for the quantification of target cardiac biomarkers in phosphate buffer solution under optimum conditions.



Radio & Atmospheric Sciences Division initiated a network project under XII five year plan. The project aims at investigating the changing atmosphere due to human and natural perturbations over Indo-Gangetic plain and Himalayan regions and the impacts of changing atmosphere on agriculture, floral biodiversity and human health. In the Radio Science area, the investigation of ionospheric response to a number of stratospheric warming events using ionosonde data from different stations in the Asian zone was carried out. An attempt was made to investigate the suitability of various prediction models using the 1.8 GHz cellular frequency narrowband measurements conducted in urban and suburban areas of Delhi in northern India.

Landfills are major sources of methane emission contributing to the Global Warming and Climate Change. With the increasing urbanization, the contribution from this source is increasing. Annual Methane emission estimation from Municipal Solid Waste deposited in the Landfills in the different cities of India using the methane emission factor developed by CSIR-NPL was made. Further, for climate modeling, estimation of Emission Factors for organic carbon and elemental carbon emissions for different kinds of biofuel used in various Indian States was developed. Role of ambient ammonia in the formation of inorganic aerosol over Indo Gangetic Plain were also studied. Solar occultation spectra have been recorded in Delhi using Bruker 125 HR for retrieval of realistic profiles of N_2O and C_2H_6 in the troposphere. Long term spectral variations of Aerosol Optical Depth and Angstrom parameters have been studied to examine the seasonal, annual and inter-annual variations at Delhi.

A Primary Ozone Standard facility was established for providing traceability in surface Ozone measurements in India and South Asian Region and calibration measurement capability (CMC) for same has been submitted after successful completion of peer review. Efforts were made to set up Space Physics Laboratory at a new Indian Research Station “Bharati” ($69^{\circ}24'S$, $76^{\circ}11'E$), at Larsemann Hills, Antarctica which is 3000 km away from the present “Maitri” ($70^{\circ}45'S$, $11^{\circ}44'E$) Station. It is heartening that Dr. Rupesh M. Dass from the Laboratory is leading the 31st Indian Antarctica Expedition as its first leader to “Bharati”.

The Division of Apex Level Standards and Industrial Metrology continued to help calibration and testing laboratories of the country not only for providing traceability through calibration but also for maintaining their Measurement Assurance Programme (MAP) by providing training and conducting proficiency testing in different parameters. Many groups of this division are participating in international inter comparisons to maintain their capability. Training programs in various parameters were organized for development of skilled man power in the field of metrology in the country as well as neighboring countries. Some of the significant achievements included: Establishing (i) Long Gauge Blocks up to 4 meter (ii) High Temperature Blackbody Source, (iii) Secondary hardness standardizing machines for Rockwell, Vickers and Brinell scales, (iv) A new facility for the Study of Standard Inductor, (v) Measurement facility in the frequency range of 1 MHz to 2 GHz for the characterization of RF power etc. Another accomplishment was CMC of 1 kg at $\pm 28\mu g$ at $k=2$, which only a few other NMIs like PTB (Germany) and KRISS (Korea) have achieved.

Time and Frequency Division, which covers activities such as ultra stable Atomic Frequency Sources, Physics of Cold Atoms and Precise Timing Systems, had some significant scientific achievements. These included: Cs fountain becoming fully operational as a primary frequency standard; time scale –UTC (CSIR-NPLI) was upgraded to a more stable version based on a steered hydrogen maser output and backed up by an ensemble of five Cs clocks; Installation of a dual frequency multichannel GPS receiver and a Two Way Satellite Time & Frequency Transfer (TWSTFT) link to enhance the accuracies of CSIR-NPL's BIPM traceability. In addition to this, design and development of a second generation Cs fountain – Novel





Optically pumped Cs fountain was initiated. The division also worked on a Design Validation Model of a Rb frequency standard for ISRO's IRNSS navigation system and carried out routine calibrations of stop watches, timers, frequency counters, Cs and Rb clocks, GPS and Teleclock receivers. Major facilities that had been procured and installed during the year included: Hydrogen Maser, TWSTFT link and Commercial Cs clock.

Sophisticated & Analytical Instruments Division (SAID) comprising of four groups namely X-ray Analysis, Electron and 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 facilities like High-Resolution X-ray Diffractometer (HRXRD) cum X-ray Reflectometer (XRR) system, Fully Automated X-ray Fluorescence Spectrometer, variable pressure Scanning Electron Microscope (SEM), high-resolution Transmission Electron Microscope (TEM) with Energy Dispersive X-ray Spectroscopy and Scanning TEM attachments, Electron Paramagnetic Resonance (EPR) spectrometer, Atomic Force Microscope/Magnetic Force Microscope (FM/MFM), Secondary ion mass spectrometry (SIMS) and Scanning Probe Microscope (SPM) etc. Inductively Coupled Plasma-High Resolution Mass Spectrometry (ICP-HRMS) and a new X and Q band EPR Spectrometer were recently installed.

Crystal Growth and X-ray Analysis group of SAID successfully grew technologically important single crystals like Fe and Zn doped LiNbO_3 , BSO, LC-added Benzophenone etc by Czochralski method and variety of nonlinear optical organic and semiorganic NLO crystals [Cr-doped ZTS, LHN, L-alanine doped KDP, Mn-doped L-alanine, Glycine Phosphite, trans-stilbene etc.] by solution growth methods. Doping in NLO crystals were specially targeted as the properties could be engineered for tailor-made applications. The grown crystals and variety of MOCVD and MBE grown GaN based solid state light emitting diode structures from CEERI-Pilani and in-house activity were characterized by variety of techniques. The major achievements of Electron and Ion Microscopy group were: (i) Preparation of database for aerosol optical modeling by morphological characterization of atmospheric ambient particles (in collaboration with IIT, Kanpur) and (ii) ZnO decorated luminescent graphene as a potential gas sensor at room temperature was developed with a large sensor response and quick recovery time with preferred selectivity towards electron donor gases like CO and NH_3 and (iii) A US patent was filed for the removal of As and Cr from water using zinc peroxide nanoparticles. EPR Spectroscopy group carried out spectroscopic studies on $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Gd}_x\text{Fe}_{2-x}\text{O}_4$ ($x = 0.1, 0.2, 0.3$) nanoparticles in as-grown and annealed states. In the Analytical Chemistry group, International Peer Review in O_3 & elemental solutions was completed successfully for 13 CMCs. Five new elemental aqueous certified reference materials namely Pb (2 types), Cr, Ca and SO_4 were prepared and certified according to quality management system.

Towards Human Resource Development, CSIR-NPL provided training to students, pursuing M.Sc./M. Tech./MCA, or their equivalent degree programmes from different educational institutions spread all across the country. During the year, about 126 students underwent short and long term training. A Post Graduate Research Programme in Engineering (PGRPE) in "Advanced Materials Physics & Engineering" was initiated at CSIR-NPL, with an intake of 10 students. Twenty nine fresh research fellows were motivated to join the laboratory during the year, making a total strength of 96. Under the Academy of Scientific and Innovative Research (AcSIR)¹, 34 students were registered for Ph.D. in Physical and Chemical Sciences. 60 students

¹AcSIR was established by an Act of Parliament, the Academy of Scientific and Innovative Research Act, 2011 vide The Gazette of India No.15 dated February 7, 2012 and notified on 3rd April 2012.



were already registered for Ph.D. at other universities such as IITs, Delhi University, Delhi Technological University and JNU etc. Industrial training was also organized in the area of Metrology as well as other specialized topics. Such training courses were attended by various national and international organizations. A national seminar on “Recent development in Materials Devices for Solar Energy Applications” was also organized in Hindi by Raj Bhasha Unit during September 1-3, 2011.

Organization of institutional visits involving students, teachers, faculty members from school, colleges, universities, technical institutes, S&T organizations is an important activity of the CSIR-NPL. Eleven institutional visits were arranged which helped enhancing CSIR-NPL’s visibility in the society. Industrial training was also organized in the area of Metrology and Quality Management System. Four 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 330 scientific and technical papers were published in SCI indexed Journals. Forty two papers had impact factor in the range of 4 to 13. Ten patents were filed abroad and six patents were filed in India. Six international patents and five Indian patents filed in previous years were granted during 2011-12. Seventeen new projects (sponsored and consultancy) were undertaken and 2243 calibration reports were issued, which contributed to generation of an ECF of about 425 lakhs.

“World Metrology Day” together with “National Technology Day” was celebrated on May 20, 2011. The theme of “World Metrology Day”, as decided by Bureau International des Poids et Mesures (BIPM, Paris) was Metrology-Measurement in Science and Technology: a Bridge to Innovation. This was exemplified by the distinguished speakers invited on the occasion, Prof. Srikumar Banerjee, Chairman, AEC and Secretary, DAE, Govt of India and Dr. Krishan Lal, Chairman, INSA. Dr. Lal gave a preamble to the occasion and Prof. Banerjee delivered a very interesting and informative key note address entitled “Chemistry & Nuclear Energy”.

Hon’ble Minister of Science & Technology, Earth Sciences and Vice President, CSIR, Sh. Vilasrao Deshmukh² paid a goodwill visit to the laboratory on 22nd September, 2011. He met and keenly interacted with scientists as well as addressed them. He also visited and appreciated some of the important research activities and recently created state-of-art facilities. To mark the occasion, he along with officials of CSIR and CSIR-NPL planted the seedlings of *Callistemon lanceolatus* in front of the main building.

The Open-Day is once a year opportunity for interaction between scientists and the interested public eager to know more about the cutting edge research being conducted at the laboratory. The CSIR-NPL open day was held on 28th September, 2011 as part of CSIR’s Foundation Day Celebrations. Around 1900 visitors including students from schools and colleges turned up on the occasion.

In honour of Sir C.V. Raman, for his legacy and discovery of the Raman Effect on February 28, 1928, the National Science Day 2012 was celebrated on 28th Feb, 2012. Prof. Kehar Singh, formerly with IIT Delhi, delivered the inaugural lecture entitled “Security Holograms”. A Poster Presentation Event was also organized where the work of all research fellows of CSIR-NPL was exhibited. Prof. Kehar Singh had a lively interaction with the students and to encourage them further distributed five best poster awards.

² It was really shocking to learn about the sad and sudden demise of Shri Vilasrao Deshmukh on 13th August, 2012. It was unbelievable. We still cherish the sweet memories of his visit to NPL and interaction with staff members. I, on my own behalf and on behalf of CSIR- NPL staff, convey our heart felt condolences to the bereaved family.





Apart from scientific endeavors, we also participated in Pusa Horticulture Show held at IARI, Delhi, during February 25-26, 2012. Out of 105 entries that were submitted in 16 categories, we won 103 prizes which included 33 first prizes, 58 second prizes, 12 third prizes and 7 Challenge Cups/Shields. The efforts made by our Horticulture Section were quite impressive.

All these achievements could be possible due to the whole hearted support of each and every member of CSIR-NPL staff and young researchers. I, earnestly, appreciate the same. I also take this opportunity to acknowledge the valuable help, support and encouragement received from CSIR Head Quarters, Research Council and Management Council which assisted us to a large extent in achieving our aims. The regular visits of national and international experts at CSIR-NPL had been highly rewarding and valuable.

Last, but not the least, I would also like to acknowledge the contribution of the Publication Committee under the leadership of Dr.Virendra Shanker in bringing out this report. The co-operation and special efforts of Dr. Shanker, Sh Raghavendra, Sh. N.K. Wadhwa, Sh Prem Chand, Ms Anita Sharma, Ms Saroj Upadhyay and Sh Subhash Chandra are also appreciated.

(R. C. Budhani)

Director