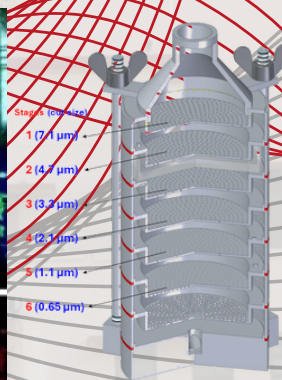


सी. एस. आई. आर. - एन. पी. एल.

**CSIR-NPL**



Indigenous Bi-luminescent security ink



Bioaerosol Sampler

Recycling of Plastic Wastes  
into Tiles

---

# ANNUAL REPORT 2022-23

# Annual Report

---

2022-2023



**सीएसआईआर - राष्ट्रीय भौतिक प्रयोगशाला**  
**CSIR-National Physical Laboratory**

(राष्ट्रीय मापिकी संस्थान)  
(National Metrology Institute)  
नई दिल्ली/ New Delhi



सी एस आई आर-राष्ट्रीय भौतिक प्रयोगशाला  
(भारत का राष्ट्रीय मापिकी संस्थान)  
**CSIR-NATIONAL PHYSICAL LABORATORY**  
(National Metrology Institute of India)



डॉ. के. एस. कृष्णन मार्ग, नई दिल्ली - 110012, भारत / Dr. K. S. Krishnan Marg, New Delhi - 110012, India  
[www.nplindia.in](http://www.nplindia.in)

## गुणवत्ता नीति : Quality Policy

अंतरराष्ट्रीय मानकों के अनुरूप सतत् अनुसंधान और विकास के माध्यम से राष्ट्रीय मापन मानकों का प्रापण, स्थापना, रखरखाव व उन्नयन करना और भारतीय निर्देशक द्रव्य (बी एन डी<sup>®</sup>) का विकास/उत्पादन करना।

आई एस/आई एस ओ/आई ई सी 17025 : 2017 की आवश्यकताओं के अनुरूप ग्राहकों को मापन की अनुमार्गणीयता बनाए रखने के लिए शीर्षस्तरीय अंशांकन/परीक्षण सेवाओं तथा मानकों का प्रसार निष्पक्ष और प्रभावी ढंग से प्रदान करना।

आई एस/आई एस ओ 17034 : 2016 की आवश्यकताओं के अनुरूप प्रयोक्ताओं हेतु अनुमार्गणीयता के प्रसार के लिए बी एन डी का विकास/उत्पादन करना और निर्देशक द्रव्य उत्पादकों (आर एम पी) को बी एन डी के विकास/उत्पादन में तकनीकी सहायता प्रदान करना।

To realize, establish, maintain and upgrade the national standards of measurement compatible to international standards and to develop/produce Bharatiya Nirdeshak Dravya (BND<sup>®</sup>), through continuous research and development.

To provide apex level calibration/testing services and dissemination of standards for maintaining the traceability of measurements to the customers fulfilling the requirements of IS/ISO/IEC 17025 : 2017, impartially and effectively.

To develop/produce BNDs for disseminating traceability to the users and to provide technical support to the Reference Material Producers (RMPs) in the development/production of BNDs, conforming to the requirements of IS/ISO 17034 : 2016.

## उद्देश्य : Objectives

ग्राहकों/प्रयोक्ताओं की संतुष्टि के लिए निर्दिष्ट समय-सीमा में निष्पक्षता व सक्षमता से अंशांकन/परीक्षण सेवाएं और बी एन डी प्रदान करना।

अंशांकन, परीक्षण व बी एन डी विकास/उत्पादन से संबंधित सभी कर्मियों को गुणवत्ता प्रणाली प्रलेखन तथा नीतियों और प्रक्रियाओं के कार्यान्वयन से परिचित करना।

To provide calibration/testing services and BND within the specified time, impartially, competently and to the satisfaction of the customers/users.

To familiarize all personnel concerned with calibration, testing and BND development/production with the quality system documentation and implementation of policies and procedures.

प्रो. वेणु गोपाल आचन्टा  
निदेशक

Prof. Venu Gopal Achanta  
Director

# CSIR-NPL: Vision and Mandate



**Shri Narendra Modi**  
Hon'ble Prime Minister  
President, CSIR



**Dr. Jitendra Singh**  
Hon'ble Union Minister of State  
(Independent Charge) Science &  
Technology, Minister of State  
(Independent Charge) Earth Sciences  
Vice President CSIR



**Dr. N Kalaiselvi**  
Director General,  
CSIR and Secretary DSIR



**Prof. Venugopal Achanta**  
Director, CSIR-NPL

## Vision and Mission

“Accurate and precise measurement are essential to drive the growth engines of Indian Science & Industry as it removes chaos and prompts innovations, which in turn, would save precious lives, resources and time....

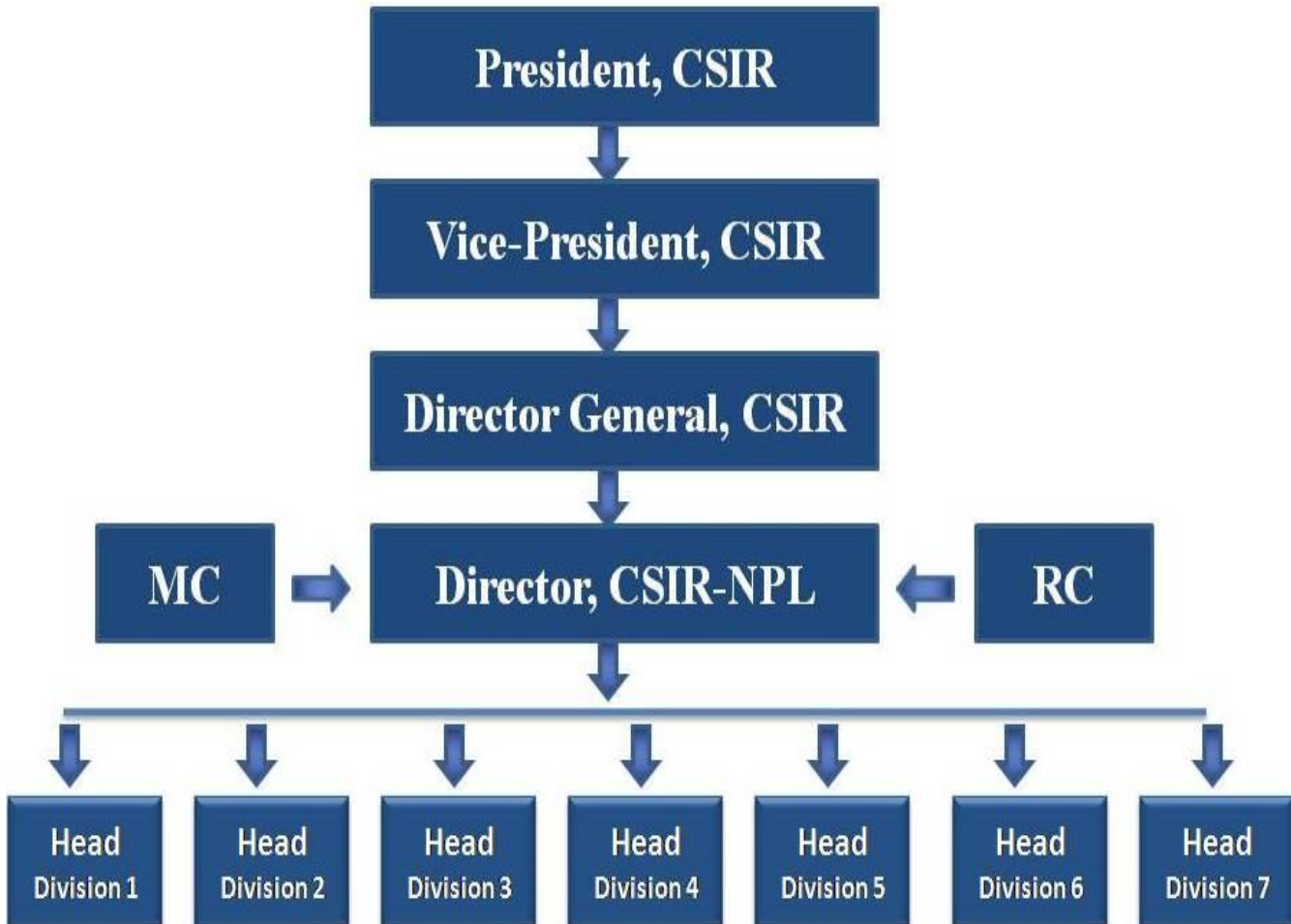
- a) *Developing India's measurement standards that are internationally accepted and disseminating the measurement capabilities to industry, government, strategic and academia that underpin the India's prosperity and quality of life.*
- b) *Conducting multidisciplinary R&D with a mission to establish the futuristic quantum standards and upcoming technologies so that India remains on par with international measurement laboratories.*
- c) *Developing sophisticated analytical equipments (i.e. import substitutes) under “Make in India” programme to cater the ever increasing demands of emerging India.*
- d) *Training of young scientists and industry personnel in the area of measurements under “Skill India” programme.*

## Mandate

CSIR-National Physical Laboratory (NPL-India) is mandated to be India's “National Metrology Institute” (NMI) by the act of Parliament and is the custodian of “National Standards” with a responsibility of the dissemination of measurements to the needs of the Country.

# Organizational Structure

## CSIR-NPL: Assuring Quality of Life



- Division 1:** Physico-Mechanical Metrology
- Division 2:** Electrical & Electronics Metrology
- Division 3:** Environmental Sciences and Biomedical Metrology
- Division 4:** Advanced Materials and Device Metrology
- Division 5:** Bharatiya Nirdeshak Dravya (BND®): Indian Reference Materials
- Division 6:** Indian Standard Time Metrology

# Contents

---

<b>Quality Policy</b>	i
<b>CSIR-NPL: Vision and Mandate</b>	ii
<b>Organizational Structure</b>	iii
<b>Preface</b>	v
<b>CSIR-NPL Enabling Quality Infrastructure</b>	x
<b>Significant Contributions</b>	1
<b>Glimpses of Events</b>	19
<b>Report from our Divisions/ Divisional Activities</b>	
Physico-Mechanical Metrology	41
Electrical and Electronics Metrology	48
Environmental Sciences and Biomedical Metrology	56
Advanced Materials and Device Metrology	67
Bharatiya Nirdeshak Dravya (BND®): Indian Reference Materials	86
Indian Standard Time Metrology	88
Directorate	98
<b>Annexure I: R&amp;D Projects</b>	120
<b>Annexure II: Awards &amp; Achievements</b>	122
<b>Annexure III: Staff; Patents, Reports; and Budget Outflow</b>	127
<b>Annexure IV: Patents list</b>	128

## Preface



It is my pleasure to present the Annual Report of CSIR-National Physical Laboratory (CSIR-NPL) for the year 2022-2023. Being an institute of national importance, the objective of the laboratory is to strengthen R&D in physics, chemistry, and allied areas for the overall development and innovation in science and technology. The CSIR-NPL is mandated to be India's National Metrology Institute (NMI) by an act of parliament and is the custodian of National Standards with a commitment to ensure accurate dissemination of measurements, contributing to the development of a robust quality system and infrastructure for import/export activities, as well as ensuring high standards in everyday life. Since its inception, CSIR-NPL has been a pillar for Indian industries and society in providing continuous advancement in knowledge-based technologies by working on metrological traceability, R&D activities, and innovation. Furthermore, CSIR-NPL embraces the importance of science and technology in addressing societal issues, fostering skill development among youth, and generating valuable knowledge. These activities aim to strengthen the nation's economic growth engine, fostering higher and more sustainable economic output.

During the year 2022-23, remarkable research were undertaken in all the six distinguished divisions, each dedicated to a specific theme, namely, Physico-Mechanical Metrology, Electrical & Electronics Metrology, Environmental Sciences & Biomedical Metrology, Advanced Materials and Device Metrology, Bharatiya Niradeshak Dravya (BND®): Indian Reference Material, and Indian Standard Time Metrology. As a result of the outstanding fundamental and applied research conducted in these fields, numerous papers have been published in high-impact journals, and significant inventions have been patented.

The Physico-Mechanical Metrology division in 2022-23, has established, a clinical thermometer calibration facility at RRSL Ahmedabad; spectroradiometer (2.0 m) for LED testing; pneumatic pressure standard from 0.2 MPa to 100 MPa; low liquid flow calibration facility from 5 ml/hr to 1500 ml/hr; and temperature testing facility for personal protection equipments (masks, gloves, gowns), ventilators and IR thermal body scanners as per National/International Standards at CSIR-NPL. Upgradation of primary sound standard in the frequency range of 1 Hz to 25 kHz, designed and developed Pd-C fixed point (1491.45 °C), and investigation of structural stability of DyScO<sub>3</sub> under extreme conditions of pressure & temperature was carried out. The Length, Dimension and Nano Metrology sub-division has participated in three International Inter-comparisons: Glass Scale ILC, APMP.L-K8 and APMP.LK4.n0.

The Electrical & Electronics Metrology division has contributed towards the development of a novel memristor demonstration kit, superconducting nanowire single photon detector (SNSPD), and broadband THz absorption using nanosheets of Bi<sub>2</sub>Te<sub>3</sub> grown on a transparent conductor.

The Environmental Sciences & Biomedical Metrology division has a profound involvement in the development of secondary ozone standard for ozone generator calibration, calibration facility for electrocardiogram (ECG) simulator, six-stage bioaerosol sampler technology, and observation of signature of Y-forking in Ionogram traced at low-mid latitude Indian station during earthquake events that occurred in the vicinity of New Delhi.

The Advanced Materials and Device Metrology division has been thrusting on the development of indigenous, economically viable and efficient organic and inorganic photovoltaic and thermoelectric devices, luminescent materials, carbon-based materials, composites and thin-film based gas sensors. The division undertook this mandated research and development of multi-functional RGB luminescent security pigment based golden ink with Myriad Security features to curb counterfeiting of Passport to address national security needs to avoid forgery. Self-driven UVC-NIR Broadband Photodetector with High-Temperature Reliability based on a Coco Palm-like MoS<sub>2</sub>/GaN heterostructure and potential selectivity of monolayer MoS<sub>2</sub> quantum materials for terahertz applications and its legitimate comparison with Bulk MoS<sub>2</sub> has been demonstrated successfully. CNTs - polyurethane composites-based strain sensor for human motion detection has been developed and demonstrated for bio-medical applications. A souvenir, a square pyramid with CSIR and NPL logos using FDM 3D Printer has been designed and developed at CSIR-NPL.

The Bharatiya Nirdeshak Dravya (BND<sup>®</sup>): Indian Reference Material division, known for its state-of-the-art measurement methods for the determination of chemical composition and/or physical properties created a facility for trace elemental analysis by inductively coupled plasma–mass spectrometry (ICP-MS) system. Elemental standard solution Indian reference material (Bharatiya Nirdeshak Dravya, BND) for drinking water has been released. Chemical BNDs (BND<sup>®</sup> 1036, BND<sup>®</sup> 1037, BND<sup>®</sup> 1038 and BND<sup>®</sup>1042), Precious Metals BNDs (BND<sup>®</sup> 4205, BND<sup>®</sup> 4207, BND<sup>®</sup> 4208, BND<sup>®</sup> 4209), Ultimate Tensile Strength BNDs (BND<sup>®</sup> 2216, BND<sup>®</sup> 2217, BND<sup>®</sup> 2218, BND<sup>®</sup> 2219) and Hardness BND (BND<sup>®</sup> 2207) were released on the occasion of CSIR-NPL Foundation Day – 2023 in collaboration with different RMPs.

The Indian Standard Time Metrology division has dedicated research in designing ultra-stable clock lasers for Yb<sup>+</sup> ion based optical frequency standards, demonstration of laser-cooling of cesium atoms in India's first indigenously developed primary frequency standard NPLI-CsF1, dissemination of Indian Standard Time using Precision Time Protocol: towards resilient time synchronization using optical fibers for critical infrastructure in India, upgraded AC-DC current transfer difference calibration facility and developed



magnetic-based detection of muscular contraction for controlling hand prosthesis. The LF, HF Voltage and Microwave Metrology sub-division piloted a supplementary comparison on digital multimeter (APMP.EM-S8). In order to enhance precision in power grid operations, CSIR-NPL provided traceability to PGCIL's phasor measurement unit calibration system.

The global recognition of the need for science, technology, and innovation to drive sustainable development and tackle environmental challenges resulting from rapid industrialization is undeniable. The CSIR-National Physical Laboratory is excelling in its responsibility and is actively playing a crucial role in advancing this objective, making significant contributions towards enhancing India's global competitiveness in all areas of development. To achieve its goals, CSIR-NPL has been steadily and consistently transforming to become a leading and globally recognized laboratory. This transformation has continued in the year 2022-23, with further enhancements made to the already existing world-class research infrastructure of the laboratory.

This year, CSIR-NPL commemorated a series of significant events aimed at raising awareness on various societal issues and celebrating milestones. These included the observance of International Noise Awareness Day and World Hearing Day marking a dedication to traditional healing practices, along with the recognition of World Metrology Day, and the 7<sup>th</sup> Ayurveda Day. Furthermore, CSIR-NPL honored its own heritage, observing the 81<sup>st</sup> Foundation Day of CSIR, along with hosting the CSIR-NPL Open Day 2022, which is once a year opportunity for direct interaction between scientists and the public to know about research activities of the laboratory. Around 2500 participants from various schools and colleges turned up on the occasion. These events are pivotal in highlighting the institution's contributions and advancements in scientific endeavors. As a tribute to Sir C.V. Raman, the festivities also encompassed the commemoration of National Science Day 2023, underlining its commitment to promoting scientific knowledge and innovation for the betterment of society.

CSIR-NPL also hosted two prestigious events to pay homage to the esteemed legacy of Dr. K.S. Krishnan, the visionary founding director of the institute. The 36<sup>th</sup> Krishnan Memorial Lecture was honored by the esteemed presence of Dr. T. Ramasami, Former DST Secretary and Chairman K.S. Krishnan Memorial Trust. Additionally, the event served as the auspicious occasion for the formal inauguration of the illustrious Dr. Krishnan Memorial Scholar's Gallery, symbolizing a lasting tribute to his profound contributions. Furthermore, in partnership with AcSIR, a distinguished lecture was orchestrated to honor the 125<sup>th</sup> anniversary of Sir K.S. Krishnan's birth. Distinguished Professor Suresh K. Bhargava from RMIT University, Australia, delivered an enlightening discourse titled 'Establishing a Platform for Solution Engineering: Redefining Innovation'.

Throughout the calendar year, CSIR-NPL organised various educational, developmental, and collaborative initiatives spanning diverse domains. Among these, hands-on training

sessions were conducted on Thin Film Growth Techniques such as ‘Sputtering and Pulsed Laser Deposition’, aimed at enhancing technical expertise in this specialized field. A notable webinar titled ‘Advances in Metrology by the Custodian of Indian National Standards: CSIR-NPL’ was hosted under the CSIR Success Stories platform, shedding light on cutting-edge advancements in metrological sciences. Furthermore, the institute played a pivotal role in organizing the International Workshop on Building Acoustics and Noise Control (IWBA-2022), addressing critical issues in architectural acoustics and noise mitigation strategies. The year also witnessed the International Conference on ‘Advances in Metrology’ (AdMet-2022), along with the Pre-AdMet Workshop, a major scientific event held every three years, serving as a prestigious forum for global discourse on metrological advancements. The 8<sup>th</sup> National Conference on Advances in Metrology (AdMet-2023), and Pre-AdMet Workshop, highlighting CSIR-NPL's dedication to fostering excellence in metrological research and education were also organised. Under the Skill Development Programme, 22 specialized trainings were conducted covering various facets of metrology, including Low Frequency Voltage & Current, Length & Dimension, Force, Torque, and Hardness Metrology, among others, aiming to foster skill development in these critical areas. Collaborative efforts with international partners, such as onsite training to NMI Bangladesh and joint endeavors with PTB Germany on Gas Metrology standards, underscored CSIR-NPL's commitment to global cooperation in advancing metrological practices. Moreover, the institute actively engaged in outreach activities, including the Jigyasa Program, and Pollution Awareness Workshops, aiming to instill scientific curiosity and environmental consciousness among school children. Participation in Defence Expo 2022 further showcased the institute's multifaceted contributions to the scientific community. Additionally, special training programs were tailored for specific audiences, such as students from Kanya Maha Vidyalaya, Jalandhar (Punjab), underscoring the institute's commitment to nurturing talent and fostering inclusivity in the scientific landscape. Furthermore, the laboratory actively seeks collaborations through various engagement platforms like MoUs, Technical Services Projects, and Licensing of Technology/KnowHow with organizations such as Phoenix Contact (India) Pvt. Ltd, New Delhi; Sound Works, Nirmala Toilet, Haryana; Envirotech Systems Limited, Uttar Pradesh; Aron Universal Limited, Karnataka; Jalan and Company, New Delhi; Aashvi Technology LLP, Ahmedabad; National Council for Cement and Building Materials (NCB), Ballabgarh; Global PT Provider Pvt. Ltd., New Delhi; Pharmaffiliates Analytics & Synthetics Pvt. Ltd., Haryana; SUMS Techno Labs Private Ltd, Karnataka; SRK Instruments, Hyderabad; RMP Global PT Provider Pvt. Ltd. (GPTP), New Delhi; RMP Pharmaffiliates Analytics & Synthetics Pvt. Ltd., Panchkula among others. Such collaborations are anticipated to yield high-impact technologies and products, ultimately enhancing the quality of life for the masses.

In addition to the aforementioned activities, under an MoU was signed between CSIR-NPL (NMI of India) and Bhabha Atomic Research Centre (BARC, Designated Institute of India for Ionizing Radiation) in October 2020 for providing guidance to the Radiation Standard Section (RSS), a team of scientists from CSIR-NPL visited RSS, BARC for verification of the

implementation of the quality system. These agreements and MoUs underscore CSIR-NPL's commitment to fostering collaborative efforts with industry partners, driving innovation, and addressing societal challenges through cutting-edge research and development initiatives.

In recognition of their commendable work during 2022-23, CSIR-NPL researchers also received several prestigious honors such as CSIR-NPL was elected as a Member of the International Committee for Weights and Measures (CIPM); Dr. N Vijayan was awarded the MRSI Medal during IUMRS-ICA 2022 at IIT Jodhpur; Dr. Govind Gupta received the Fellowship of the Electron Microscopy Society of India (FEMSI); Dr. Poonam Arora was elected as a Fellow of MSI, and selected as a Senior Member of the International Union of Radio Science (URSI); Dr. Anshul Varshney was selected to participate in the BRICS Young Scientist Forum Conclave 2022 held in Xiamen, China; Dr. Jai Shankar Tawale was honored with the EMSI Excellence in Microscopy Award. These honors highlight the exemplary research and expertise of CSIR-NPL researchers in their respective fields.

Further, during the period, i.e., from 1<sup>st</sup> April 2022 to 31<sup>st</sup> March 2023, CSIR-NPL demonstrated its prowess with 359 publications in SCI journals and 07 patents granted in India. Beyond its role as a leading R&D institute, CSIR-NPL actively contributes to Human Resource Development in Metrology. The institute imparts knowledge to students from various educational institutions nationwide through academic training programs focusing on CSIR-NPL's research areas. During this period, 116 students received training to fulfill their academic degree requirements. Additionally, 36 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. programme, resulting in a total strength of 335 Research Fellows (JRFs+SRFs) as of 31<sup>st</sup> March 2023.

I am indebted to thanks DG-CSIR, CSIR Headquarters, Chairman and members of the Research Council, and the Management Council for their valuable guidance and support in steering the laboratory's endeavors to success. I am also acknowledging the support and encouragement we have received from various funding agencies and end-users, and extend appreciation to all the scientists and staff members of CSIR-NPL for their utmost dedication and commitment to the institute's objectives and goals. I am confident that together we can bring pride to our nation through our pioneering Research and Development work in Metrology and allied areas.

(Prof. Venugopal Achanta)

Director CSIR-NPL

# CSIR-NPL: Enabling Quality Infrastructure

---

List of selected organizations to whom support, advices and apex calibration services are being provided

## **Government/PSU**

DRDO, ISRO, Election Commission of India, CPCB, Indian Railways, Indian Airforce, Air India, BSF, BIS, Legal Metrology, DAE, CPRI, HAL, BHEL, BEL, GAIL, ONGC, IOCL, HPCL, Indian oil, State Electricity Boards, NTPC, Delhi Jal board, MSME Testing Centres, Ordnance Factory, Steel Authority of India and Scientific Institutes/Labs, Universities etc.

## **Private Sector/Industries**

Tata Steel; Mysore Paints & Varnish; CK Birla Group; GE power systems; ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Adani Electricity; Binani Cement; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej & Boyce Mfg. Co. Ltd; Havells India; Honda Cars; J.K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen & Toubro; Maruti Suzuki; Philips India; Rapid Metro Rail Gurgaon; Samsung India; Honda Siel; Surya Roshni, Wipro consumer care & lighting; Orient Electric; ITC, Halonix Technologies, Astra lighting; Bharat Forge; Tektronix India; Fluke Technologies etc.

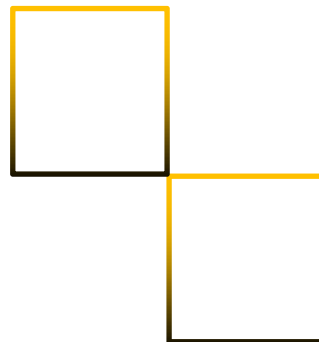
## **SAARC Nations**

Nepal Bureau of Standards & Metrology (MBSM), Bangladesh Standards and Testing Institution (BSTI), Measurement Units, Standards and Services Department, Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Maldives Standards and Metrology Unit



**ANNUAL  
REPORT  
2022-23**

**Significant Contributions**

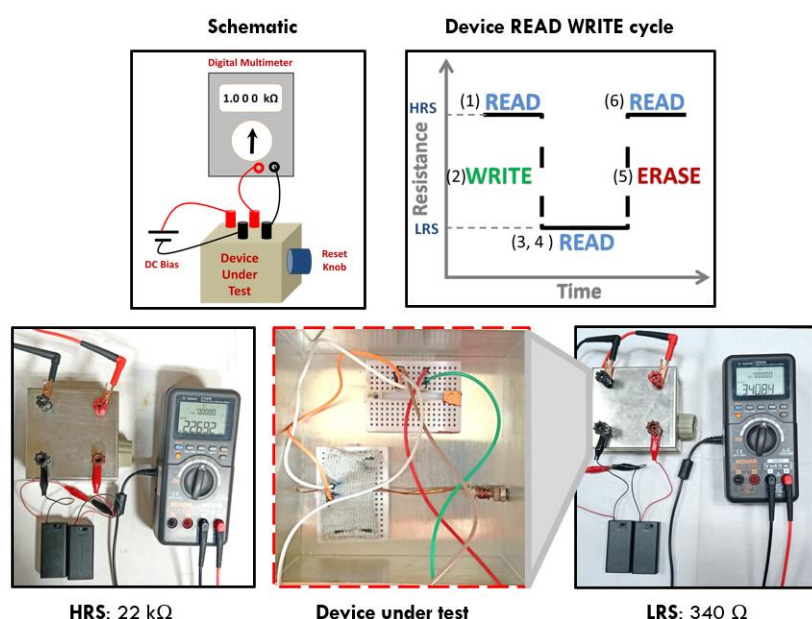


## Development of Novel Memristor Demonstration Kit at CSIR-NPL

In the realm of modern electronics, the memristor has emerged as a remarkable component with diverse applications. This two-terminal electrical device possesses the unique ability to store and regulate the flow of electrical current within a circuit. Often hailed as the fourth fundamental circuit element alongside resistors, capacitors, and inductors, the memristor combines the characteristics of memory and resistance. Its resistance can dynamically change over time based on the past current flow, rendering it as an intriguing and influential component in the field of electronics.

Memristors find one of their most vital applications in resistive random-access memory (ReRAM or RRAM), a form of computer memory. The ability to retain information even when power is disconnected makes memristors ideal for non-volatile memory devices like solid-state drives. Furthermore, memristors have the potential to revolutionize artificial neural networks, enabling learning and adaptation over time. This capability opens doors to various fields, including image recognition and natural language processing. Memristors stand as a captivating and crucial component in modern electronics, promising wide-ranging applications in computing, communications, and artificial intelligence.

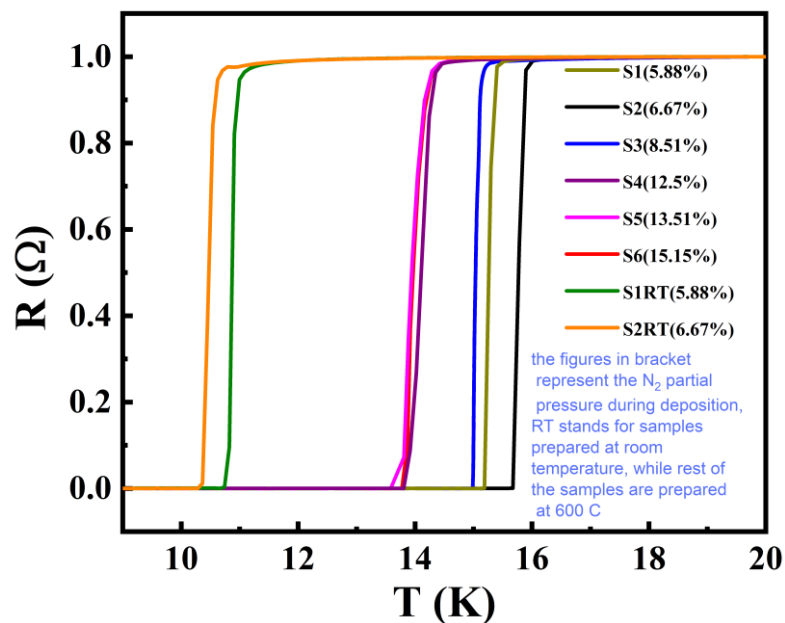
A cost-effective, user-friendly, reliable, and reusable experimental setup for showcasing the operation of a write-once-read-many times (WORM) memristor was developed. Utilizing an electro-conductive textile as a phase change material, our setup exhibits typical memristive behaviour. It swiftly transitions from a high resistance state (HRS) of tens of kilohms to a low resistance state (LRS) of hundreds of ohms upon the application of a short-duration DC bias, using a 9V battery. The transition is non-volatile and stable. If needed, the device can be reset to HRS through a small mechanical perturbation while the battery is disconnected. The experiment can be repeated multiple times as required.



Memristor demonstration kit developed at CSIR-NPL

## Superconducting Nanowire Single Photon Detector (SNSPD) Development

The detector development and allied topics are part of the DST (QuEST) sponsored project on developing single photon detectors (SPD) using superconducting nanowires. The superconducting properties of different systems in the 2D regime, i.e., thickness in the range from 5 nm -10 nm were optimized. The systems include NbTiN, VN etc., and the transition temperature of these systems are in the range of 5-10 K, suitable for SNSPD operation  $\sim 2$ K. W(Focused Ion Beam fabricated) nanowires and meander structures with varying width from  $\sim 100$  nm -850 nm were tested for their superconductivity, and is found to be of robust superconducting system having  $T_c \sim 5$ K. The figure given below gives the results of the optimization studies of NbTiN thin films with respect to the  $N_2$  partial pressure during deposition, wherein deposition was performed at the substrate temperature of  $600^\circ\text{C}$  and room temperature. An optical setup for generating photons to the tune of single photons by continuously attenuating laser light is being tested at room temperature. Exploration of 2D superconducting systems for relevant physics, such as superconductor-to-insulator transition or superconductor-to-metallic transition is being investigated. Also, suitability of each system for the SNSPD application is also being carried out, invoking principles of vortex motion with respect to small applied magnetic fields. Inter-comparison of Zener reference standards against the Josephson voltage standard has been undertaken, and the report has been submitted to BIPM for evaluation.

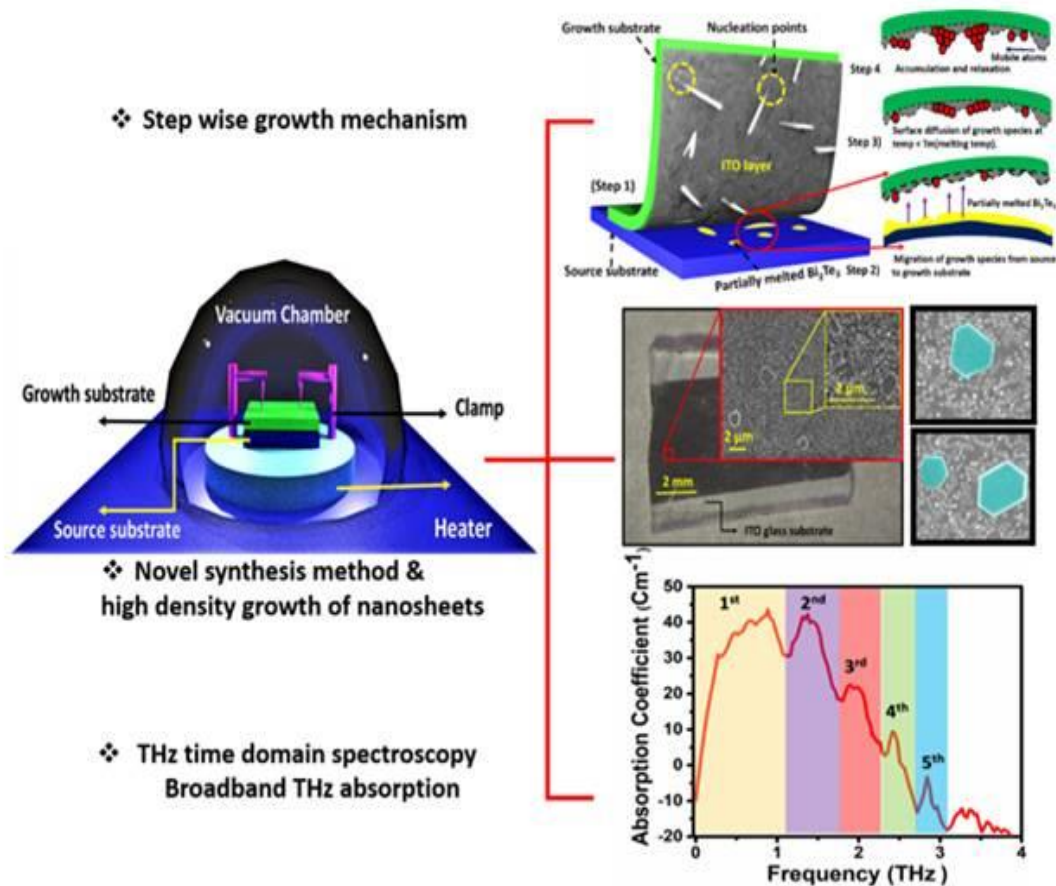


Normalised resistance as a function of temperature for NbTiN films of thickness  $\sim 50$  nm as part of  $N_2$  partial pressure optimization studies

## Broadband THz Absorption using Nanosheets of $\text{Bi}_2\text{Te}_3$ Grown on a Transparent Conductor

FIB Lab has used an unconventional route to synthesize the high-density  $\text{Bi}_2\text{Te}_3$  nanosheets on a transparent conducting substrate without using a conventional template and catalyst. The material characterization tools such as Raman and TEM confirm the synthesized single crystalline quality of the nanosheets. The THz- time-domain spectroscopy in transmission mode was employed to investigate the absorption

properties of  $\text{Bi}_2\text{Te}_3$  nanosheets between 0.1 to 4.0 THz. This broadband absorption indicates that the work has a considerable possibility that  $\text{Bi}_2\text{Te}_3$  nanosheets can be used as THz absorbers in the fields like terahertz electromagnetic stealth, communication and optoelectronics industries.

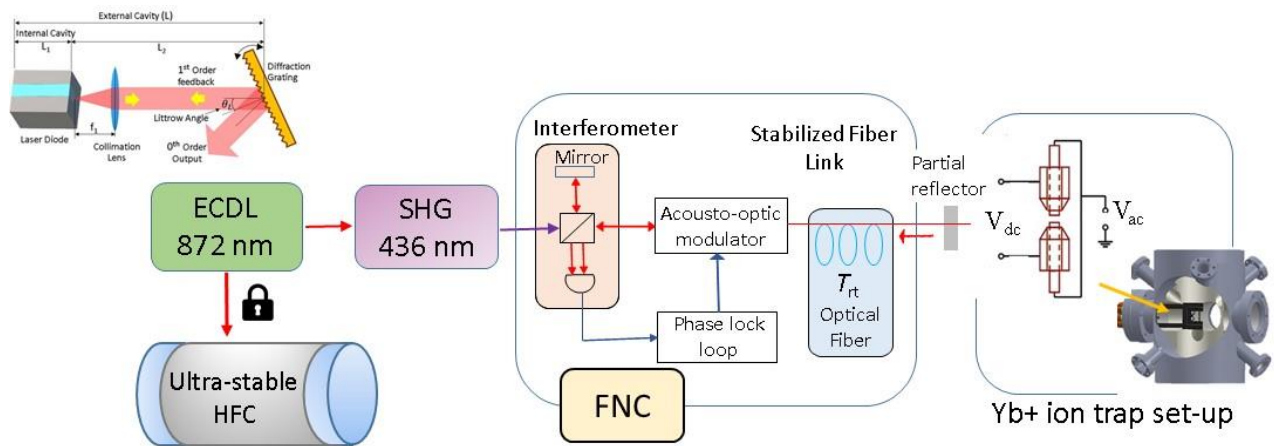


Fabrication of  $\text{Bi}_2\text{Te}_3$  nanosheets-based broadband THz absorber

### Design of Ultra-stable Clock Lasers for $\text{Yb}^{+}$ -ion based Optical Frequency Standards

Time is one of the base SI units, and atomic optical frequency standards have been realized with  $10^{-18}$  level of accuracy and stability, which are two orders of magnitude better compared to the present SI second, based on Cesium microwave standard. Such optical clocks are potential candidates for the re-definition of the SI second in the near future. However, the smooth and effective transition of “Time” requires that more and more laboratories in various countries across the world are able to realize such optical clocks in their standards laboratory. Realization of such clocks require an ultra-stable laser, used as the oscillator for interrogating the clock transition in the atomic species. At CSIR-NPL, we have designed an external cavity diode laser and a high-finesse cavity to be used for the ultra-stable clock laser.





Schematic of the proposed design for the ultra-stable laser; ECDL: External cavity diode laser; SHG: second harmonic generation; FNC: Fiber noise canceller

### Demonstration of Laser-cooling of Cesium Atoms in India's First Indigenously Developed Primary Frequency Standard NPLI-CsF1

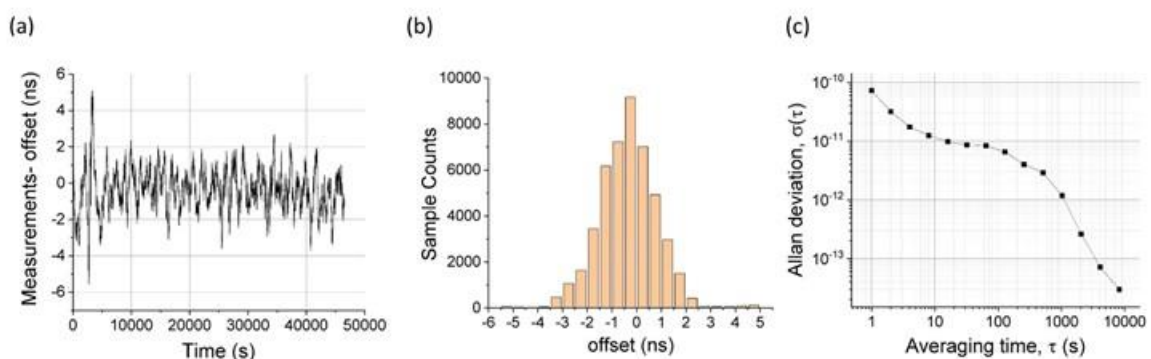
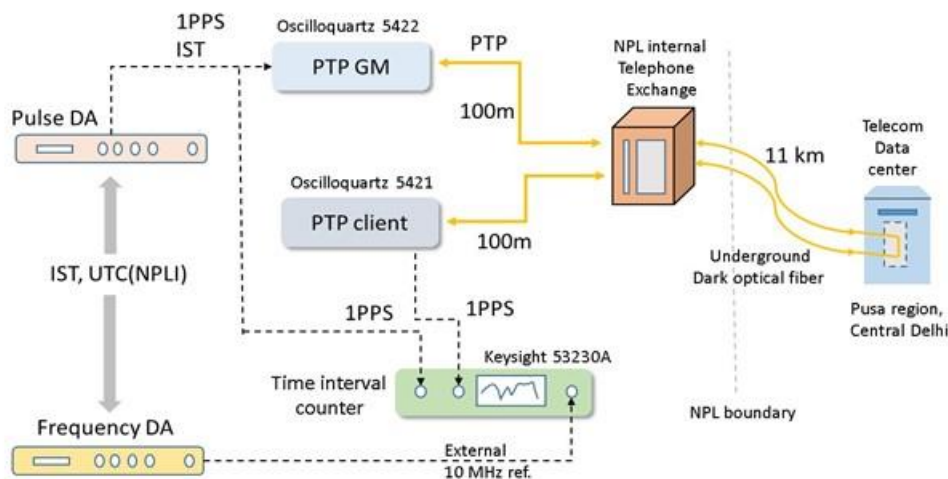
Millions of Cesium atoms were laser cooled to a few micro kelvin temperature, inside the vacuum chamber of NPLI-CsF1 after many years. Efforts were made to launch the cold atoms, detect them and realize the fountain operation and trademark Ramsey Fringes. The indigenously developed fountain clock is a complex interdisciplinary work and it was a herculean task to get all the subsystems up and working one by one. The fountain primary standard was finally revived in December 2022 with cooling and trapping of Cesium atoms.



Image of laser-cooled cloud of Cesium atoms, trapped in a magento-optical trap (MOT), captured with an Infrared CCD camera mounted on one of the viewports on the vacuum chamber. In the bright spot (atomic cloud), more than 10 million Cesium atoms are trapped at few micro kelvin temperature. The cold Cesium atomic cloud is used to realize SI Second in India's first and only indigenously developed Cesium Fountain Primary Frequency Standard

## Indian Standard Time Dissemination using Precision Time Protocol: Towards Resilient Time Synchronization using Optical Fibers for Critical Infrastructure in India

National time dissemination using terrestrial ethernet and optical fiber cables is an alternative to satellite-based systems and provides redundancy to reliable time services for critical infrastructure in the country. Precision time protocol based on IEEE 1588 standards using such cables and fibers can provide sub-microsecond time synchronization between a provider and the client. The method employs hardware time stamping, dedicated traffic-free fiber links, and PTP-aware network elements. CSIR-NPL has carried out a proof of concept experiment for the distribution of Indian standard time using the IEEE protocol in a laboratory and the effect of introducing a PTP-supported switch on the distribution performance. Further, synchronization experiments were performed with an underground dark telecom optical fiber lying outside the laboratory in the central Delhi region, which is used as the medium of communication. The one-second pulse-pulse jitter is found to be within 2.5 ns.

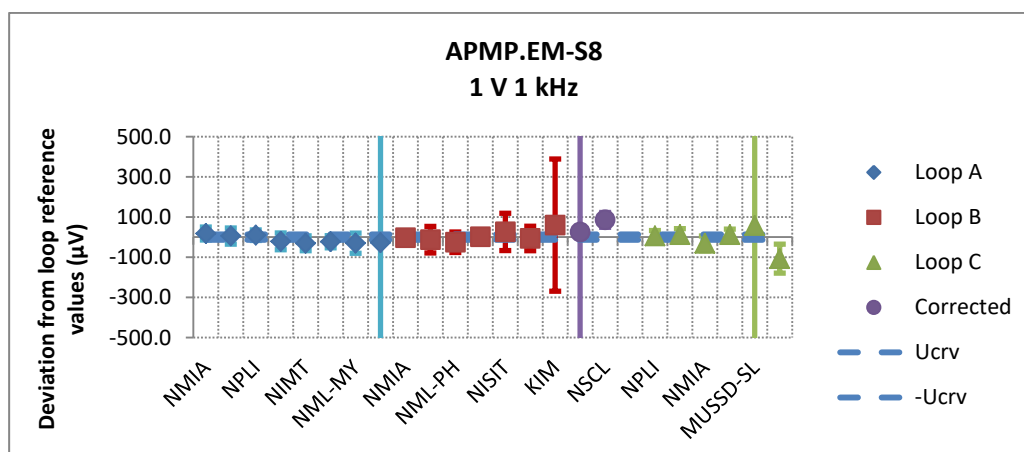


Schematic of the PTP based time dissemination in the Central Delhi region for a dark 11 km long optical fiber link. (a) Offset measured for a duration of 12 hours, (b) Jitter distribution, (c) Stability for the time recovered at the client location

## Piloted a Supplementary Comparison on Digital Multimeter (APMP.EM-S8)

A measurement comparison of DC voltage, DC current, DC resistance, AC voltage and AC current has been carried out among seventeen national metrology laboratories with the travelling standards 6½ digit multimeter (Fluke model 8846A) as Loop A, Loop B and Loop C for the nominal values of the measured parameters DC Voltage (100 mV, 1 V, 10 V, -10 V, 100 V and 1000 V), DC Current (10 mA and 1 A), DC Resistance (100 Ω, 1 kΩ and 10 kΩ (using 4-wire), AC Voltage (100 mV, 1 V, 10 V, 100 V and 700 V at 40 Hz and 1 kHz) and AC Current (10 mA and 1 A at 40 Hz and 1 kHz) for establishing the degrees of equivalence among the participating NMIs. . The seventeen laboratories participated are CSIR-NPL India (NPLI), NMI Australia, CSIR-NML South Africa, ESLMASM Mongolia, NIM Thailand, SCL Hong Kong, NMI Malaysia, MUSSD Sri Lanka, VMI Vietnam, NML Philippines, NISIT Papua New Guinea, KIM-LIPI Indonesia, KIM Kazakhstan, NIS Egypt, NSCL Syria, JNMI Jordan and NMC Singapore.

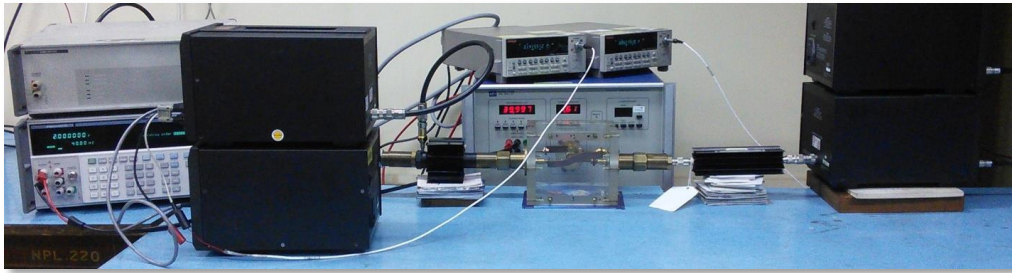
CSIR National Physical Laboratory (India) acted as the pilot laboratory for the comparison with full support from NMIA (National Metrology Institute, Australia). The comparison results received for the three Loops as correction in measured parameters and the corresponding expanded uncertainties were graphically represented. The comparison chart for 1V 1kHz is as shown in the following figure.



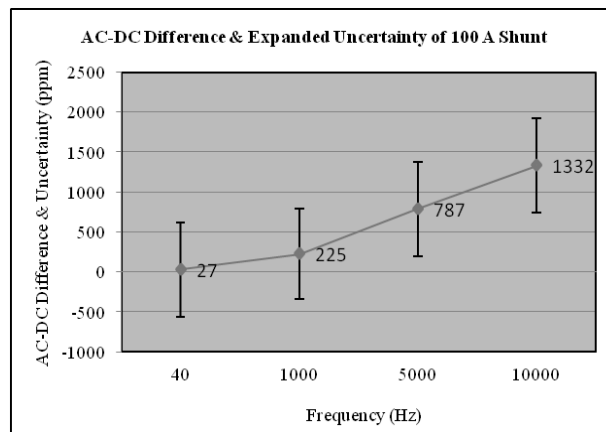
Comparison chart for AC voltage 1V, 1kHz

## Upgradation of AC-DC Current Transfer Difference Calibration Facility

- **AC-DC Current transfer difference calibration facility established for 100A from 10Hz to 10kHz:** CSIR-NPLI being an NMI of the country is involved in upgrading the reference standard calibration facilities to support and provide traceability to lower level laboratories in the country. Through rigorous research and development NPLI has extended the AC-DC current transfer calibration facility from 20A to 100A in form of buildup technique in the frequency range 40 Hz - 10 kHz. The measurement setup and measurements (represented graphically) for assigning AC-DC transfer difference at high current are as shown in the following figures respectively.

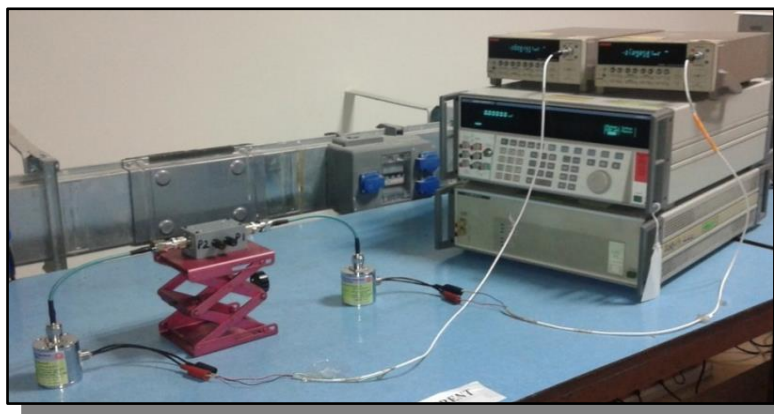


Measurement setup

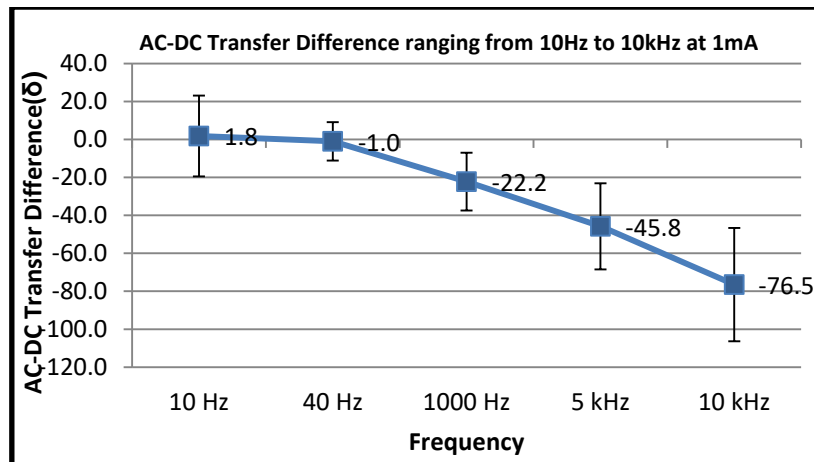


AC-DC transfer measurement for 100A Current shunt

- AC-DC Current transfer difference calibration facility established for 1mA from 10 Hz to 10 kHz using Primary Standard NPLI-MJTC(Multi-junction Thermal Converter):** Using Build down technique NPLI has extended the AC-DC current transfer calibration facility down to 1mA in the frequency range 10 Hz - 10 kHz. The measurement setup and measurements (represented graphically) for assigning AC-DC transfer difference at low current are as shown in the following figures respectively.



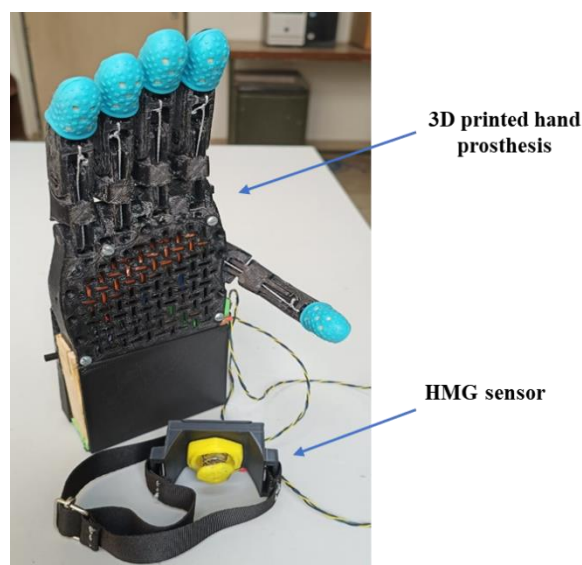
Measurement setup



AC-DC transfer measurement for 1mA current shunt

### Magnetic-based Detection of Muscular Contraction for Controlling Hand Prosthesis

A novel magnetic-based hall myography (HMG) sensor has been developed that can measure the muscle contraction information from the residual upper limb of subjects for controlling hand prosthesis. The sensor is low-cost, compact and easily wearable at forearm of subjects. The sensor's output was observed quite similar and more stable as compared to that of EMG sensor. Also, unlike EMG sensor the HMG sensor is free from electrical interferences, insensitive to sweat or moisture and does not involve the use of electrodes and complex conditioning circuitry. The performance of the developed sensor was further tested on one forearm amputee and five healthy subjects for controlling the movement of indigenously prepared 3D printed hand. Proportional control scheme enabled flexion of hand fingers as per the captured HMG signal (to enable grasping several objects). Hand prosthesis system operating with such a low-cost and effective sensor can be a better option for amputees regarding affordability and functionality.



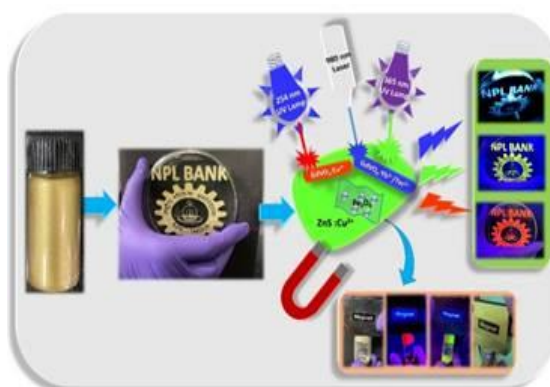
Developed HMG sensor and indigenously prepared 3D-printed hand



Trial of developed HMG sensor and 3D-printed hand on a transradial amputee

### Development of Multi-functional RGB Luminescent Security Pigment based Golden Ink with Myriad Security features to Curb Counterfeiting of Passport

Multi-functional luminescent security pigment (MLSP) based golden ink (MLSI) has been developed by CSIR-NPL, which provides an optical authentication and information encryption features to protect the legitimacy of the passport. The advanced MLSP is derived from the ratiometric combination of different luminescent materials to form a single pigment which emits red (620 nm), green (523 nm) and blue (474 nm), when irradiated via 254, 365 and 980 nm NIR wavelengths, respectively as shown in the following figure. The as-synthesized MLSP shows typical ferromagnetic nature with the saturation magnetization of  $M_s = 3.68 \text{ emu g}^{-1}$  under a magnetic field of 1500 Oe at room temperature. Hence, these advantageous multi-level security features with golden appearance in visible light is a new breakthrough toward curbing the counterfeiting of passport as well as bank cheques, government documents, pharmaceuticals, military equipment, and many more.



CSIR-NPL developed multi-functional RGB luminescent security pigment formulated golden ink to curb the counterfeiting of passports

## Facility Creation for Trace Elemental Analysis by Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) System

Under the Chemical & Food BND Sectional activity, a facility has been created for trace elemental analysis by Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) system. The ICP-MS system can be used for the determination of elements/metals isotopes (with atomic mass 6-259 amu) in sub ppb level concentration in water and other matrices. Primary methods like isotope dilution mass spectrometry (IDMS) technique can also be used for some of the elements to show our analytical capability in International forum through participation in inter laboratory comparison programme. The below illustrated figure shows the exhaust hood chamber and gas chambers clamped with ICP-MS, microwave digester and supporting equipment.

Facility Creation for trace elemental analysis



ICP-MS system

### Sample Preparation



Water Purification System



Microwave Digestion System



Moisture Analyser

## Length, Dimension and Nano Metrology has participated in Three International Inter-comparison

- **Inter-Laboratory comparison for glass scale- 250 mm, 300 mm (Glass Scale ILC):** Coordinated an inter-laboratory comparison for glass scales, with SAARC NMIs (MUSSD Sri Lanka, BSTI Bangladesh, BSB Bhutan, NPSL Pakistan and NBSM Nepal), under PTB-SAARC collaboration project. Calibrated two glass scales of sizes 300 mm and 250 mm using traceable linear displacement measuring laser interferometer, analyzed the measurement observations and circulated Draft A report among the participants. After receiving participant's inputs on Draft A report, the final report was prepared and submitted to PTB.



The uncertainty of measurement at coverage factor  $k=2$ , is  $\pm 1.15.\mu\text{m}$

- Inter-Laboratory comparison for roughness standard (APMP.L-K8):** Sub-division participated in the international intercomparison APMP.L-K8 (key comparison for roughness standards and groove depth standard), piloted by NMI Australia. Measurements were performed on Stylus based Surface Texture Parameters Measuring Instrument. Measurements were analyzed followed by measurement uncertainty evaluation and communicated to the pilot NMI.



- Inter-Laboratory comparison for calibration of diameter standards (APMP.L-K4.n0):** The objective of the Asia Pacific Metrology Program (APMP) is to improve the measurement capabilities in the Asia Pacific region by sharing facilities and experience in metrology. Comparison of calibrations by different laboratories on given artefacts adds confidence in the measurement of standards and leads to international acceptance of the measurements carried out by these laboratories. This intercomparison concerns the calibration of diameter standards listed below:





Type	Identification Markings	Nominal diameter /mm	Material	Expansion Coefficient /10 <sup>-6</sup> K <sup>-1</sup>
Ring #1	Mahr 332286	15	Steel	11.5
Ring #2	Mahr 332160	50	Steel	11.5
Plug #1	1	5	Steel	11.5
Plug #2	Mahr 332182	15	Steel	11.5
Plug #3	Mahr 333761	50	Steel	11.5
Sphere #1	25-99-798	25	Ceramic (Al <sub>2</sub> O <sub>3</sub> ), with fixing stud	4.6

### Establishment of Clinical Thermometer Calibration Facility at RRSL Ahmedabad

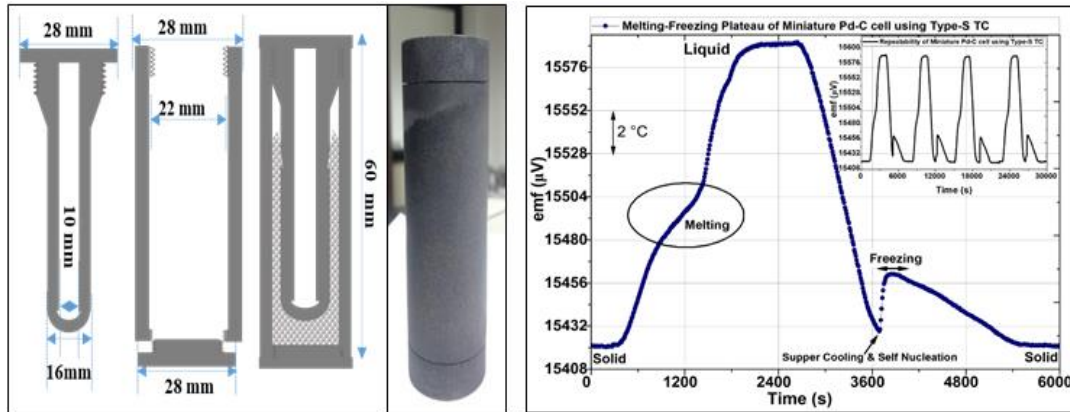
The set-ups for the project with Legal metrology “Development, fabrication and establishment of testing and calibration facility for clinical thermometers with maximum device at 2 RRSL Labs”, installed successfully at RRSLs Ahmedabad, under the Technical Services Project. Training was also provided to Legal officers at the RRSL, Ahmedabad.



CSIR-NPL temperature and humidity metrology team at RRSL Ahmedabad

### Design and Development of Pd-C fixed point (1491.45 °C)

The miniature Pd-C eutectic fixed point cell in graphite crucible was successfully designed and realized using the calibrated Type-S Thermocouple. This is one of the prominent fixed point in giving the direct traceability to thermocouple calibration upto 1600 °C, by avoiding the extrapolations.



Mini-Graphite crucible for Pd-C cell and its melting-freezing plateau

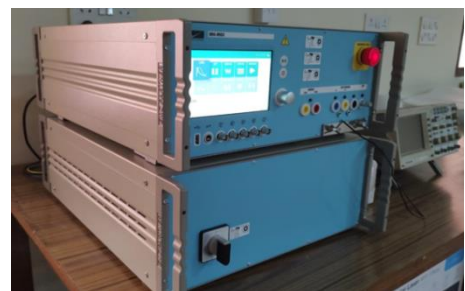
### Establishment of Spectroradiometer (2.0 m) for LED Testing

Advent of energy efficient LED lighting technology has led to manifold increase in the use of LED lights which in turn resulted in the growth of LED lighting industry and phasing out old thermoluminescence based lightings at the same time.

A National testing and calibration facility for LED lighting sources has therefore, become inevitable to establish the unbroken chain of traceability from SI units and pave the way for raising quality infrastructure in the country for LED lightings.

In this direction, the Optical Radiation Metrology Section has recently completed the installation of two of its high end metrology grade measurement/test systems; the Sphere Spectroradiometer (2.0 m) System, and the Test Instrument System in an externally funded project for the measurement, calibration and testing of various photometric and radiometric parameters as per national and international standards to disseminate the scale of radiation.

The Electrical surge, dips and Electrostatic Discharge (ESD) test System, 'Test Instruments' system was installed in the LED photometry laboratory to perform electrical testing for surge, dips and ESD of light sources as per international standards IEC61000-4-2, IEC 61000-4-4, IEC 61000-4-5, IEC 61000-4-11 etc. Currently, post-installation requirements and performance evaluation with different measurements/tests as per standards are underway.



Test instruments system

Temperature controlled Integrating sphere (2.0 m) based Sphere Spectroradiometer System has also been installed recently in the LED Photometry laboratory to measure associated photometric and colorimetric parameters required for calibration/testing of light sources as per standards IES LM-79, IES LM-82 etc. These measurement facilities along with others, would help in



Sphere spectroradiometer (2.0 m) System

increasing the CSIR-NPL's measurement capabilities and measurement traceability dissemination services in the time to come.

Further, the state of the art facility, once fully equipped with all envisaged measurement systems, would not only help significantly in stopping arrival of substandard/hazardous lighting products in market, reducing international trade barrier, dependence on foreign calibrations and in generation of trained manpower but would also enhance visibility of CSIR-NPL India in the area of LED metrology among the leading NMIs.

### **Establishment of Pneumatic Pressure Standard from 0.2 MPa to 100 MPa**

To cater to the growing demand of high pneumatic pressure, a high pneumatic pressure standard/measurement facility from 0.2 MPa to 100 MPa was successfully established. It is a liquid-lubricated and gas-operated piston gauge with automatic mass handler. The high pneumatic pressure is generated with the help of a gas booster and supplied to the piston gauge through high-pressure controller. With the successful establishment of this system, our pneumatic pressure measurement capability has been enhanced from the pre-existing 40 MPa to 100 MPa



High pneumatic primary pressure standard from 0.2 MPa to 100 MPa

### **Low Liquid Flow Calibration Facility from 5 ml/hr to 1500 ml/hr**

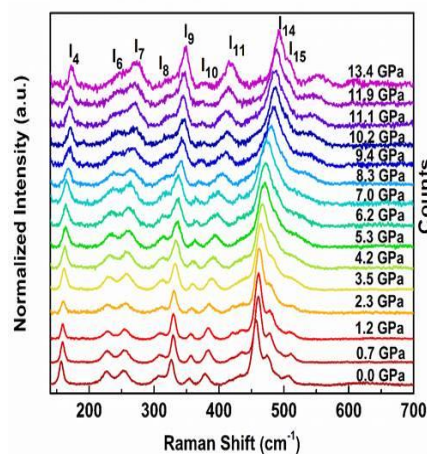
Over the past decade, low fluid flow measurement has become increasingly important. Accurately detecting and controlling low flow rates is a common challenge during medical operations and treatments. Syringe pumps and infusion pumps are often used in hospitals and research laboratories for accurate and precise drug dosing for cancer patients undergoing chemotherapy, among other important applications. Syringe pumps and infusion pumps typically use liquid flow rates of less than 1500 ml/h. Syringe Pump, Infusion Pump, and Infusion Device Analyzer calibrations have been in high demand in India during the past few years. For such a solution, the Fluid Flow Metrology Section developed low liquid flow calibration facility in the range of 5 ml/h to 1500 ml/h, with an expanded uncertainty (at  $k = 2$ ) of 0.40% to 0.60% for totalized volume and 0.50% to 1.0% for volume flow rate. This facility utilizes a static weighing method and a 220 g /82 g (dual range) weighing balance.



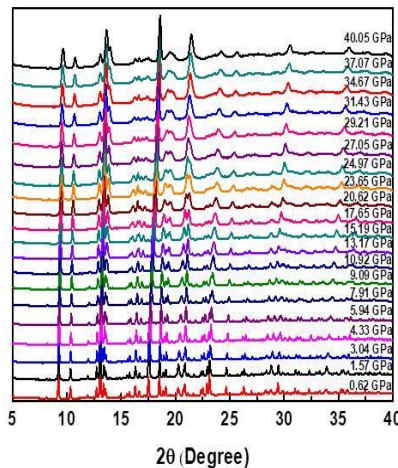
Low liquid flow calibration facility with main components: syringe pump, infusion device analyzer (IDA), beaker and weighing balance Standard 5 ml/hr to 1500 ml/hr

## Structural Stability of DyScO<sub>3</sub> under Extreme Conditions of Pressure and Temperature

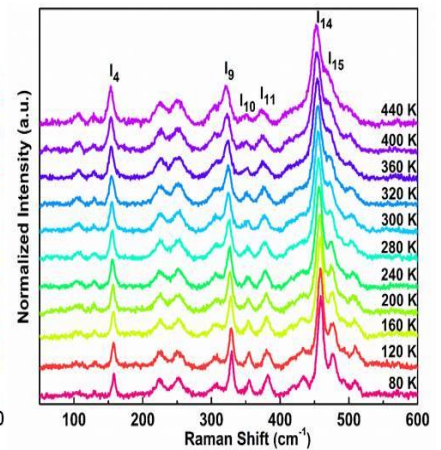
The effect of high pressure and low temperature on the structural and vibrational stability of Dysprosium Scandate (DyScO<sub>3</sub>) is investigated. The high pressure studies were carried out using high pressure synchrotron X-Ray diffraction (HPXRD) up to 40 GPa and high pressure Raman spectroscopy (HPRS) up to 13.4 GPa. While, temperature dependent study was carried out via Raman Spectroscopy in the temperature range of 80 K to 440 K. HPXRD study shows the excellent phase stability of the material up to the maximum studied pressure of 40 GPa. Both high pressure studies i.e. HPXRD and HPRS suggest a change in the preferred orientations in the crystalline structure with the increased pressure, however the structure is found to be stable. It was found that lattice parameters were decreased with a volume collapse of 12 % with increasing pressure. Further, phonon softening and broadening of the peaks for different Raman modes was observed in temperature-dependent Raman study and two phonon decay was found to be predominant.



Evolution of Raman modes of the DyScO<sub>3</sub> with increasing pressure



Evolution of Diffraction data of the DyScO<sub>3</sub> with increasing pressure. Each diffraction



Observance of the Redshift in the Phonon frequency with the increase of the sample

## Up-gradation of Primary Sound Standard in Frequency Range of 1 Hz to 25 kHz

The up-gradation of primary sound standard at CSIR-National Physical Laboratory, New Delhi was successfully completed in October, 2022. The primary objective of the up-gradation was focused on extending the measurement frequency range from 1 Hz to 25 kHz with measurement uncertainty ( $k=2$ ) of  $\pm 0.05$ - $0.15$  dB. The up-gradation shall be very helpful in calibration of the reference standard microphones in the frequency range from 1 Hz to 25 kHz and



Upgraded primary sound calibration standard using reciprocity method in frequency range of 1 Hz to 25 kHz

strengthening the measurement traceability chain for sound parameter throughout the country.

### **Setting up of Testing Facility at CSIR-NPL for Personal Protection Equipments (Masks, Gloves, Gowns), Ventilators and IR Thermal Body Scanners as per National / International Standards**

During Covid-19 pandemic condition, CSIR-NPL received project from CSIR for setting up testing facility for PPEs, Ventilators, IR Thermal Scanner as per National/ International Standards and development, procurement and establishment of various instruments and devices are going on in advanced stage. The Fluid Flow Metrology Section is taking care of ventilator calibration/ testing. For this purpose, the ventilator, ventilator tester and electrical safety analyzer have been procured and installed. After installation of the system, now its performance verification and making calibration procedures to include into the quality system is being done. There has been substantial progress in the Personal Protection Equipment (Mask, Gloves and Gowns) and IR thermal Scanner part of this project.



Set-up for calibration of ventilator using ventilator tester and electrical safety analyzer

### **Development of Secondary Ozone Standard for Ozone Generator Calibration**

A secondary ozone standard was developed for the calibration of ozone generators in the 0 to 500 nmol/mol range to provide the calibration service to the customers. The traceability of the secondary standard is obtained from the Primary ozone standard of CSIR-NPL.

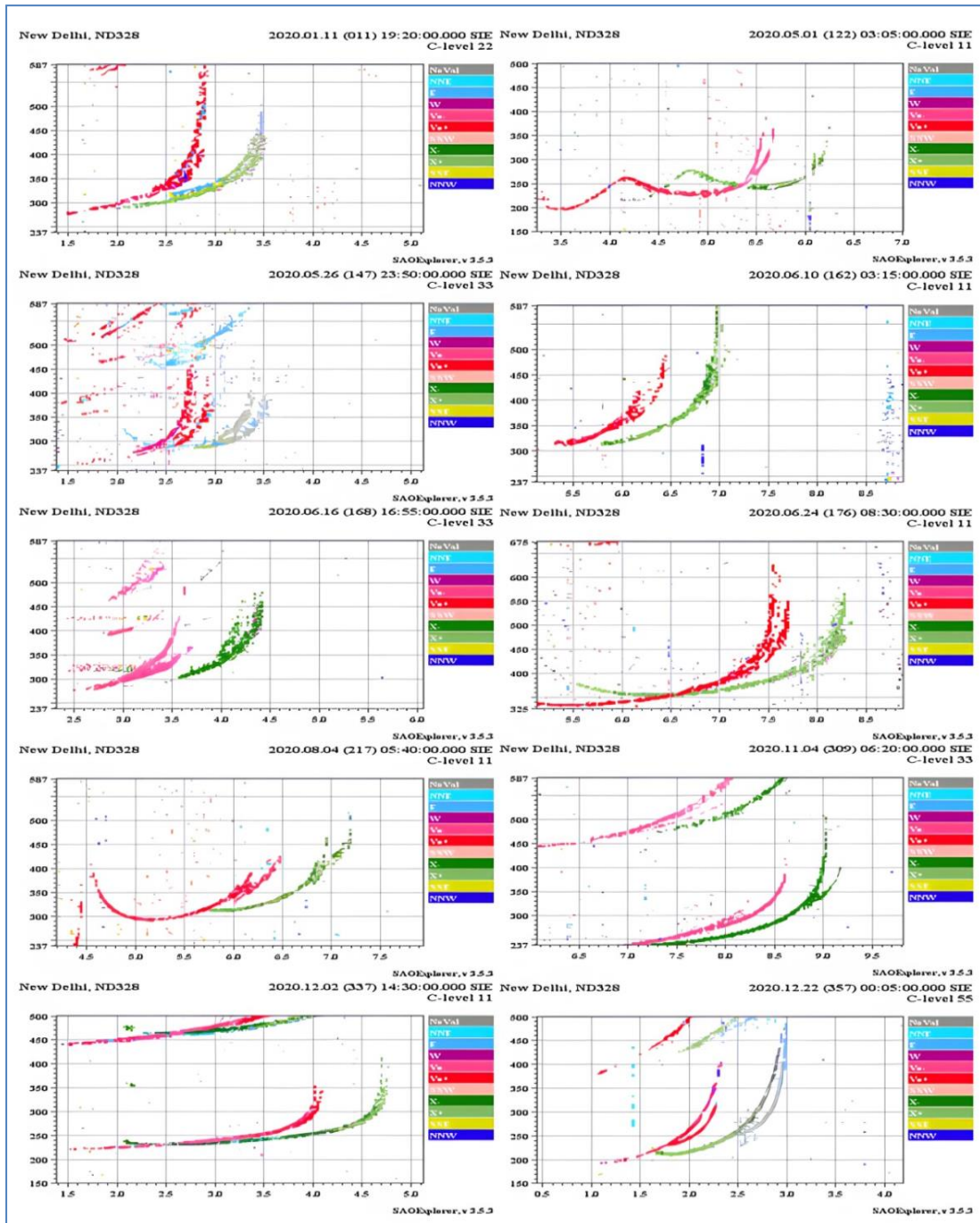


Secondary ozone standard for the calibration of ozone generators

### **Signature of Y-forking in Ionogram Traces Observed at Low-mid Latitude Indian Station, New Delhi during Earthquake Events of 2020: Ionosonde Observations**

Ionospheric response to eleven earthquake events measuring less than four on the Richter scale during the year 2020 that occurred in the vicinity of New Delhi (28.6°N, 77.2°E, 42.4°N dip) has been examined. Perceptible ionospheric perturbations, 2–9 days prior to these earthquake events resulting in more than 250% variation in electron density were observed. Distortion of ionogram trace in the form of Y forking majorly at New Delhi on the precursor day and after the earthquake event was observed. Traces of Y

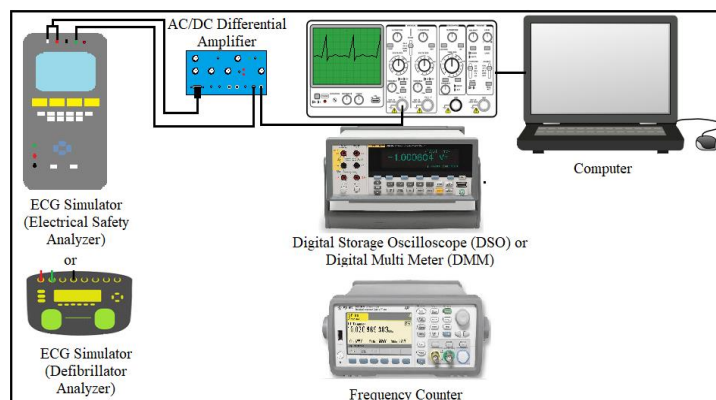
forked ionograms were also observed at Ahmedabad (23°N, 72°E, 15°N dip) and Trivandrum (8.5°N, 76.9°E, 0.5°N dip). These Y-forked ionograms are one of the first observations during any earthquake events and are being looked at as a signature of Travelling Ionospheric Disturbances.



Plot showing Y-forked signature in Ionogram traces on the precursor day

## Calibration Facility for Electrocardiogram (ECG) Simulator

ECG simulator generates various waveforms such as ECG, sine, square, triangular, pulse etc. These waveforms are used in the testing and verification of ECG machines and patient monitors as per relevant written standards. A calibration facility of ECG simulator for voltage and frequency parameter comprising of an AC/DC differential amplifier, a reference frequency meter [Digital Storage Oscilloscope (DSO) and frequency counter] and a reference voltage meter (DSO and Digital Multimeter) has been developed.



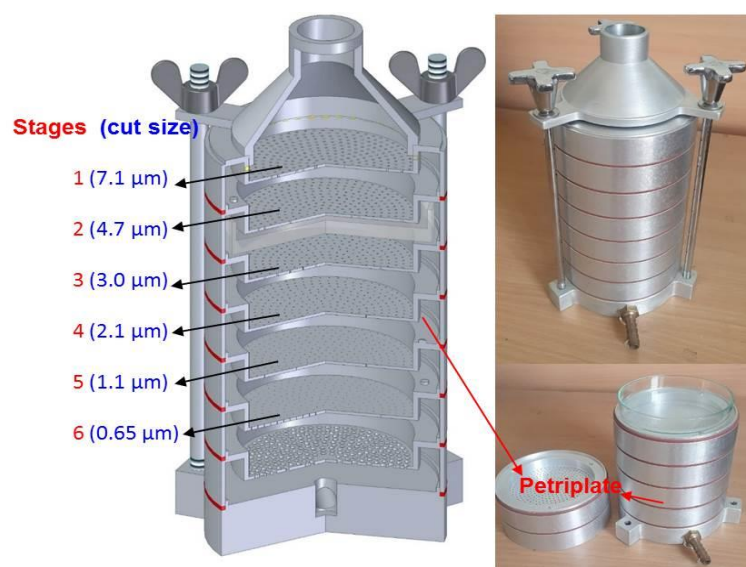
Calibration setup of ECG Simulator

## Six-stage Bioaerosol Sampler Technology Developed

A mask testing setup design is developed for particle and bacterial filtration efficiency testing (PFE and BFE), and breathability testing of half-face mask. The setup comprised of aerosol sampling system in which aerosols/bacterial particles entered from aerosol generation and conditioning units. For filtration efficiency test of mask, aerosol sampling system has a provision to measure particle concentration

before (upstream) and after

(downstream) the object/ mask under test (OUT). A six-stage bioaerosol sampler is designed to test bacterial filtration efficiency of mask types. This sampler has novel design, and can be used for bioaerosol sampling in ambient air simultaneously for both, particle mass and colony counting units. The differential pressure across the OUT can also be measured using this design. The aerosol sampling system can also be reconfigured to test whole mask types such as N95, etc., for particle filtration efficiency using mask holding enclosure unit.

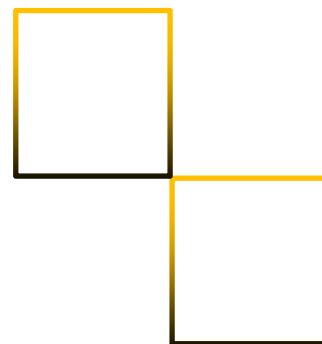


Developed bioaerosol cascade impactor (BCI)



**ANNUAL  
REPORT  
2022-23**

# Glimpses of Events





## International Noise Awareness Day and World Hearing Day at CSIR-NPL (April 27, 2022)

The programme was organized in online and physical mode by CSIR-NPL in association with Metrology Society of India (MSI) with a theme: Protect your hearing, protect your health. Around 850 school children from various schools in NCT, Delhi participated in this event.



## World Metrology Day (May 20, 2022)

The World Metrology Day was jointly organized by CSIR-NPL and Metrology Society of India (MSI) on 20<sup>th</sup> May 2022 at CSIR-NPL and it was highly successful. The theme was Metrology in Digital Era. More than 300 participants attended this program in offline and online mode. Foreign Experts delivered the lectures online.



## Hands-on Training for Thin Film Growth Techniques-“Sputtering and Pulsed Laser Deposition” (June13 – 19, 2022)

Under the DST-SERB Accelerate Vigyan Scheme- "Abhyaas" program, 'KARYASHALA' a high-end workshop, on “Hands on training for Thin film growth techniques-Sputtering and Pulsed laser deposition” has been conducted by Electrical & Electronics Metrology Division, CSIR-NPL with an aim to provide opportunities to acquire specialized research skills to the students primarily from universities, colleges, and private academic institutions on thin film deposition using Sputtering and Pulsed Laser. The program funded by DST-SERB was meant to support motivated PG and Ph.D. level students with a strong will to excel in their scientific research pursuits. This program was basically a skill development program on thin-film growth techniques required for research work.



## Krishnan Memorial Lecture (June 14, 2022)

36th Krishnan Memorial Lecture held at CSIR-NPL on 14/06/2022. The event took place in the gracious presence of Dr. T. Ramasami (Former DST Secretary, and Chairman K.S. Krishnan Memorial Trust) & Prof. Venugopal Achanta (Director, CSIR-NPL). The event also includes inauguration of Dr. Krishnan Memorial Scholar's Gallery.



**Agreement for the Development and/or Production of Hardness Blocks/UTS/PMMA Blocks BNDs was signed between CSIR-NPL, New Delhi and RMP Global PT Provider Pvt Ltd. (GPTP) New Delhi (June 28, 2022)**



**A Webinar on “Advances in Metrology by the Custodian of Indian National Standards: CSIR-NPL” under the CSIR Success Stories (July 29, 2022)**



## International Workshop on Building Acoustics and Noise Control (IWBA-2022) (August 22-23, 2022)

CSIR-NPL in association with Metrology Society of India (MSI), and Bureau of Indian Standards (BIS) had successfully organized the event. Around 120 participants in online and offline mode participated in the event including some of the participants from Thailand, Indonesia and Denmark. The workshop discussed about the latest developments in the field of building acoustics, noise mapping, control, mitigation methods and computational modeling. A compendium on Noise Control in buildings was released.



## International Conference on “Advances in Metrology” (AdMet - 2022) along with Pre-AdMet Workshop (August 22-26, 2022)

11<sup>th</sup> AdMet 2022 was successfully organized at CSIR-NPL. The conference was jointly organized by CSIR-NPL and Metrology Society of India (MSI), New Delhi. The organization of the AdMet series of conferences is one of the major events of MSI.



## Training Program on Low Frequency Voltage & Current Metrology under Skill Development Program (September 06-08, 2022)

Imparted industrial training on LF Voltage & Current Metrology under skill development program as per CSIR-NPL training calendar. Participants from different laboratories (Young Engg & Calibration Services Pvt Ltd, Skytechsaras Calibration Labs Pvt Ltd, etc.) participated in this program.



## Training Program on “Length & Dimension Metrology and Applications of Interferometry” under Skill-India Program (STP-6) (September 08-09, 2022)

A training program under skill India program was organized on Length & Dimensional Metrology and Application of Interferometry. A total 24 participants attended this course. This program includes lectures on dimensional metrology, it’s application and measurement demonstrations for line scale calibration using laser interferometer and gauge block calibration using mechanical gauge block comparator.



## Training Program on “Force, Torque and Hardness Metrology” (September 12-13, 2022)



### Training Programme on Force, Torque and Hardness Metrology 12 - 13 September, 2022



Training Programme  
on  
Force, Torque and Hardness  
Metrology  
was organised by HRD  
12 to 13 September, 2022,  
CSIR- NPL, New Delhi.  
The Training included lectures,  
presentations and hands on  
training in the labs.



## 7<sup>th</sup> Ayurveda Day Celebration at CSIR-NPL (September 17, 2022)



**MoU between CSIR-NPL and ARON Universal Limited, Bengaluru (September 19, 2022)**

CSIR-NPL has signed an agreement for sponsored project "*Development of mono/bi-invisible fluorescent pigments and visible/invisible fluorescent security threads/fibres for anti-counterfeiting technology*" with ARON UNIVERSAL LIMITED, Bangalore on 19/09/2022 at CSIR-NPL.



**PTB Project (September 18 – 22, 2022) & (December 05 -16, 2022)**

Imparted onsite training to NMI, Bangladesh on LF Voltage & Current Metrology during under SAARC-PTB Project. Also, imparted training to two participants from NMI, Nepal on LF Voltage & Current Metrology during (05<sup>th</sup>-16<sup>th</sup>) December, 2022 under SAARC-PTB Project.



## Celebration of 81<sup>st</sup> Foundation Day of CSIR at CSIR-NPL (September 27, 2022)

Dr. Parvinder Maini, Scientific Secretary at the Office of the Principal Scientific Advisor to the Government of India, was the Chief Guest.



## CSIR-NPL Open Day 2022 (September 28, 2022)

Around 2500 participants from distinct schools/colleges visited the R&D facilities at CSIR-NPL.





## Hindi Conference on अपशिष्टसेसंपत्ति: उपयोगी उत्पादों के लिए अपशिष्टपदार्थों का पुनर्चक्रण पर राष्ट्रीय सम्मेलन-2022, (September-2022)



## Special Campaign 2.0 under Swachh Bharat Mission & Fit India Freedom Run 3.0 at CSIR-NPL (October 02-31, 2022)



## Training Program on Pressure, Vacuum & Ultrasonic Metrology and Non-destructive Testing (October 11-13, 2022)

Training program was organized by Pressure, Vacuum and Ultrasonic section of the Physic-Mechanical Metrology division at CSIR-NPL.



## Gas Metrology related to Hydrogen, Natural- and Bio-Gas Standard in India of NPLI and PTB Germany with Gas Industries (October 20, 2022)



## Three-days Training Program on “Air Quality Measurement” (November 02-04, 2022)



### Three Days Training Program on “Air Quality Measurements”



2-4 November 2022

(under the CSIR Integrated Skill Initiative, CSIR-NPL)



## One-day Training Program on "Materials Characterization" (November 09, 2022)



### One Day Training Program on “Materials Characterization”

(November 9, 2022)



CSIR Integrated Skill Initiative



The program was designed for researchers, industry personnel, academician and students with the objectives of providing an understanding and related nitty-gritties of material characterization considering important sophisticated techniques followed by demonstration a few.



Organized by

**Bharatiya Nirdeshak Dravya (BND) Division**  
CSIR-National Physical Laboratory  
New Delhi-110012, India

**Training Program on 'DC & Impedance Metrology' under CSIR Integrated Skill Initiative (November 10-11, 2022)**



**Training Program (STP-4) on Temperature, Humidity and Moisture Metrology and Applications to Healthcare and Agricultural Grains and Cereals (November 16-18, 2022)**



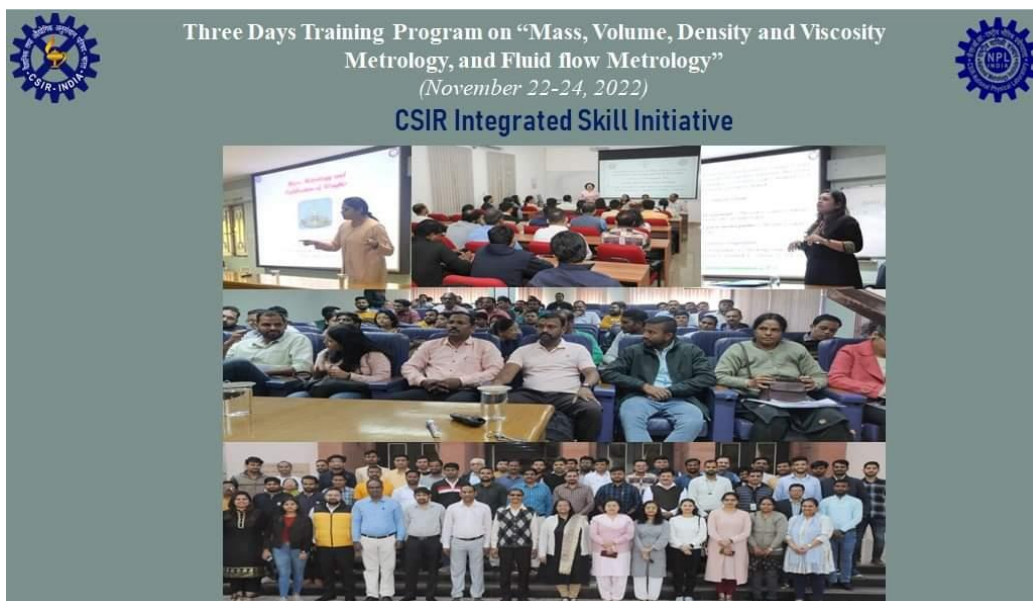
### **Training Program (STP-14) on Optical Radiation Metrology (November 16-18, 2022)**

A Hands-on specialized 3-days training program (STP-14) on the Optical Radiation Metrology subject area was organized for Professionals/ students/ faculties who are working or interested in the area. The training program was aimed to create the trained work force in the subject area for catering the growing industrial demands in the specialized field.



### **Training Program on Mass, Volume, Density, Viscosity Metrology and Fluid Flow Metrology (November 22 – 24, 2022)**

Imparted training on Mass, Volume, Density, Viscosity Metrology and Fluid Flow Metrology as per CSIR-NPL training calendar. Around 65 participants from various laboratories, industries participated in this program.



## Jigyasa Program (November 24, 2022)

Kendriya Vidyalaya students visited CSIR-NPL under Jigyasha Program on 24.11.2022.



## One-day Pollution Awareness Workshop for School Children (November 25, 2022)

CSIR-NPL in association with IIT Delhi and Technical University, Dresden organized a one day pollution awareness workshop for school children. The workshop discussed about various aspects of air pollution, noise pollution and waste material recycling in order to inculcate awareness amongst the young minds about the adverse health effects associated with pollution and means to control it.



## Training Program “Awareness Program on Laser and Laser Interferometer” under Skill-India Program (STP-16) (December 01-02, 2022)

A training program under skill India program was organized on awareness on laser and laser interferometer. A total 26 participants attended this course. This program includes lectures on Basic of laser, Basic of interferometer and it’s applications in dimensional metrology. Participants got measurement demonstrations for line scale calibration using laser interferometer and gauge block calibration using mechanical gauge block comparator.



## A “Special Lecture” on the 125<sup>th</sup> Birth-year of Sir K.S. Krishnan (December 12, 2022)

CSIR-NPL in coordination with AcSIR has organized a special lecture on the 125th birth-year of Sir K.S. Krishnan. Distinguished Professor Suresh K. Bhargava (RMIT University, Australia) delivered lecture on ‘Establishing a Platform for Solution Engineering Redefining Innovation’.



## CSIR-NPL Foundation Day (January 04, 2023)

The occasion was graced by Dr. N. Kalaiselvi (Secretary, DSIR & DG CSIR), Dr. G. Satheesh Reddy (Scientific Adviser to Raksha Mantri, GoI.), Prof. Venugopal Achanta (Director, CSIR-NPL)



Agreement for the Development and/or Production of Organic Substance BNDs was signed between CSIR-NPL and RMP Pharmaffiliates Analytics & Synthetics Pvt Ltd. Panchkula (January 04, 2023)





**New BNDs (in collaboration of CSIR-NPL & different RMPs) were released on the occasion of CSIR-NPL Foundation Day, National Metrology Conclave (NMC)-2023 (January 04, 2023)**



Release of Chemical BNDs (BND<sup>®</sup> 1036, BND<sup>®</sup> 1037, BND<sup>®</sup> 1038 and BND<sup>®</sup> 1042) in collaboration of CSIR-NPL, New Delhi and RMP AASHVI Tech LLP, Ahmedabad



Release of Precious Metals BNDs (BND<sup>®</sup> 4205, BND<sup>®</sup> 4207, BND<sup>®</sup> 4208, BND<sup>®</sup> 4209) in collaboration of CSIR-NPL, New Delhi and RMP Jalan & Co., New Delhi



Release of Ultimate Tensile Strength (UTS) BNDs (BND® 2216, BND® 2217, BND® 2218, BND® 2219) in collaboration of CSIR-NPL, New Delhi and RMP Global PT Provider Pvt Ltd (GPTP), New Delhi



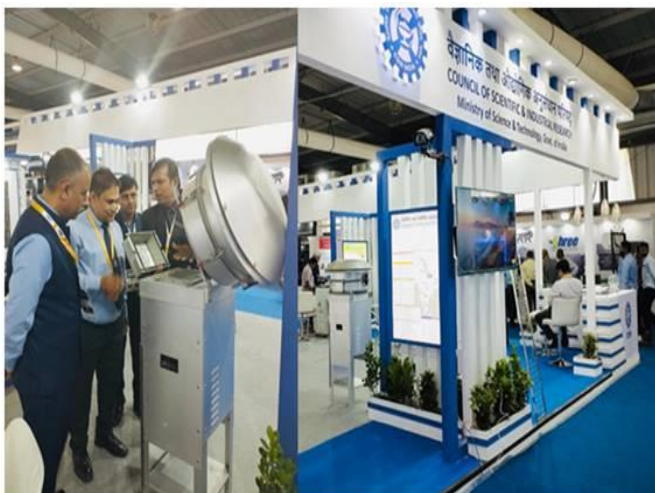
Release of Hardness BND (BND® 2207) in collaboration of CSIR-NPL, New Delhi and RMP Global PT Provider Pvt. Ltd (GPTP), New Delhi

## **Training Program on “Scientific Communications” under Skill-India Program (STP-18) (January 19-20, 2023)**

A training program under skill India program was organised on Scientific Communications. A total 10 participants attended this course. This program comprised of lectures on scientific writing, plagiarism, ethics, popular science writing, grant writing etc.



## **Participation with PM2.5 Sampling Technology in Defence Expo 2022 (October 18-20, 2022) at Gandhinagar, IISF (January 21-24, 2023) in Bhopal, Bharat Parv Exhibition at Red Fort, Delhi (January 26-28, 2023)**



Technology showcasing in Defence Expo 2022 at Gandhinagar



Technology showcasing in Bharat Parv Exhibition at Red Fort, Delhi

## Training Program on Scanning Electron Microscopy (SEM) (February 06, 2023)

As part of the International Conference on Electron Microscopy (EMSI-2023), more than 15 students were trained on Scanning Electron Microscope (SEM) characterization techniques at CSIR-NPL.



## National Science Day - 2023 (February 28, 2023)

A poster display symposium was arranged for Ph.D. students. Around 80 registered (in AcSIR) Ph.D. students were participated and display their recent results of research. Posters were evaluated by external jury members and 15 posters were awarded in three different theme areas. On this occasion, a booklet on "Poster Symposium" was also released.



## Foreign Delegates Visit at CSIR-NPL (March 02, 2023)

Delegates from Ethiopian National Accreditation Office (ENAO), the national accreditation body of Ethiopia and delegates from Kathmandu, Nepal visited CSIR-NPL on 2<sup>nd</sup> March 2023.



## Half-day Workshop on 'Career Women: Challenges, Opportunities & Success Stories' (March 03, 2023)

CSIR-NPL in collaboration with IIT Delhi, and Tata Institute of Fundamental Research (TIFR) organized a half-day workshop on 'Career Women: Challenges, Opportunities & Success Stories'.



**8<sup>th</sup> National Conference on Advances in Metrology (AdMet-2023) along with Pre-AdMet Workshop jointly organized by CSIR-NPL at BARC, Mumbai (March 23-25, 2023)**

This was jointly organized by MSI, BARC, IDEMI, CSIR-NPL and NABL.



**Training Program for Students from KanyaMahaVidyalaya Jalandhar (Punjab) (March 27-28, 2023)**

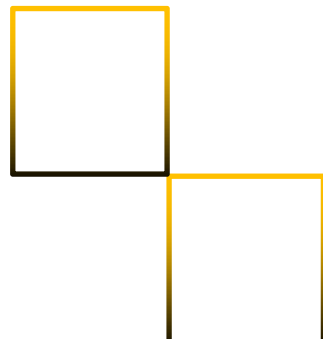
In-House BND Group, CSIR-NPL organized a training program for students.





**ANNUAL  
REPORT  
2022-23**

**Divisional Activities**



# Physico-Mechanical Metrology

---

The mandate of the Physico-Mechanical Metrology (PMM) division is to establish, maintain, disseminate and continuously upgrade the Physico-mechanical standards. The Division is responsible for establishing four SI base units and derived units. The division activities include Mass, density and viscosity; Length, dimensions and nanometrology; Temperature, humidity and moisture; Optical radiation; Force, torque and hardness; Pressure, vacuum & ultrasonic; Acoustic and vibration, and Fluid flow metrology. These physico-mechanical parameters are crucial metrology activities that impact our users' science and engineering endeavors. The world-leading measurement solutions provided by us are important to new start-ups, industries and government R&D organizations. These activities help to accelerate research and innovation, thereby improving quality of life and enabling trade opportunities.

This year, the division has successfully completed the projects from CSIR and other agencies:

- Legal Metrology Technical Services Projects for Length, Temperature and Pressure Metrology.
- PTB Project for the SAARC NMIs

Division has made significant progress in the following Projects:

- Facility Creation Project SMART-PM, “Strengthening Metrological Activity for Research and Technology in Physico-Mechanical”, consisting of setting up of few primary and secondary standards facilities.
- Setting up a testing facility at CSIR-NPL for personal protection equipment's, ventilators and IR thermal scanners as per national/ international standards.
- NCP Project for Boltzmann Constant and FBR project for quantum pascal.
- Establishment of LED Testing Facility, etc.

The PMM division has contributed to train the Human Resources in Metrology through one year Post-Graduate Diploma (PGD) course on Precision Measurement and Quality Control (PMQC) under AcSIR. Several undergraduate and MSc/M.Tech students performed their summer projects in metrology. During 2022-23, the division has published over 75 SCI papers, about 60 conference presentations, 2 books, a few book chapters, several Invited Talks, and about seven students got Ph.D. in PMM Metrology. A glimpse of the activities of each subdivision is described below.

## Mass Metrology

Mass measurements are essential for trade, technology, fundamental research etc. Reliable measurements of mass and its derived parameters which include volume, density, force, pressure, hardness, etc. are indispensable to support many diverse areas. Mass Metrology section maintains the apex level standards for Mass, Volume, Density and Viscosity and provides traceability to the various sectors such as Legal Metrology, Space, Atomic Energy, MSMEs, Delhi Jal Board, Indian Oil Corporation, CPCB, various industries, etc. One of the important sectors is pharmaceutical industries which are



making drugs and medicines. During 2022-23, the section has continued its efforts for unceasing upgradation of the national standards and providing traceability to the whole nation. Mass metrology is undergoing two international intercomparisons in volume currently to enhance the range of CMCs organized by APMP.

Some of the achievements during 2022-23 are mentioned below:

- Intercomparison for volume metrology under the collaborative project of SAARC-PTB under GAP-181232. This will help establish the CMC in volume in microlitre range.
- Intercomparison for volume metrology under the collaborative project of APMP key comparison APMP. M. FF-K4.2.2021. This will help establish the CMC in volume in microlitre range.
- Working towards upgradation of two pan balance in to 100 g Kibble Balance under OLP-214832.
- Reestablishment of the secondary standards of mass through subdivision technique against the NPK-57(National Prototype of Kilogram in India). This strengthens the traceability of the mass and related parameters.
- Provided continuous traceability to the various fields (derived parameters) related to mass like Pressure, Force, Hardness, Vacuum, Fluid Flow, Gas, Environment, Biomedical, Advanced materials.
- Digital Alcoholmeters from U.P Excise Department to be supplied to different customers are tested continuously and test reports are given.
- Calibration of the volumetric vessels and micropipettes for the BND section that helps to provide CRMs for the country.
- Robotic mass comparator has been established at CSIR-NPL and the operation has commenced.
- Primary density standard has been upgraded as a semi-automatic system for more accurate measurement.

### **Length, Dimension and Nano-metrology**

Dimensional metrology is an essential element of technological infrastructure for industrial and economic development of a country. Reliable dimensional measurements play vital roles in various aspects of social life and significantly empower numerous scientific and technical fields such as manufacturing, aerospace, automobile, defense and semiconductor etc. This section provides apex level calibration services for various dimensional measurement instruments to maintain unbroken chain of traceability across the nation and the SAARC countries. Length, dimension and nano-metrology section fulfills the parliamentary mandate to maintain primary standard of length for realization of SI unit “meter” through Iodine stabilized He-Ne laser, wave



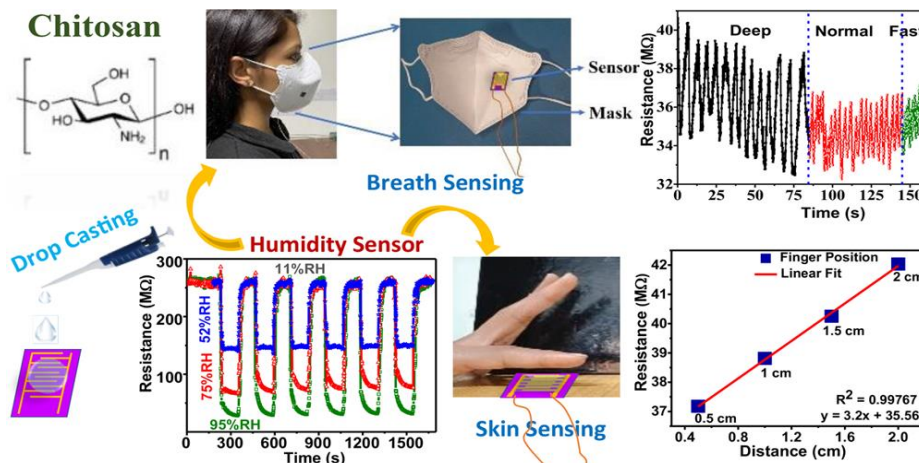
**Primary Standard of Length at CSIR-NPL**

length 633 nm. This section has various state-of-the-art facilities such as Coordinate Measuring Machine, Length Measuring Machine, 3D Optical Profiler, Roughness and Contour Measuring Machine, Flatness Measuring Interferometer, Linear Displacement Measuring Interferometer, Gauge Block Interferometer and Roundness Tester etc., to cater the ever-increasing demands of various industrial and R&D segments. Additionally, continuous research and development in the field of precision dimensional metrology for advanced measurement techniques/ standards/ instruments is one of the prime objectives of the section. This group is involved in R & D activity for augmenting and upgrading the standards at par with other leading National Metrology Institutes (NMIs) and continuously participates in international inter-comparisons to establish international equivalence to the international measurement system. Furthermore, technical workshops, training programs were conducted and provide consultancy services to various industries were provided for capacity building across India.

### Temperature and Humidity Metrology

The subdivision maintains the primary standard of temperature and humidity parameters from -200 °C to 3000 °C and 10 % RH to 95 % RH. Apex level calibrations and traceability to SPRTs, RTDs and various resistance sensors, LIGTs, thermocouples, pyrometers, blackbodies, thermo-hygrometers, dew/frost measurements, moisture measurements and mercury-free (electrical and IR based) clinical thermometers to NABL accredited Labs, SAARC NMIs and the government sectors lies in the mandate of division. During this year, research activities include: (i) Development of Acoustic Gas Thermometry for the measurement of thermodynamic temperature to realize new kelvin based on Boltzmann constant, (ii) Development of Pd-C fixed point blackbodies for high temperature thermometry, (iii) study of self-heating effect in different type of platinum resistance thermometers, (iv) Development of Humidity sensor based on SnO<sub>2</sub>, and Chitosan and shown their applications in human breath monitoring, (v) Development of testing facility for establishing the traceability to IR Thermal Imagers in India, (vi) The in-house developed IR facility for model approval of IR forehead/ear thermometer was show cased in Defense-expo Oct, 2022, IISF during 21-24 Jan., Bharat Parv from 26-31 Jan, 2023, etc.

Various humidity sensors based on semiconductor metal oxides, chitosan polymer and GO/RGO were developed and standardized. These sensors are tested for the breath monitoring and contactless touching etc. applications.



Chitosan-based highly sensitive viable humidity sensor for human health monitoring

## Optical Radiation Metrology

Photometry is the branch of metrology which includes measurement and quantification of the light and its attributes as perceived by the human eye. LED based lighting, being energy efficient as compared to the other available classical sources, longer life time, most rugged and eco-friendly to nature, are being adopted by the society as popular solution of illumination today. Government of India is also running its major flagship programs, namely Unnat Jyoti, UJALA etc. towards promoting LED lighting sources to save electricity and reduce carbon footprints of India.

- The Optical Radiation Metrology Section has been entrusted upon a project of national importance by the Bureau of Energy Efficiency (BEE) to establish an apex level calibration and testing facility for LED based lightings, funded by Ministry of Power, India. The major project envisages creation of an apex level measurement facility to characterize and provide traceable measurement of LED lighting as per national and international standards.
- The installation of two apex metrology systems, Sphere Spectroradiometer (2.0 m) System and the Test Instrument system in the externally funded project have recently been completed and their performance is under evaluation as per the standards.
- Apart from efforts to create a state-of-the art calibration and testing facility at CSIR-NPL for the apex measurement and calibration as per national and international standards, the Optical Radiation Metrology Section is grossly engaged in frontier research area of radiation metrology and Photon Physics. The importance of interference patterns in the identification and mitigation of lateral misalignment in optical set-up, through the Radial Shearing Self-Interferometric (RSSI) technique used for the generation of the interference pattern of a perfect vortex beam (PVB) was demonstrated. The technique could prove to be a step towards self-aligning optical set-ups.

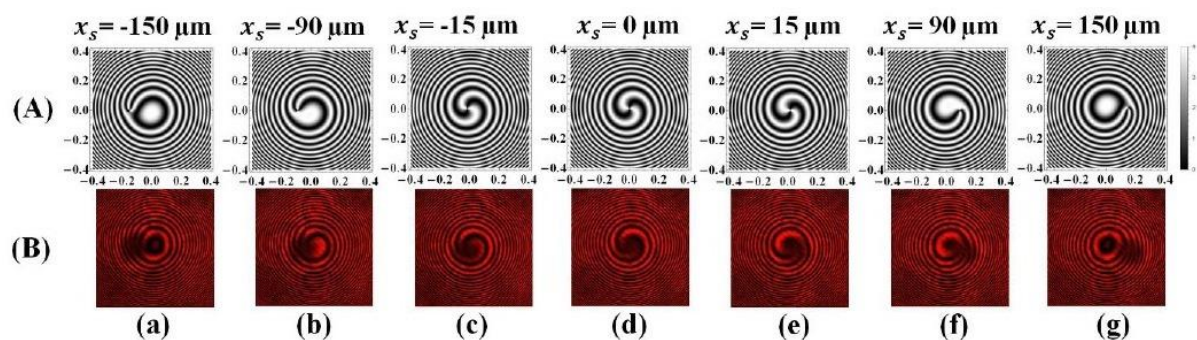


Fig. (A) Theoretical and (B) Experimental plots of RSSI interference for different lateral misalignments ( $x_s$ )

- In our next important research work, a photon-counting method based on a data acquisition card (DAQ Model: Agilent U1071A), which works in the discrete to continuous photon regime, where the commercial photon counters stop counting, is elaborated. To facilitate the precise counting of the discrete and merged pulses, an executory program has been developed in LabVIEW platform incorporating the

logic of pulse width and amplitude. The developed technique is tested for its functionality and compared with the commercially available photon counter (Stanford Research Systems SR400).

### Force Metrology

A high-resolution DMP 41 Digital indicator has been installed with a 3 MN force machine for calibrating analogue force proving rings and digital load cells with higher range capacities, ranging from 2000 kN to 3000 kN. The calibration requirements within this range are in high demand due to numerous ongoing construction projects in major metropolitan areas, such as metro rail construction, high-rise residential building projects, bridges, flyovers, reservoirs, and dams, among others.



DMP 41 installed with 3 MN force standard machine

### Pressure, Vacuum & Ultrasonic Metrology

Pressure plays a very important role in various diverse industries such as Semiconductor, Space, Heavy industries, Defence, Aviation and Automobile etc. This section primarily maintains and disseminates Pressure, Vacuum & Ultrasonic parameters. It provides apex level calibration to the various stakeholder viz. VSSC (ISRO), BHEL, GAIL, NTH, & ERTL etc.

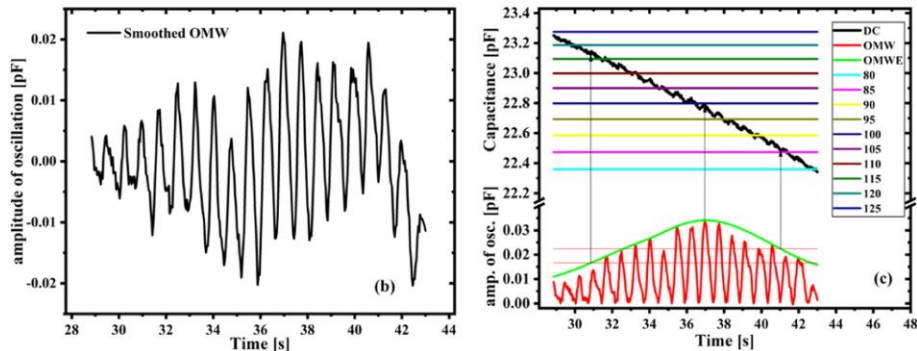
The section is working towards the Research & Development work. Successfully upgraded pneumatic pressure measurement facility from 40 MPa to 100 MPa which would be beneficial for various stakeholders like ISRO & Air Force etc.

In addition, for realization of quantum pascal through new primary standard: Optical Interferometer Manometer, the international co-operation with NIST, USA has been establishment of a new quantum standard at CSIR-NPL.

Furthermore, the section also engaged in skill development through various training programs and also provides technical services in Pressure & Vacuum metrology.

Some recent developments are as follows:

- Developed device “Human Oscillometric Waveform Recorder” and presented at ‘Bharat Parv’ organized by Government of India during 26-31 January 2023 at LalKila, New Delhi, India.
- Developed device “Human Oscillometric Waveform Recorder” and presented at ‘Government Development Scheme Expo-2023’ organized by Government of India during 3-5 March 2023 at Pitampura, New Delhi, India.



Human BP measurement (a) oscillations record during BP measurement (b) extracted smoothed OMW (c) BP computation by the extracted OMW

## Acoustic and Vibration Metrology

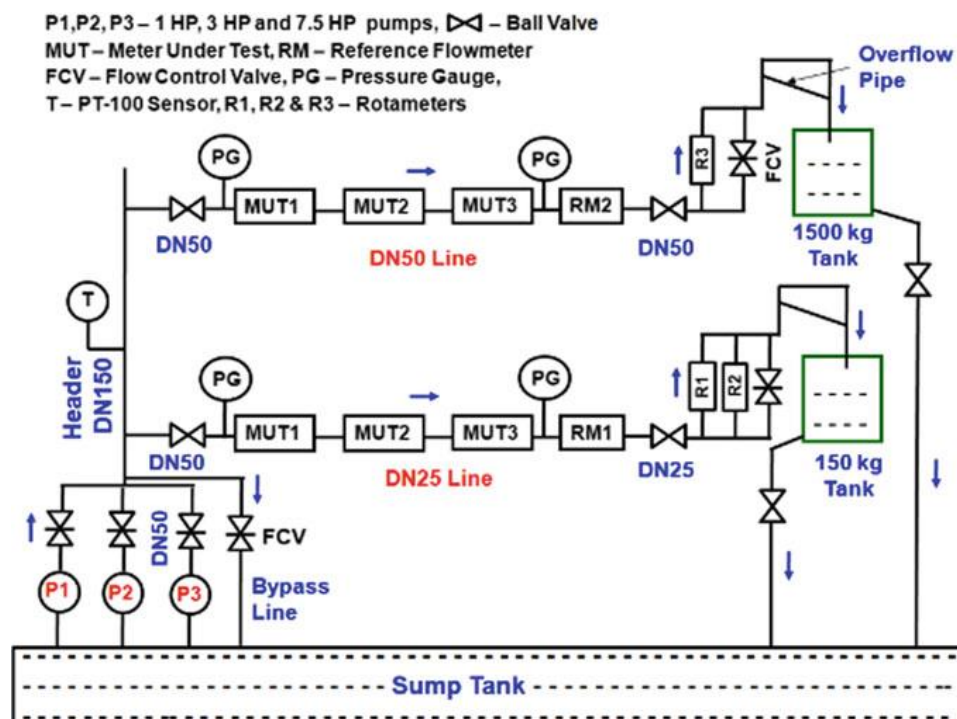
Since its inception, the Acoustics and Vibration parameters of CSIR-NPL have played a key role in the industrial growth and reducing air and noise pollution in the country. The major activities involved are calibration of acoustical instruments, evaluation of industrial products and acoustical materials, performance characteristics of audio devices, auditorium acoustics and noise and vibration measurements and control. The calibration and other facilities available in CSIR- NPL in the area of Acoustics and Vibration are comparable with facilities in other countries. The section had been able to provide apex level calibration and testing services and technical advisory consultancy in architectural acoustics to the industry and institutions of the country. The sub-division focused on up-gradation of the primary sound and vibration standards. Up-gradation of Primary Sound Standard for extending the measurement frequency range from 1 Hz to 25 kHz with measurement uncertainty ( $k=2$ ) of  $\pm 0.05-0.15$  dB was successfully completed in October, 2022. The sub-division also participated in an informal comparison on LS microphone with HBK, Denmark and DPLA, Denmark after upgradation of primary sound standard in frequency range of 1 Hz to 25 kHz in October, 2022. New facilities were established for testing of noise barriers, acoustic louvers, absorption coefficient evaluation using sound impedance tube, sound absorption coefficient of hanging baffles and chairs, on-site vibration calibration of shakers and vibration machines etc. Acoustics and Vibration Standards also contributed towards developing the Noise Guidelines for Construction sites for noise pollution control in metropolitan cities to be followed by all State Pollution Control Boards.

## Fluid Flow Metrology

CSIR-National Physical Laboratory (CSIR-NPL) is the National Metrology Institute (NMI) of India. It is the custodian of physical parameters of national standards. The objective of the Fluid Flow Metrology Section of CSIR-NPL is to establish, maintain and upgrade primary and secondary standards of fluid flow and provide traceable calibration service to various user organizations in the country.

- **Domestic Water Meter Testing Facility**

The water meter testing facility is used for testing domestic water meters of sizes DN15 to DN50 as per IS 779, IS 6784, and ISO 4064 standards and is also used for calibration of rotameters. It is based on the standing start and standing finish method. It uses two weighing scales of 150 kg and 1500 kg capacities. It has 1, 3 and 7.5 HP pumps to supply the required flow in the range of 0-38,000 lph for testing of water meters and calibration of rotameters. Flow in the line is monitored by electromagnetic flowmeters and rotameters. The uncertainties in the total volume and volume flow rate are 0.10% and 0.25% (at  $k = 2$ ), respectively. Rotameters are calibrated by the weighing method at low flow rates (up to 1000 lph), while at high flow rates (above 1000 lph), they are calibrated by comparison method employing electromagnetic flowmeters of DN25 and DN50 sizes as reference standards. The accuracy of the water meters/flowmeters tested/calibrated at this facility is in the range of 2-5%. Water meters (called bulk water meters) above DN50 and up to DN200 sizes are tested in the primary water flow calibration facility. The following figure shows a schematic diagram of the facility.



Domestic water meter testing facility

# Electrical and Electronics Metrology

---

The Electrical and Electronics Metrology Division mainly involves establishing, maintaining, disseminating, and continuously upgrading the standards of electrical and electronics parameters based on the research and indigenous development of quantum standards. The electrical parameters include voltage, current and resistance; low frequency and high frequency impedance-related quantities such as capacitance, inductance, and AC resistance; DC high voltage; and AC high voltage & current; AC power & energy; and quantum standards such as quantum hall resistance (QHR), quantum current (QC) and quantum nanophotonics (QN). The traceability of the above-said parameters are based on Josephson Voltage Standard (JVS), QHR standard, and frequency standards (time). The measurements are disseminated through an unbroken chain of calibrations at par with other leading NMI's to the industries, strategic sectors, regional calibration and testing laboratories and support the robust quality infrastructure required for various ongoing government vision/missions such as AtmaNirbhar Bharat, Make-in-India and Vocal-for-local. The metrological services of the division are internationally recognized by the International Committee for Weights and Measures through mutual recognition arrangement (CIPM-MRA) and follow the quality system as per ISO/IEC 17025:2017. The division is unceasingly putting major efforts to upgrade and maintenance of existing facilities for various electrical and electronics parameters to cater to the mandate and requirements of the industries. This division also contributes to recognizing the international notch of equality in measurement through international inter-comparisons. Along with these, this division also works on various quantum materials such as graphene, 2D materials, topological insulators, superconductors, and nitrides-based thin film for the development of quantum standards like single photon detection, quantum current, and quantum Hall resistance. During the year 2022-23, the division has published over 35 SCI journals, 30 conference presentations and invited talks, and a few book chapters. The division has successfully conducted one training program in thin film growth. Glimpses of activities of each subdivision are described below.

## **LF, HF Impedance and DC Metrology**

The LF, HF Impedance and DC Metrology sub-division is responsible for maintaining national standards of impedance parameters (up to radio frequencies), precise AC voltage ratio, DC voltage, DC current, and DC resistance, charge (Coulomb) and DC high voltage up to 100 kV. Along with metrological services, the division also carries out cutting-edge and fundamental research in frontier areas of condensed matter such as superconductors and magnetic materials.

- **Upgradation of DC High Voltage Metrology Facility upto 100 kV**

The present DC High Voltage standard facility, which is a part of the Electrical and Electronics Metrology Division, was established in 2004 at CSIR-NPL with the help of PTB, Germany. It has measurement capability (CMC) up to 100 kV, which is traceable to the primary standard "DC Josephson voltage" at CSIR-NPL. It is maintaining three CMCs, i.e., a high-voltage Probe/Divider, kilo-voltmeter, and High-Voltage Sources.



DC High Voltage metrology facility at CSIR-NPL

### AC High Voltage and Current Metrology

The AC High Voltage and Current Metrology subdivision is maintaining the National Standards of AC High Voltage Ratio measurement upto 100kV, High Voltage Capacitance & Tan  $\delta$  facility up-to 200 kV and AC High Current Ratio measurement upto 5 kA. The subdivision has 8 CMCs for AC High Voltage and High Current parameters at par with International level. It is providing Apex Level Calibration Services for Voltage Transformers (VT's), Voltage Transformers Test Sets, AC High Voltage Sources, HV Break Down Test Sets, HV Dividers, HV Probes, kV Meters, Capacitance & Tan  $\delta$  Bridges, VT Burdens, Current Transformers (CT's), Current Transformer Test Sets, AC High Current Sources, Clamp Meters, Current Probes, CT Burdens, etc.,to various Power Utilities, Electrical Equipment Manufacturers and Electrical Testing and Calibration Laboratories like IDEMI, ERDA, BHEL, CPRI, ERTO, ERTL, NTH, KVTEK, ELTEL Industries and so on.



Calibration set-up for 200kV AC HV Divider



Upgradation of the calibration facility of AC HV ratio measurement up to  $220/\sqrt{3}$  kV and for HV Capacitors, kV meters up to 300 kV, is in the pipeline to meet the calibration and traceability requirements from Power Industries, Electrical Equipment Manufacturers, Electrical Testing & Calibration Laboratories.

- **Spectral Response Studies on Fresh Mineral Oil-Based CCTO Nanofluids**

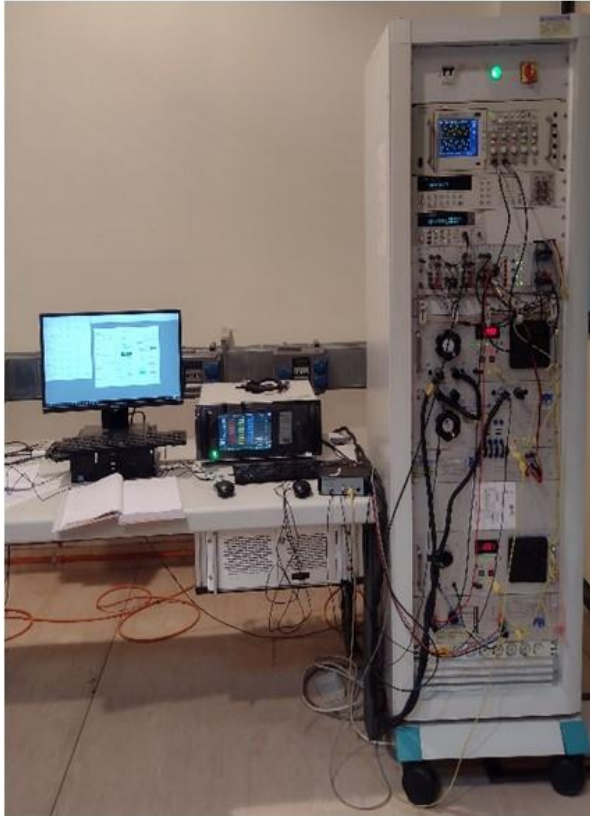
Nanofluids are being considered as a futuristic and replacement to the existing liquid insulation for High voltage power apparatus. Now-a-days, spectral studies are highly preferred for nanofluids to evaluate certain limitations like stability issues and structural changes. For evaluation of the spectral response, Dynamic Light Scattering (DLS) and Fourier Transform Infra-Red (FT-IR) techniques are basically preferred by the researchers globally. The MO based CCTO nanofluid samples are prepared from different volume concentrations. It is seen that the developed high dielectric nanofluids are resulted in moderate stability (i.e., 0.08–0.7) and FTIR results provides the traces of oxidation products (carbonyl group) and moisture content in the tested nanofluids. Further, investigation is needed for detailed evaluation of stability, organic and inorganic by-products present in the aged nanofluid samples. Further, statistical approach are to be conducted with high dielectric Nanofluids/Nanomaterials for the condition assessment studies for HV application as according to IEC, ASTM, IEEE & BIS standards.

### **AC Power & Energy Metrology**

The laboratory is engaged in maintaining & upgrading the primary standards of power & energy parameters and to disseminate apex level of measurement traceability to the power/energy sectors. The primary and reference power/energy standards with measurement uncertainty from 10 ppm to 150 ppm are being used to maintain traceability chain throughout the nation for calibration and testing certification. The laboratory also engaged in providing testing services to the industries for acceptance test and available test facility at CSIR-NPL on all types of energy meters as per international/ national standards such as IEC: 62053-21, IEC: 62053-22, IS: 13779, IS 16444(2015), IS-14697, IS: 13010 and CBIP-88.

#### **Measurement Scope:**

- Voltage: 10V-576V
- Current: 0.01A-120A
- PF: 0 to UPF
- Frequency: 40Hz to 70Hz and upto 400Hz
- Power: Active, Reactive, Apparent
- Energy: Active, Reactive, Apparent



Calibration of energy meter using primary standard PPCS energy meter



Testing of smart energy meter

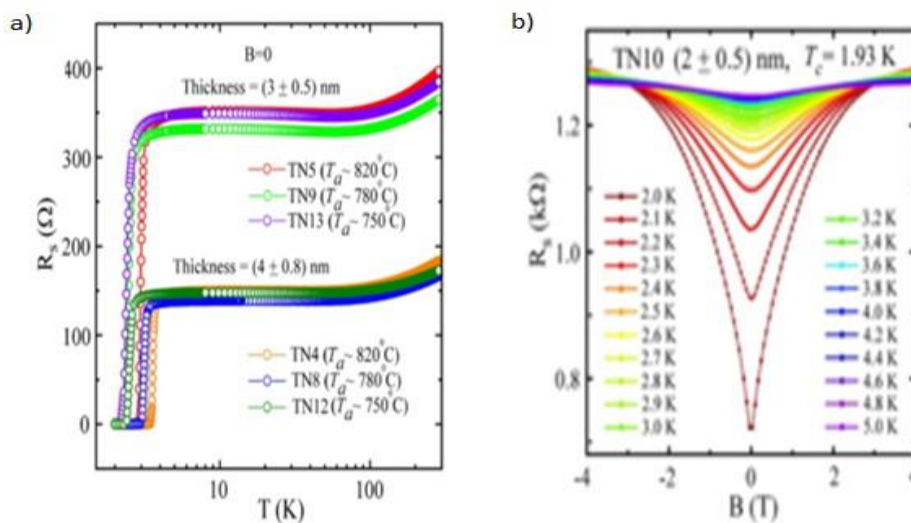
### Significant Contributions

- Initiatives for national facility creation for testing of smart energy meters as per IS 16444(2015), IS 15959
- Traceability of AC Power and Energy Parameters to energy sectors
- Calibration/Test reports issued during 2022-2023: 411 Reports to testing/calibration labs/manufacturers such as HPL India, Power Grid Corporation of India Ltd.(PGCIL), Uttar & Dakshin Haryana BijliVitrans, Andhra Pradesh Power Distribution Co, CPRI, ERTL, ETDC, ERDA, IDEMI, Genus Power, L & T, Allied Engg. etc.
- Upgradation of testing facility for tamper test as per customers requirements
- Hands on Training programs to PMQC and industrial training to Diploma Students

### Quantum Nanophotonics Metrology

The division of Quantum Nanophotonics Metrology focuses on research and developmental activities related to developing quantum electrical standards. The main focus of the activity is the development of a quantum current (Ampere) standard based on the principle of quantum phase slip (QPS) observable in a superconducting nanowire with a cross-sectional area of the order of the coherence length of the superconductor. The group has demonstrated the capability of ultrathin film fabrication with signatures of quantum phase fluctuations, including QPS. The group also focuses on developing

single-photon detectors using the superconducting nanowires in the meander wire geometry, alternatively called the superconducting nanowire single-photon detectors (SNSPD). In this direction also, the group has demonstrated superconductivity in the 2D limit (film thickness of the order of  $\sim 10$  nm) as well as in W meander wires of different widths using focused ion beam deposition (FIB). Apart from this, the group holds research on developing memristor switches exploring the quantum conductance behavior in multilevel systems incorporating insulator materials. The division is also the custodian of the primary voltage standard using the programmable Josephson voltage standards (PJVS) based on Josephson junctions (JJ). The group has completed an international inter-comparison with BIPM for Zener Reference standards against PJVS, and the results have been published. Exploring the novel phenomena in topological systems is another area where the group is actively engaged on. The figure below shows the superconducting properties of TiN ultrathin films of thickness in the range of  $\sim 2$ -3 nm.



(a) shows the resistance variation of TiN with different thicknesses and different processing temperatures, while (b) shows the magneto-resistance isotherms of a TiN film of thickness  $\sim 2$  nm

## Quantum Hall Resistance Metrology and 2D Physics

The sub-division is responsible for maintenance and operation of the National Standard of Resistance i.e. Primary Resistance Standard based on Quantum Hall Effect (QHE). Primary Resistance Standard based on QHE (QHRS) was established in 2003 at CSIR-NPL and peer-reviewed twice in 2005 and 2010. The Quantum Hall resistance standard (QHRS) is realized in perfectly quantized 2-dimensional electron gas (2DEG) in GaAs/AlGaAs system at low temperature and high magnetic field. The QHRS provides resistance traceability to temperature, DC, and LF/HF standards through the measurement of 1 k $\Omega$  standard

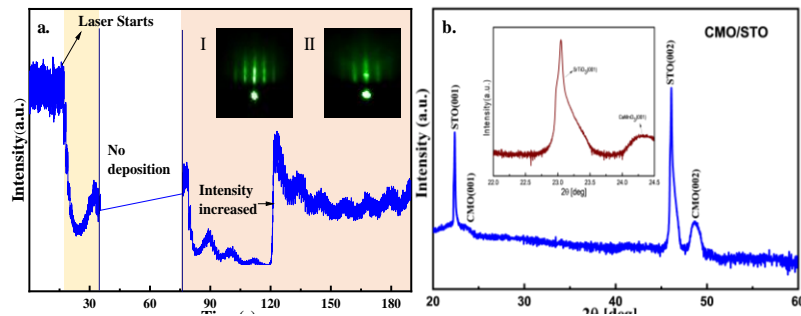


resistors stabilized in a constant temperature bath. The calibration was carried out using a DCC bridge in the 13:1 ratio and the  $R_k$  ( $i=2$ ) plateau. The combined expanded uncertainty ( $k=2$ ) was found to be better than 0.08 ppm for 1 k $\Omega$  standard resistors. Upgradation of the QHRS facility is underway as it is essential and inevitable to sustain Quantum Resistance Standard.

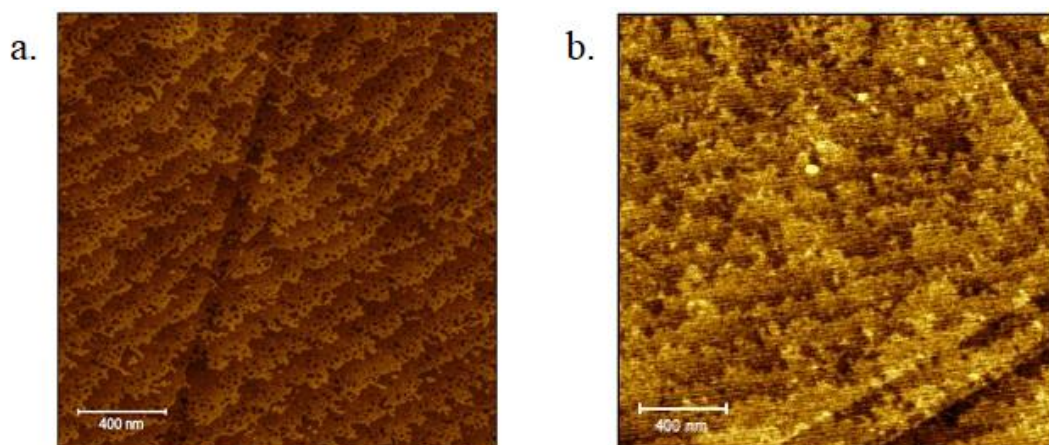
- **Suppression of Conductivity by 1uc Buffer Layer at LAO/STO Interface**

The conducting properties of oxide heterointerface can be significantly affected by buffer layers, gate voltage, capping layer, etc. Sometimes, a monolayer is enough to show a drastic change in these properties. In this study, one unit-cell (uc) of  $\text{CaMnO}_3$  material was inserted as a buffer layer at conducting  $\text{LaAlO}_3/\text{SrTiO}_3$  (LAO/STO) interface. One unit cell

thick buffer layer of  $\text{CaMnO}_3$  was grown at the interface of LAO/STO using the PLD technique, growth being monitored via reflection high energy electron diffraction (RHEED).  $R(T)$  measurements show resistance of the order of  $\sim 10^7$  ohms and no considerable change in resistance has been observed with temperature. 1uc of  $\text{CaMnO}_3$  material as a buffer layer at LAO/STO interface turns it into an insulator. The buffered heterostructure has been studied with HRXRD, AFM,  $R(T)$ , and XPS. The presence of  $\text{MnO}_2$ -layer in  $\text{CaMnO}_3$  uc at the interface blocks the charge transfer to  $\text{SrTiO}_3$  which makes the interface conducting as explained by the polar catastrophe model.



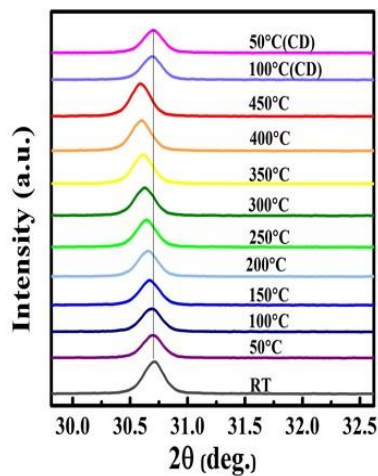
(a) RHEED oscillations observed during growth of LAO(10uc)/CMO(1uc)/STO heterostructure (I and II shows streaky pattern before and after deposition respectively)  
 (b) HRXRD pattern (in  $2\theta$ - $\omega$  mode) of CMO/STO heterostructure. (Inset graph shows  $2\theta$  scan about the peak corresponding to (001) plane)



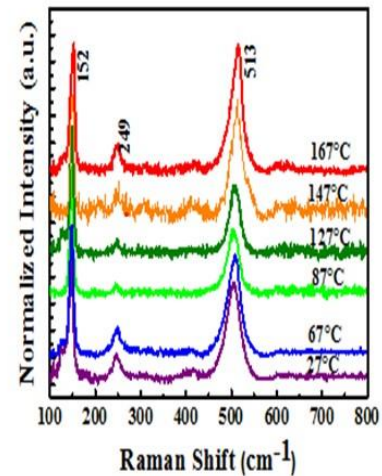
AFM image of (a)  $\text{TiO}_2$ -terminated STO and (b) grown heterostructure LAO(10uc)/CMO(1uc)/STO heterostructure)

- **Temperature-dependent Dielectric Measurements of Barium Stannate (BaSnO<sub>3</sub>)**

BaSnO<sub>3</sub> is known to be a promising candidate for applications like; thermally stable capacitors, gas sensors, humidity sensors etc. In this work, a collective study of the effect of high temperature on structural parameters and dielectric properties of bulk BaSnO<sub>3</sub> in a broad range of temperatures and frequencies with the help of temperature-dependent X-ray diffraction and dielectric measurements was carried out. The compound



a): Enlarged view of XRD pattern of Bulk BSO at different temperatures

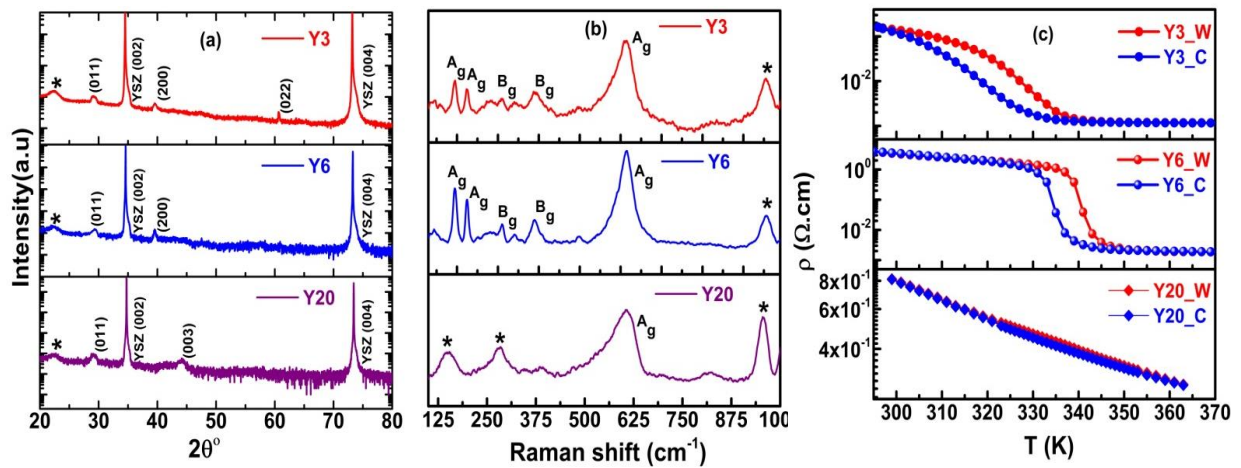


b): Raman plot of BSO showing different modes of vibrations at different temperatures

maintains cubic symmetry even at high temperatures and exhibits a gradual increase in unit cell volume owing to thermal expansion, which is evident in XRD data (Fig-a). Raman measurements, showcasing the signature of strain relaxation in terms of the progressive peak shifting at high temperatures (Fig-b), support XRD measurements. The anomalously high value of dielectric constant 860 was obtained at 500 Hz frequency and 200 °C due to the onset of humidity in the sample. The presence of moisture was also noticed in TGA measurement, which shows a total 3% weight loss up to 1000 °C without any phase transition supporting the results of dielectric measurements. The porous nature of the sample is responsible for moisture absorption which was confirmed by SEM-EDX analysis.

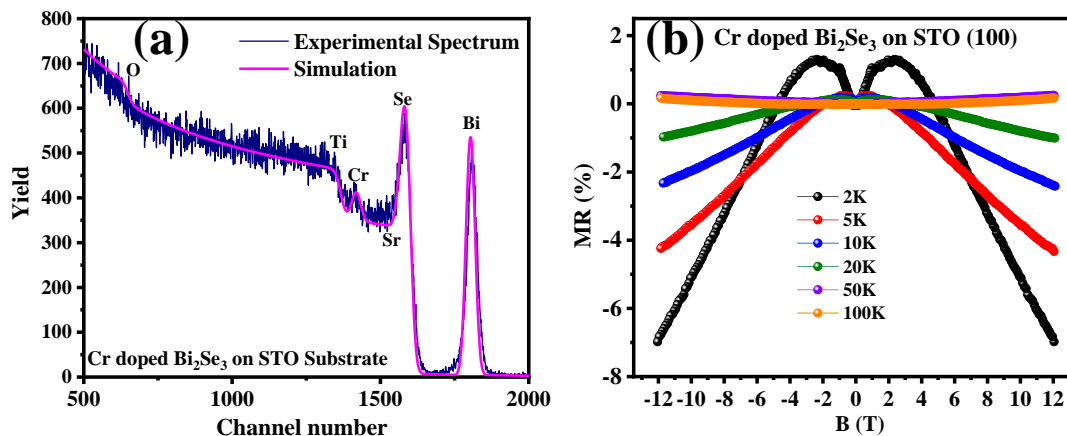
- **Phase Transition Characteristics in VO<sub>2</sub> Film by Sputtered V<sub>2</sub>O<sub>5</sub> Target**

Vanadium dioxide (VO<sub>2</sub>) have been extensively studied for their first order reversible and ultrafast phase transition from a high temperature metallic rutile phase to a low temperature monoclinic insulating phase around ~340K. This transition is accompanied by a significant change in electrical, optical, and thermal properties making VO<sub>2</sub> promising for various applications ranging from smart windows, sensors, thermo chromic devices and so on. Three sets of VO<sub>2</sub> films (~ 120 nm) were grown by RF sputtering (on YSZ) of self-synthesized V<sub>2</sub>O<sub>5</sub> target in only Ar ambient pressure of ~3, 6, and 20 mTorr (no oxygen) keeping all other processing parameters fixed. X-ray and Raman confirms the polycrystalline growth with dominant VO<sub>2</sub> phase having secondary V-O phase at higher Ar pressure in all films. Low Ar pressure (3 & 6 mTorr) grown films shows IMT of ~ 330 K and 341K, with hysteresis width (ΔH) of ~10K and ~8K, respectively, which is close to V-metal sputtering. Higher pressure (~ 20 mTorr or above) shows no IMT and ΔH. Thus, good quality VO<sub>2</sub> films with comparable properties can be grown by RF sputtering of V<sub>2</sub>O<sub>5</sub> in Ar gas only.



- **Magnetic-doped Topological Insulator Thin Films using Magnetron Sputtering**

Chromium (Cr) doped  $\text{Bi}_2\text{Se}_3$  topological insulator thin film on STO (100) was prepared using co-sputtering of  $\text{Bi}_2\text{Se}_3$  with the Cr in the same condition and parameters. Rutherford backscattering (RBS) analysis of Cr doped  $\text{Bi}_2\text{Se}_3$  thin film is shown in Fig.



(a), which confirms the formation of  $\text{Bi}_{2-x}\text{Cr}_x\text{Se}_3$  and  $x$  is found to be 0.18. The low temperature magneto transport properties of Cr doped  $\text{Bi}_2\text{Se}_3$  were studied in a varying magnetic field (-12 T to 12 T) for different temperatures and the magnetoresistance (MR) data is shown in Fig. (b). Cr doped thin film exhibit a negative MR at higher fields and lower temperatures, which was interpreted as the quantized bulk band channels weak localization (WL) contribution. Also, the positive magnetoresistance with a sharp cusp up to 20K in the low magnetic field is visible and can be attributed to weak anti-localization (WAL). The Cr doped thin films show a crossover from WAL to WL at lower temperatures near zero magnetic fields. The magneto-transport studies fascinatingly revealed the presence of WL in magnetic-doped  $\text{Bi}_2\text{Se}_3$  instead of WAL behavior which can be utilized towards QAHE applications.

# Environmental Sciences & Biomedical Metrology

---

The Environmental Sciences & Biomedical Metrology Division (ESBMD) of CSIR-NPL has been fostering quality measurements in the domain of atmospheric pollution, biomedical metrology, and sensor devices metrology under its mission project by working with different stakeholders. The division has four specialized sub-divisions viz, the Atmospheric Sciences and Metrology, Gas Metrology, Biomedical Metrology, and Sensor Devices & Metrology respectively. Each of these subdivisions is working on the issues of national importance related to the field of environment, gas standards and sensor development and biomedical. A brief detail of the activities of each sub-division may be summarized as under:

## Atmospheric Sciences and Metrology

This division is dedicated to monitoring a wide range of atmospheric pollutants, including greenhouse gases (GHGs) and particulate matter. Their goal is to study the chemical and physical properties of these pollutants and understand their impact on the ecosystem using advanced instruments and models. The division, known as ESBMD, is currently in the process of developing reliable methods for accurately measuring atmospheric trace species and aerosols. These methods are intended for adoption by various agencies and institutions in India engaged in atmospheric monitoring. This work is of paramount importance as it directly influences human health and the environment. Improved measurement techniques would contribute to better policymaking for air quality enhancement and climate change mitigation. Moreover, the division is actively engaged in creating cost-effective indigenous monitoring equipment for air pollutants. They are also establishing a testing and calibration facility for various automated Air Monitoring Systems, particularly Continuous Emission Monitoring Systems and Continuous Ambient Air Quality Monitoring Systems. Additionally, the division conducts research on characterizing ionized and non-ionized atmospheric conditions across Indian latitudes, polar regions, and terrestrial planetary environments. Their research encompasses critical aspects, such as radio propagation to enhance communication and navigation, atmospheric coupling processes in both lower and upper atmospheres, ionospheric studies related to earthquake precursors, and various societal and strategic applications. Furthermore, the division provides global users with ionospheric forecasting through the space weather Regional Warning Centre (RWC, NPL-India). Following are the recent research work of Atmospheric Sciences and Metrology:

- **Vegetation Index and Air Pollutants: Long-Term Trends in Delhi**

Delhi, one of the world's most densely populated megacities, is experiencing worse air quality due to industrial and transportation emissions. This poses a serious threat to human health and the environment. Vegetation plays a vital role in the abatement of improving air quality and reducing air pollutants. To investigate the role of vegetation in air pollution, abatement monthly variations in air pollutants (PM<sub>2.5</sub>, CO, and SO<sub>2</sub>) and vegetation indices were analyzed. The normalized vegetation index (NDVI) and enhanced vegetation index (EVI) values indicate vegetation cover and health. Long-term (2011-2021) mean monthly values of vegetation indices (NDVI and EVI) are compared with individual air pollutants. The trends of pollutant concentrations followed the

patterns of vegetation indices, suggesting that air pollution concentrations are affected by vegetation cover. CO, PM<sub>2.5</sub>, NO<sub>2</sub>, and SO<sub>2</sub> are consistently higher during the post-monsoon and early winter months (October-December). This is because the winter season has less rain, which inhibits vegetation growth. NDVI and EVI values decline from November to January. During October-November, especially in the post-monsoon season, vegetation cover is minimal. It has also been observed that NDVI and EVI values decline around October, the start of the autumn season, when trees shed their leaves. This reduces the amount of pollution absorbed by leaves, leading to higher air pollutant concentrations. Overall, our study suggests that vegetation plays a significant role in reducing air pollution concentrations.

- **Primary Ozone Standard (SRP 43) at CSIR-NPL**

CSIR-NPL is maintaining “Primary Ozone Standard” to provide Apex level calibration service to the surface ozone analyzers in 0 to 500 nmol/mol range.



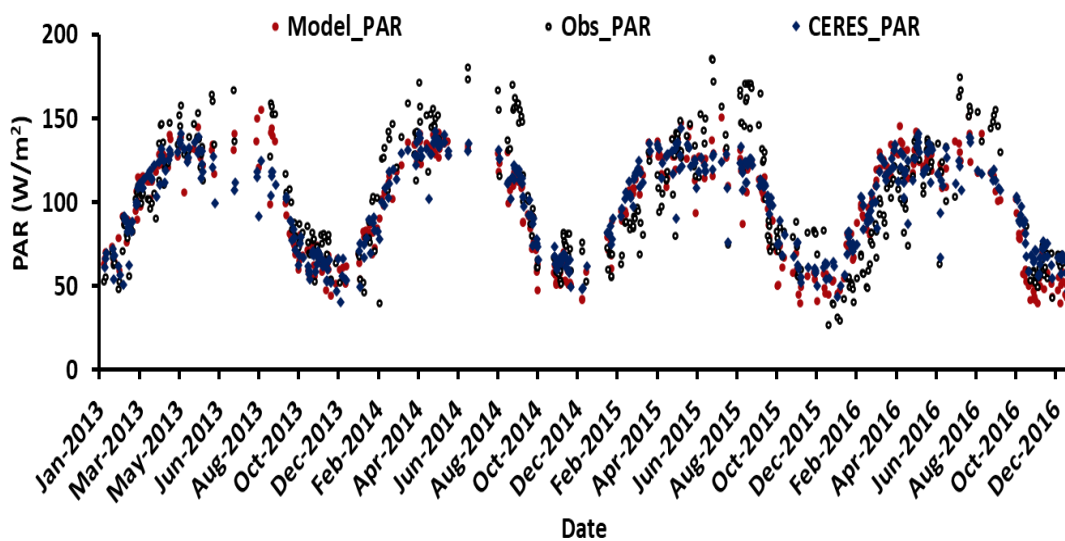
Primary Ozone Standard (SRP 43) Setup at CSIR-NPL

- **Estimation of Photosynthetically Active Radiation at Delhi using Different Methods**

Photosynthetically active radiation (PAR) received at the earth surface is the primary driver of plant growth and biomass production. In a recent investigation of Photosynthetically Active Radiation (PAR) in Delhi, dedicated measurements spanning four years (2013-2016) were presented and juxtaposed with three alternative methods of PAR estimation. PAR has been measured at the surface using Kipp and Zonen PQS1 PAR sensor and the data has been compared with the remotely sensed CERES derived all-sky PAR values. It was also compared with the PAR estimated by fractional method



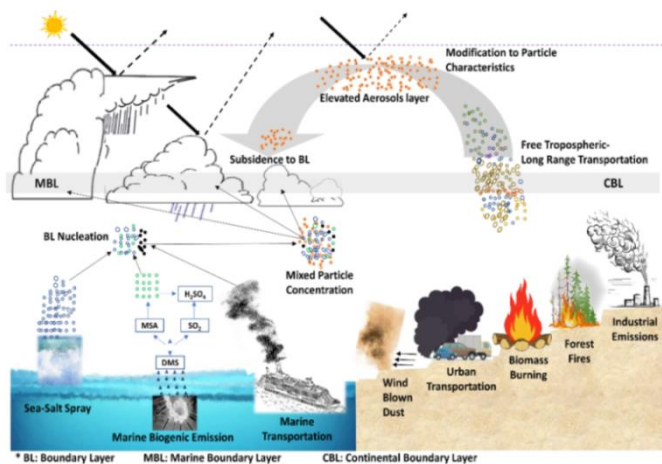
using shortwave (SW) flux measured by pyranometer and the ratio of PAR/SW fraction using long term satellite data for Delhi. It was further compared with the TUV radiative transfer model derived PAR on clear-sky days. The daily mean PAR observed at Delhi is in the range  $7.9 \text{ Wm}^{-2}$  to  $185.3 \text{ Wm}^{-2}$  (average  $94.5 \pm 1.1 \text{ Wm}^{-2}$ ) which nearly matched with the CERES derived PAR in the range  $10.8 \text{ Wm}^{-2}$  to  $144.3 \text{ Wm}^{-2}$  (average  $89.4 \pm 0.8 \text{ Wm}^{-2}$ ) and PAR derived by fractional method in the range  $8.9 \text{ Wm}^{-2}$  to  $187 \text{ Wm}^{-2}$  (with average  $88.1 \pm 0.8 \text{ Wm}^{-2}$ ). The TUV model estimated PAR on clear-sky days was found in the range  $39.1 - 154.9 \text{ Wm}^{-2}$  (average  $96.8 \pm 1.4 \text{ Wm}^{-2}$ ) which showed a strong correlation of 0.82 with the observed PAR values on concurrent days. PAR estimated by all the three methods showed a good correlation with the observations ( $>0.80$ ). It may be concluded that in the absence of a regular PAR measurements, any of the aforesaid three methods of PAR estimation can give fairly accurate value at a point but CERES gives added advantage of providing PAR over large spatial area in the region.



PAR estimated by TUV Model compared with Observed and CERES PAR during clear-sky days for the observation period (2013-2016)

• **Interaction between Aerosols and Clouds over Northern Indian Ocean Region**

The interactions between aerosol and cloud play a vital role in global climate change. The Northern Indian Ocean (NIO) gains significant importance amongst the scientific communities since the understanding of aerosols and their interaction with cloud over this region is very crucial from a regional and global perspective as well. A review has, thus been done, which provides (a) an overview of the aerosol loading and cloud occurrence patterns and their trends in the last two decades over the NIO (b) current understanding of aerosol-cloud

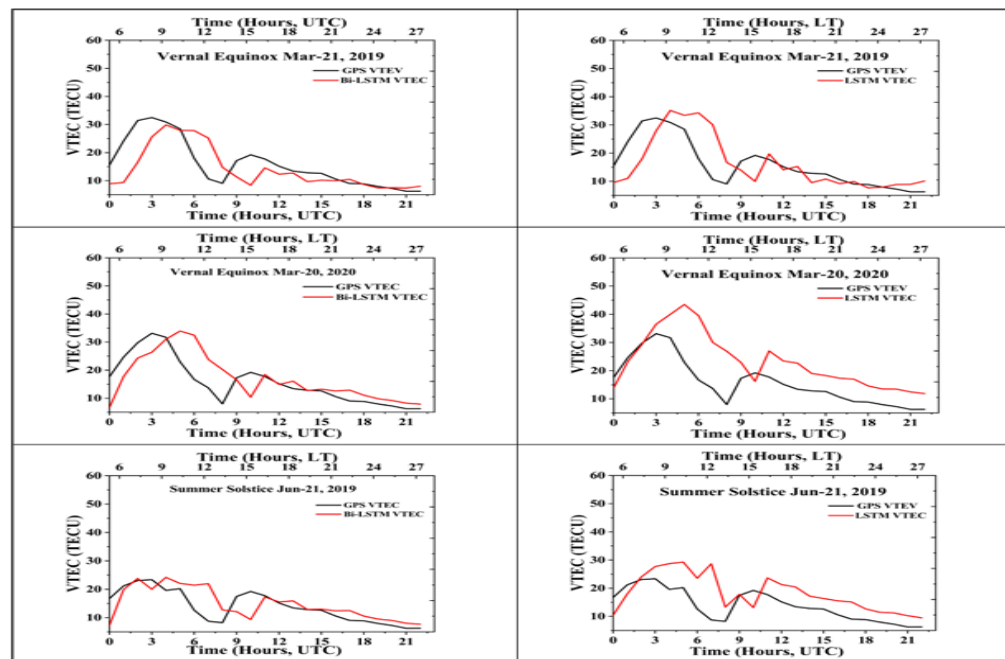


Schematic diagram representing aerosol source-sink, transportation, and aerosol-cloud interaction mechanism over the marine region

interaction (ACI) over the NIO and (c) impacts of ACI on the oceanic ecosystem and Indian Summer Monsoon (ISM). Strong spatio-temporal variability was found and positive trend in aerosol loading and cloud parameters which is largely modulated by the wind circulation pattern and Inter Tropical Convergence Zone (ITCZ) movement. Long range transportation is the key process in aerosol loading over the this region and significant contribution of continental aerosol over the central AS (31%) and central BoB (28%) is found.

- **Bi-LSTM based Vertical Total Electron Content Prediction at Low-latitude Equatorial Ionization Anomaly Region of South India**

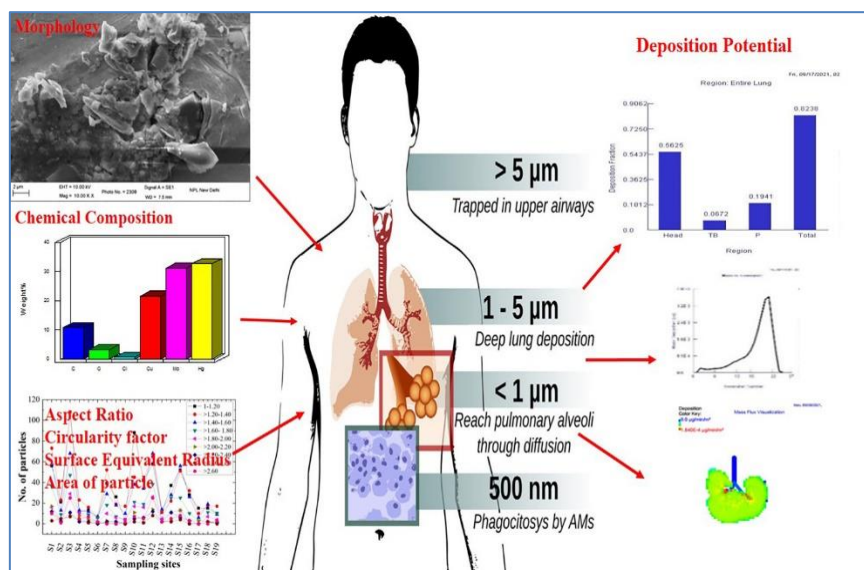
The study was performed to predict Vertical Total Electron Content (VTEC) over Thanjavur (Geographic 10.72N, 79.01E, Geomagnetic 2.34N, 152.19E) through Bi-directional Long Short Term Memory (Bi-LSTM) model. This station is located at low latitude Equatorial Ionization Anomaly (EIA) region of geomagnetic dip latitude and has unique ionospheric dynamics. In this region, the VTEC prediction is imperative and challenging for space weather and the Sixth Generation (6G) Internet of Space (IoS) application to support early warning systems and future spatial data transmissions. A Deep Learning (DL) model based on Bi-LSTM was developed and trained for F10.7 and Dst index for predicting the VTEC. This study highlights the prediction of VTEC for any day which includes solstice and equinox time frames. The Bi-LSTM has an improvement of 28 % in mean absolute error (MAE), 48% in mean square error (MSE) and 24% in root mean square error (RMSE) as compared to the conventional Long Short Term Memory (LSTM) network. Hence, this Bi-LSTM model can be helpful in predicting the VTEC in the EIA region and may prove beneficial for to extrapolating over the unmeasured grid region of ocean and land.



The Bi-LSTM and LSTM model prediction of VTEC against GPS measurements during Equinox and Solstice days of 2019–2021

- Role of PM Morphology and Chemical Composition on Particle Deposition in Human Respiratory System**

Morphology and chemical composition altogether determine the fate of atmospheric particulate matter (PM) deposition and inhalation. Site-wise (#20 sites) and cumulative variations in morphology and chemical composition of PM<sub>5</sub> in Delhi showed dominance of non-spherical (sharp-edged, angular and flattened) particles followed by spherical ones, rich in elements



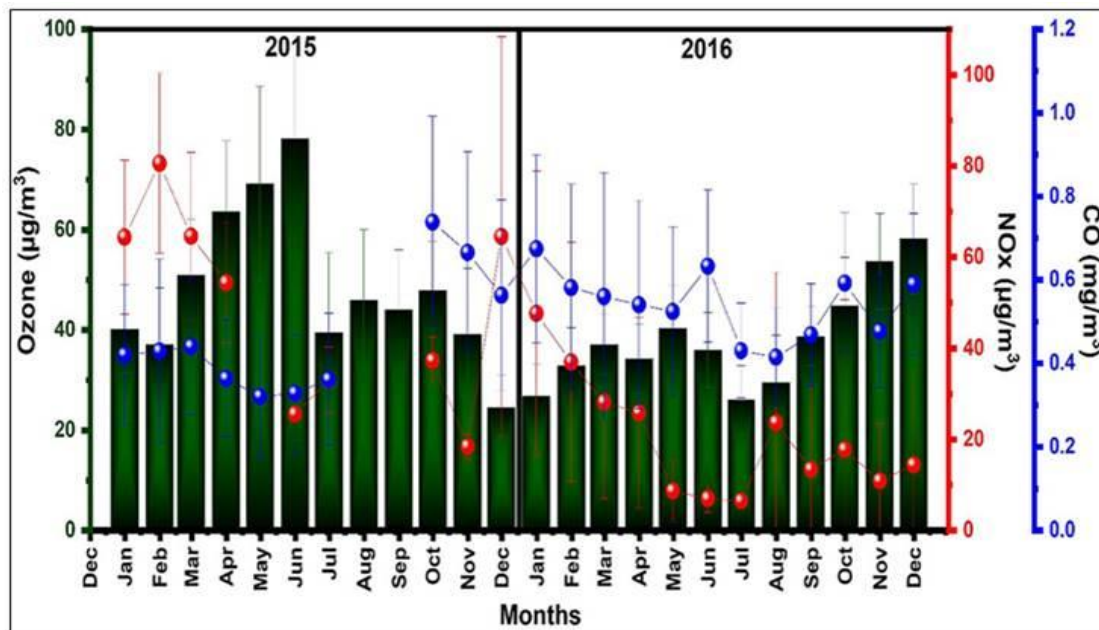
PM Physico-chemical characteristics and deposition in human respiratory system

such as C, S, N, Al, Si, Cu, Ca, Na, Cl, Fe, Ni, Cr, Zn, Hg, Pb, Mo, etc. having potential health effects. #2650 individual particles were analyzed for the morphological parameters like aspect ratio (AR), circularity factor (CIR), surface equivalent radius (SER) and area. Dominant AR and SER values found between  $\geq 1-1.60$  and  $> 0-0.50 \mu\text{m}$ , respectively showing dominance of non-spherical and fine-size particles in Delhi. The Multiple Path Particle Dosimetry (MPPD) Model used to study variations in deposition potential (regional deposition, lobar deposition, mass deposition and mass flux) of different PM sizes (PM<sub>0.4</sub>, PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>5</sub>) at different AR values which suggested that AR is an important input parameter of health models to get realistic and unbiased output health data. In addition to this, the study revealed the higher coarse particles deposition in the head region affecting upper respiratory tract with their non-spherical shapes, whereas the higher fine particles deposition in TB and pulmonary regions affecting inner parts of the lungs.

- Influence of Precursors and Meteorology on Ambient Ozone Over Indian Western Himalayas**

Mountain sites are considered the best sites to study the background concentration of ozone due to their harsh topography and less human interventions which leads to low or no local pollution. The high-altitude sites altitude more than 1200 m above mean sea level (AMSL) are generally considered representatives of the free troposphere. The surface ozone, oxides of nitrogen (NO<sub>x</sub>), and carbon monoxide (CO) were measured for the period 2015 to 2016 at a high altitude monitoring station (32.12°N, 76.56°E; at 1347m AMSL) in Palampur, Himachal Pradesh in the Indian western Himalayan region to study the temporal variability of ozone and the influence of precursor gases and meteorological parameters. The ozone showed anti-correlation with NO<sub>x</sub> and CO, indicating its photochemical origin. Significant variabilities were recorded in the annual mean values of these species in 2015 & 2016. The NO<sub>x</sub> showed ~60% fall in the mean

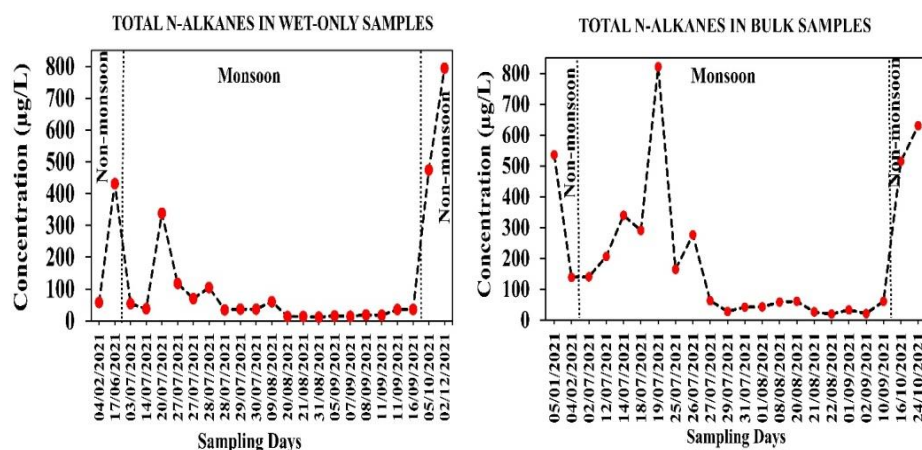
annual concentration in 2016 as compared to 2015, while a 17% increase in CO concentration and a 27% fall in mean ozone level were recorded in 2016. The observed variabilities could be due to change in wind speed, as a ~ 50% drop was recorded in the mean wind speed in 2016. The analysis showed that the site received maximum air masses from the southeast to northwest directions, where point sources are also located. The influence of biomass burning in Indo-Gangetic Plains (IGP) region, along with strong valley to mountain wind flow were also observed. The high values of NO<sub>x</sub> and CO observed in 2015 may be attributed to industrial activities and meteorology in this region.



Monthly mean variability of Ozone, NO<sub>x</sub> and CO during Jan, 2015 to Dec, 2016

- **Source Markers (n-alkanes) in Atmospheric Wet Deposition at an Urban Site in Delhi during Monsoon and Non-Monsoon Period, 2021.**

The levels of n-alkanes as molecular markers were determined in the atmospheric wet deposition for the first time in the Indian region during monsoon and non-monsoon periods in 2021. The study revealed



Total n-alkanes in wet-only and bulk depositions during monsoon and non-monsoon periods

significant variation in average total n-alkanes between wet-only and bulk samples, during monsoon and non-monsoon periods. These patterns can be attributed to

atmospheric circulation patterns, meteorological conditions, rain intensity, duration, collection time, volume, and regional emission characteristics. Furthermore, the molecular distribution of low molecular weight n-alkanes (C<sub>10</sub>-C<sub>25</sub>) in wet-only and bulk samples showed no odd-even predominance, suggesting their origin from fossil-fuel combustion and direct volatilization of unburnt fuels. In addition, the high molecular weight n-alkanes (>C<sub>25</sub>) showed weak to strong odd-even predominance in wet-only and bulk samples of the non-monsoon period. The molecular diagnostic ratios like the Carbon Preference Index (CPI) and Wax n-alkanes (WNA) % supported the prevalence of mixed emission sources with higher contribution from anthropogenic activities.

## Gas Metrology

Gas Metrology is providing testing, calibration and SI traceability dissemination services through Primary Reference Gas Mixtures, i.e. Gas BNDs to the nation. Its valuable customers are Gas industries, Government Institutions, e.g. ISRO, SRL, Automotive Industries, etc. Gas metrology is not only providing the indigenously prepared SI traceable reference gas mixture to the nation but also giving boost to Indian economy in terms of foreign currency outflow. Following are the recent achievements of Gas Metrology:

- **Establishment of Facility for Air Purifier Testing as per IS 17531 2021 and Started Service to Industries**

Services provided to inhouse, to FreshCraft Technologies Pvt. Ltd., Kerala; Voltas Ltd., Faridabad. Project is completed and final report is submitted (Project TSP 210432).

- **Gas BNDs, Calibration/Testing Work, Dissemination Services Done**

Total 18 Gas BND standards provided to gas industries, automobile industries and govt. sectors including PRL Ahmedabad, total 03 calibration/testing certificates including PM<sub>2.5</sub> cutoff size calibration and certificate of particle counter (clean room) for in-house uses

- **Testing Facility Provided to meet National Testing Needs for VVIP Security**

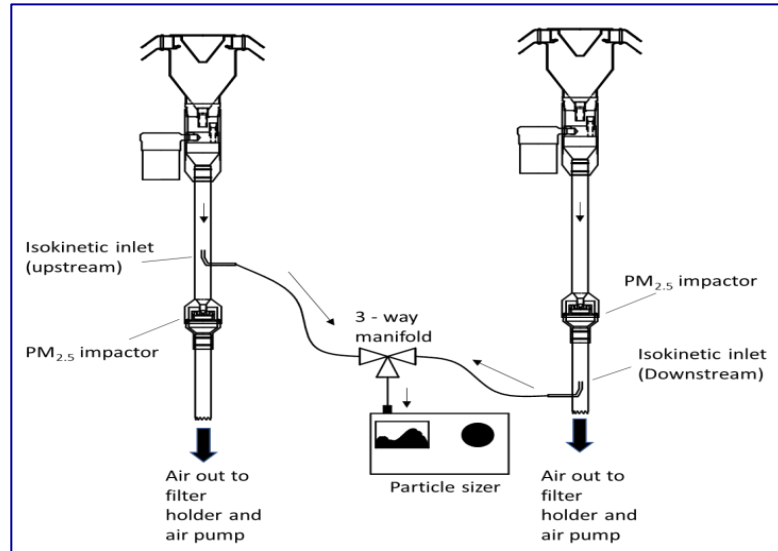
Fulfilling strategic testing needs for VVIP Security in the country; **03 test certificates issued** (Testing charges are notional).

- **Participating in the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) Pilot Study "PM<sub>2.5</sub> Cutoff Size and Mass"**

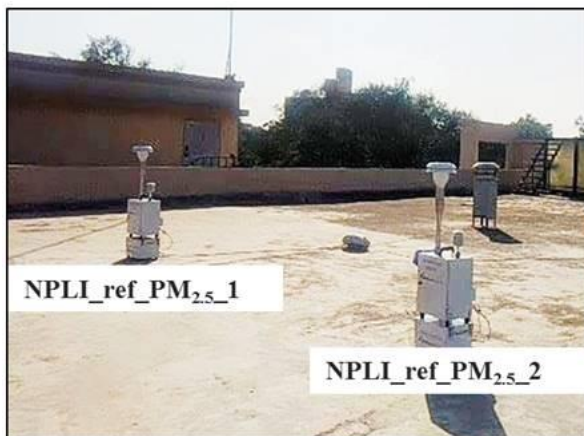
This study is first of its kind in the world and also a proud moment for India that CSIR-National Physical Laboratory (National Metrology Institute of India-NPLI)) proposed this kind of study at CCQM GAW. Finally, the above proposal has been approved by the CCQM, that the NPLI will be coordinating laboratory for the pilot study of "PM<sub>2.5</sub> cutoff size and mass". In this pilot study about 5 NMI's are participating from the different parts of the world and CSIR-NPL will be providing particulate impactors to all participating NMI's. After successful completion of this pilot study, all the NMI's can file

for Calibration and Measurement capability (CMC) at the International Bureau of Weights and Measures (BIPM).

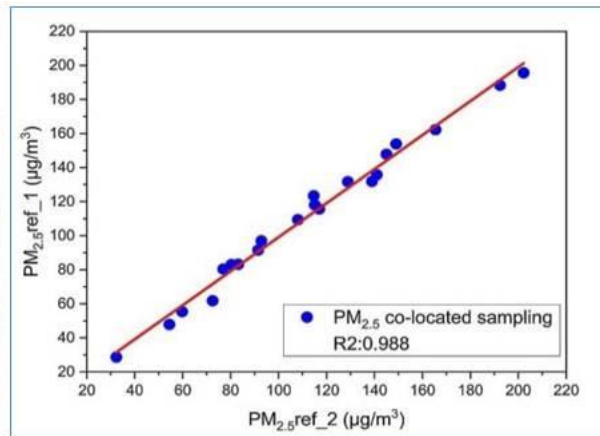
This pilot study is designed to demonstrate the capabilities of participating NMIs/DIs on successful measurement of  $PM_{2.5}$  cutoff size ( $\mu m$ ) and mass concentration ( $\mu g/m^3$ ) for normal (country specific) and elevated levels of ambient  $PM_{2.5}$  using impactor inlet with expanded uncertainties of less than 5% (cutoff size), and 10% (mass concentration), respectively.



Schematic of D50cutoff measurement in ambient air



Field measurement of PM2.5 mass



The slope and intercept of linear relationship

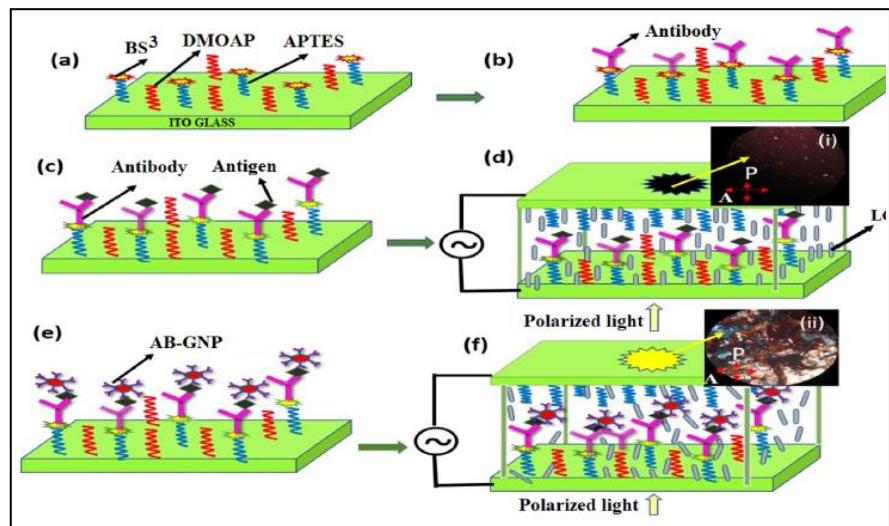
## Biomedical Metrology

The group is actively engaged in the field of biomedical metrology. Keeping in line with this, a facility has been established for the traceable calibration of defibrillators. This group has also been engaged in the technical development of biosensors for application to clinical diagnostics using various experimental techniques such as FTIR, UV-visible, Zeta potential, Contact angle, AFM, differential scanning calorimetric (DSC), cyclic voltammetry and Electrochemical impedance spectroscopy.

## Glimpses of Biomedical Metrology Section Research activities:

- The biomedical metrology related work for upgrading the calibration services of defibrillator analyzer has been taken up and the calibration of defibrillator energy measurement is being studied at different load resistance of 50, 75, 100, and 125 Ohm respectively for the calibration of defibrillator analyzer over the energy range of 50–270 Joules. The accuracy of energy measurement of defibrillator analyzer with error and associated uncertainty at various load resistance is reported with respect to energy calculated using the traceable SI units.

- New generation biosensor, a Dielectric liquid crystal based biosensor using nematic liquid crystal platform has been fabricated using sandwich immunoassay technique for the detection of a biomolecule,



human cardiac troponin I (cTnI). The optical response of Liquid crystal (LC) biosensor

and its corresponding frequency-dependent dielectric properties have been investigated as a function of cTnI concentration. Gold nanoparticles conjugate with detection antibody (AB-GNP) are used for the enhancement of both the optical and dielectric signal of the biosensor. The dielectric response of the biosensor is fitted with Hill-Langmuir equation over a concentration range of 0.01 to 10 ng mL<sup>-1</sup>cTnI. The dissociation constant 'K<sub>d</sub>' of 1.02 ± 0.24 ng/mL<sup>-1</sup> indicates strong cTnI binding affinity for substrate antibody.

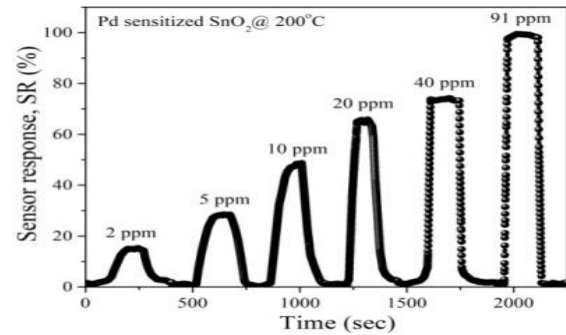
Schematic of the LC biosensor comprising various steps of surface modifications: (a) (APTES/DMOAP)/ITO, (b) CP-(APTES/DMOSP)/ITO, (c) cTnI-CP/ITO, (d) AB-GNPcTnI-CP/ITO, (e) LC cell prepared with cTnI-CP/ITO (without AB-GNP) showing (i) dark optical image, (f) LC cell prepared with AB-GNP-cTnI-CP/ITO showing (ii) bright optical image under POM

## Sensor Devices & Metrology

The group focuses on the development of smart sensors for the detection of atmospheric pollutant gases such as CO<sub>x</sub>, NO<sub>x</sub>, SO<sub>x</sub>, H<sub>2</sub>S, NH<sub>3</sub> etc., and EM radiations based on thin film/nanostructures of metal oxides, III-nitrides, 2D materials, etc. The group is equipped with various thin film growth systems and thin film and sensor characterization facilities.

- **Development of Pd-SnO<sub>2</sub> Thin Films for High Performance CO Gas Sensing**

Pd sensitized nanocrystalline SnO<sub>2</sub> thin films were sputtered at RT on alumina. An excellent sensor response of ~99.5% was observed at 200°C, with an ultrafast response and recovery time of ~8s and ~15s for 91 ppm concentration of CO gas for Pd sensitized SnO<sub>2</sub> thin film. The device shows a noticeable sensor response up to 2 ppm of CO gas and were highly selective for CO gas compared to NH<sub>3</sub>, H<sub>2</sub>S, NO<sub>2</sub> and NO gases.



Sensor responses (%) with respect to CO gas concentrations

- **Fabrication of Portable Gas Sensor for NO<sub>2</sub> Detection**

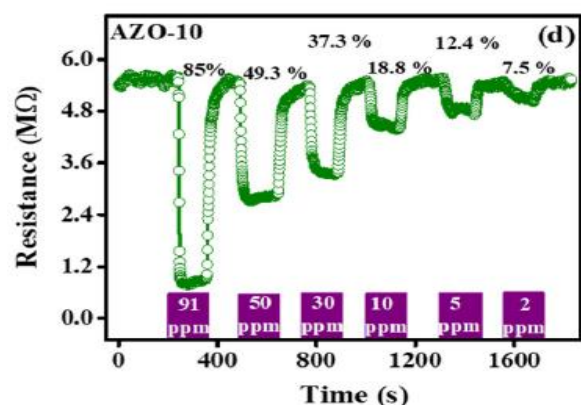
In<sub>2</sub>O<sub>3</sub> thin film based gas sensor has been developed by the thermal oxidation of In metal film deposited by thermal evaporation. Inter-digitated Au finger electrodes were fabricated and the device was packed in metal sensor housing. The sensing response and response time are achieved to be 40% and 30% respectively, at RT.



Portable NO<sub>2</sub> gas sensor based on In<sub>2</sub>O<sub>3</sub> thin film

- **Development of ZnO/SnO<sub>2</sub> Heterostructure Gas Sensors for CO Air Pollutant Detection**

Heterojunction-based gas sensors are very attractive as they substantially improve the sensing characteristics due to the effective potential barrier present at the interface. ZnO/SnO<sub>2</sub> heterojunction with optimized thickness of ZnO (~10 nm) is constructed, which shows a 6-fold enhancement in sensing response as compared to bare SnO<sub>2</sub> films against CO gas. The sensing response of 85% has been obtained against 91 ppm of CO gas with an estimated limit of detection of 0.37 ppm at 400 °C.

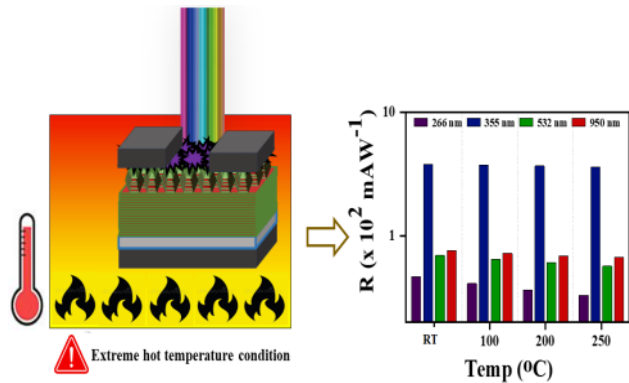


CO gas sensing characteristics of ZnO/SnO<sub>2</sub> heterostructure sensor



- **Self-driven UVC-NIR Broadband Photodetector with High-Temperature Reliability based on a Coco Palm-like MoS<sub>2</sub>/GaN Heterostructure**

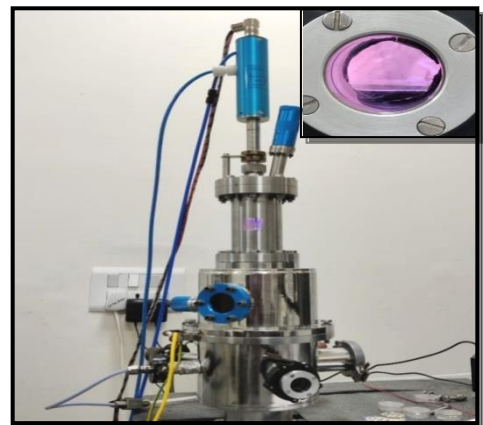
A unique coco palm-like MoS<sub>2</sub>/GaN heterojunction-based self-powered photodetector is introduced which operates in the broadband spectral range from ultraviolet-C to near-infrared. The fabricated detector displays the highest responsivity of 379 mA W<sup>-1</sup> under no applied bias at room temperature. Device exhibits consistent performance at high operating temperatures (up to 250°C). Under self-driven conditions, the device possesses the highest responsivity of 360 mA W<sup>-1</sup> at 250°C. The heterostructure-based device also achieves the best responsivity of 2.8×10<sup>6</sup> mA W<sup>-1</sup> at 8V applied bias and has remarkable low-light detection abilities down to 9 femto-watt. The high temperature-operated self-driven broadband photodetector opens up new possibilities for in-situ monitoring of optical radiations from diverse industrial processes in challenging conditions to optical signature-generating systems in the automobile, aerospace, and energy production industries



Coco Palm-like MoS<sub>2</sub>/GaN Heterostructure

### Creation of Magnetron Sputtering System Facility

A portable direct current (DC) magnetron sputtering system has been developed in-house for thin film deposition. The system operates at a background pressure of < 3 x 10<sup>-6</sup> Torr created by a turbo molecular pump backed by a rotary pump. The system has high vacuum gas inlet line for the introduction of sputter and reactive gases for thin film deposition process controlled by separate mass flow controllers. Various metal-oxide thin films like CuO, ZnO, WO<sub>3</sub>, MO<sub>3</sub>, etc. are being developed within the system for gas sensing applications. The system is also used for the fabrication of metal electrodes for gas and optical sensor devices. The DC sputtering system caters the research and development demands of CSIR-NPL scientists and scholars for the development of various thin films and nanostructures.



The DC sputtering system caters the research and development demands of CSIR-NPL scientists and scholars for the development of various thin films and nanostructures.

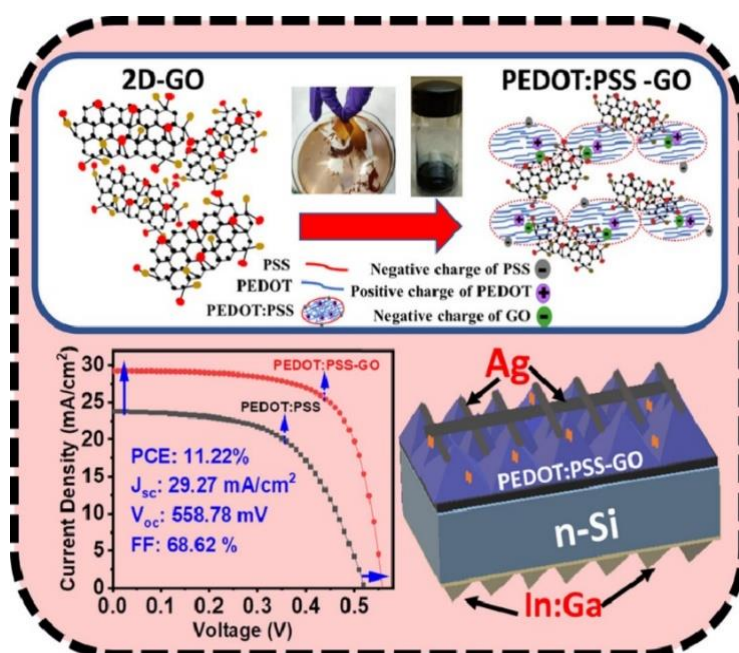
## Advanced Materials & Device Metrology

The 'Division of Advanced Materials and Device Metrology' aims towards synergizing the research and development to develop state-of-the-art bulk and nano-scale materials, process technologies and devices for Industrial, Strategic and Societal applications. The thrust is on the development of indigenous, economically viable and efficient organic and inorganic Photovoltaic and Thermoelectric devices, Luminescent materials, Carbon based materials & composites and Thin-film based gas sensors. The division undertakes this mandated research and development through several International and National projects, including Consultancy, Collaborative, Grant-in-aid and Sponsored projects. The divisional activities are classified in three groups or sub-divisions; namely Photovoltaic Metrology, Photonic Materials Metrology and Photonic Materials Metrology, and Advanced Carbon Products and Metrology. The highlights of different sub-divisional research activities for the year are as below:

### Photovoltaic Metrology

- **Development of Organic/Silicon Hybrid Heterojunction Solar Cells: Graphene Oxide (GO) modified PEDOT:PSS as an efficient hole transport layer**

Organic/inorganic hybrid heterojunction provide a viable option to replace the conventional high-temperature dopant diffusion-based p-n junction owing to their low manufacturing cost. This is because of its low thermal budget, simple, rapid and solution based processes which can be implemented in heterojunction fabrication. Since most of the incoming light is absorbed in silicon therefore heterojunction solar cell may have, in principle, efficiency comparable to a silicon p-n junction solar cell. Thus, there has been increasing interests in low temperature heterojunction solar cell concepts particularly polymer/Si-based heterojunction solar cells. With the objectives, efforts have been made to develop the heterojunction-Si solar cells with enhanced performances

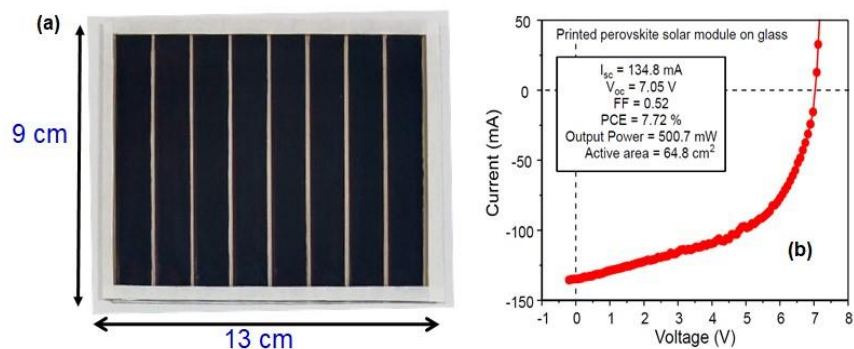


Highlights of the development of hybrid heterojunction Si solar cells (HSCs) employing the PEDOT:PSS+GO composite. Structure of GO and GO-modified PEDOT:PSS (upper part); Comparative solar cell performance of HSCs with and without GO in PEDOT:PSS (lower left), and schematic of device structure

employing lab synthesized high quality graphene oxide (GO) modified **PEDOT:PSS as an efficient hole transport layer** for high efficiency PEDOT:PSS/n-Si hybrid heterojunction solar cells. A small amount of GO incorporation resulted in significantly improved structural, electrical, Si surface passivation properties of the PEDOT:PSS and hence the photovoltaic performance of the PEDOT:PSS-GO/n-Si HSCs. The study revealed that the oxygen functional groups on 2D-GO sheets interacted with PEDOT:PSS and facilitated the improved electrical conductivity by >2 folds without affecting its optical properties. Further, the effective passivation of n-Si surface by the composite film has been found with enhanced minority carrier lifetime (~1.7 folds). The PEDOT:PSS-GO/n-Si HSCs could achieve the highest PCE of 11.22% on device dimension of 1 cm<sup>2</sup>, which is absolute ~4.14% higher with respect to that with the pristine PEDOT:PSS. The improved performance is attributed to the effective charge transport properties of the PEDOT:PSS-GO, interface passivation and thus efficient separation and collection of the photo-carriers for an optimum GO addition. The study establishes that PEDOT:PSS-GO composite could be used as an effective HTL for the efficient PEDOT:PSS/n-Si HSCs. The important results of the work are presented in the following figure.

- **Development of Perovskite Solar Cells (PSCs)**

Perovskite solar cells (PSCs) are very promising for future green energy generation. PSCs are very thin, light weight, mechanically flexible and very cost effective. PSCs find enormous applications from small area to large area, from domestic to defense sectors, transport vehicles to building

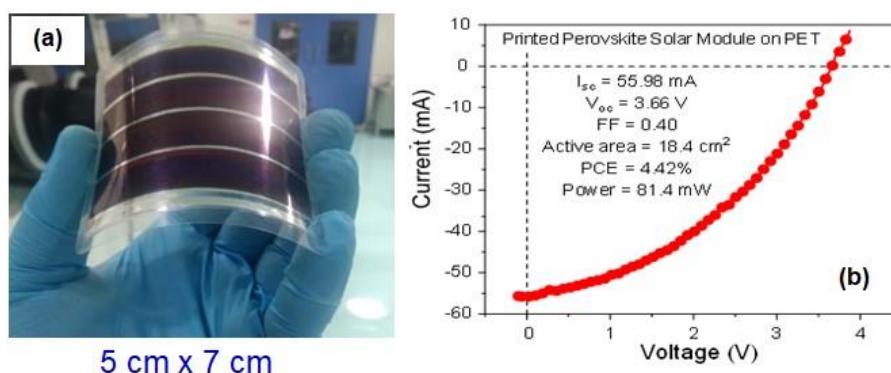


(a) Photograph of the printed PSCs module on FTO coated glass substrate. (b) I-V characteristics of the PSCs module under 100 mW/cm<sup>2</sup> irradiance of a class AAA solar simulator

integration. For commercial success, PSCs should be developed in large scale via scalable processes. PSCs can be produced roll-to-roll on plastic sheets using conventional printing methods. CSIR-NPL has undertaken to develop large area PSCs via printing method. For printing of PSCs, a computer controlled printer has been indigenously designed and developed. The printable PSCs are being developed on both glass as well as plastic substrates. For printing of PSCs on glass, fluorine doped tin oxide (FTO) coated glass substrates are used whereas for the printing of PSCs on plastic substrates, indium tin oxide (ITO) coated polyethylene terephthalate (PET) substrates are used. The PSCs have multiple layers of different materials, which play different roles in photon harvesting like electron transport layer (ETL), light absorbing layer, hole transport layer (HTL) and top metal electrode. For printed PSCs, tin oxide (SnO<sub>2</sub>) is used as electron transport layer, CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub> perovskite is used as light absorber and poly(3-hexyl thiophene) (P<sub>3</sub>HT) is used as HTL. For the printing of PSCs, first of all ETL is printed on the ITO or FTO coated substrate and then perovskite layer is printed on ETL and then HTL is printed on the perovskite layer. To complete the solar cell, Ag is

deposited as the top metal electrode by thermal evaporation in a vacuum chamber through shadow mask. Before printing any layer the previously printed layer is dried via thermal annealing at an optimum temperature in an oven to evaporate the solvent and get a solid film. High performance solar cells require optimization of processing conditions of all the layers, and optimization of individual layer results in improvement in the solar cell performance. Both the small area solar cells and large area solar modules are developed by the printer. The solar modules include a number of solar cells, which are connected in series together. One of our recently printed large area PSCs modules on glass substrate in 9 cm x 13 cm area (active area 64.8 cm<sup>2</sup>) has shown the power conversion efficiency (PCE) of 7.7% under 100 mW/cm<sup>2</sup> irradiance of class AAA solar simulator. In the above illustration, figure (a) shows the photograph of the printed solar module on FTO coated glass substrate and figure (b) shows its illuminated current-voltage (I-V) characteristics.

In case of printed large area solar modules on the PET substrates, one of the recently printed module in 5 cm x 7 cm area (active area 18.4 cm<sup>2</sup>) has shown PCE of 4.4% under 100 mW/cm<sup>2</sup> irradiance of class AAA solar simulator.

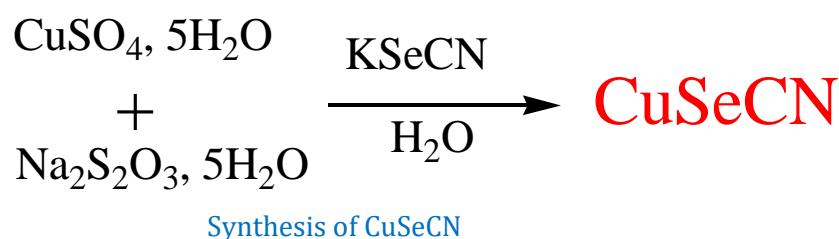


(a) Photograph of the printed PSCs module on ITO coated PET substrate. (b) I-V characteristics of the PSCs module under 100 mW/cm<sup>2</sup> irradiance of a class AAA solar simulator.

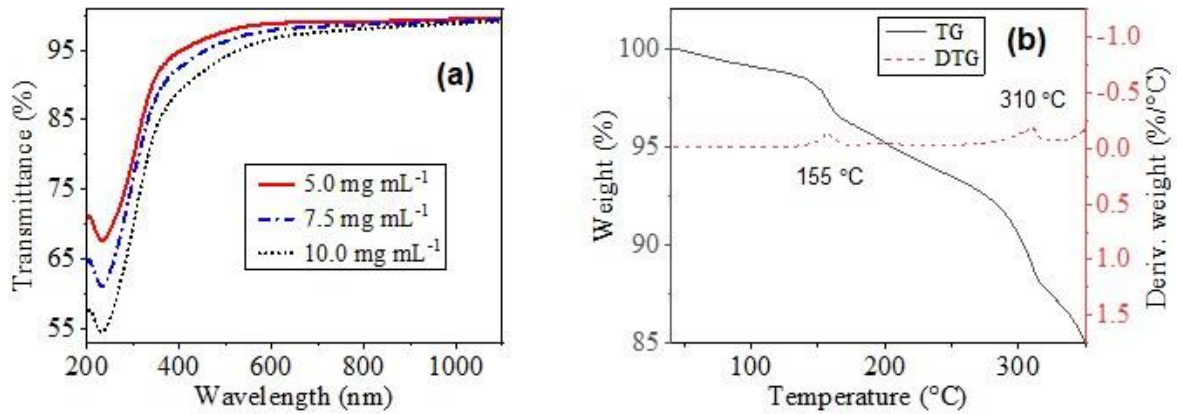
The figure (a) shows the photograph of the printed solar module on ITO coated PET substrate and figure (b) shows its illuminated current-voltage (I-V) characteristics. The solar cells printed on glass substrates have shown >250 h lifetime under continuous illumination of 1 sun intensity of a tungsten-halogen lamp.

- **Development of Copper(I) Selenocyanate as Hole Transporting Material for Perovskite Solar Cells**

Significant work have been reported on copper(I) thiocyanate(CuSCN) as an efficient hole transporting layer (HTL) for PSCs. The higher chalcogen analogue CuSeCN is unexplored yet. The CuSeCN as HTL has been synthesized by the scheme as presented below:

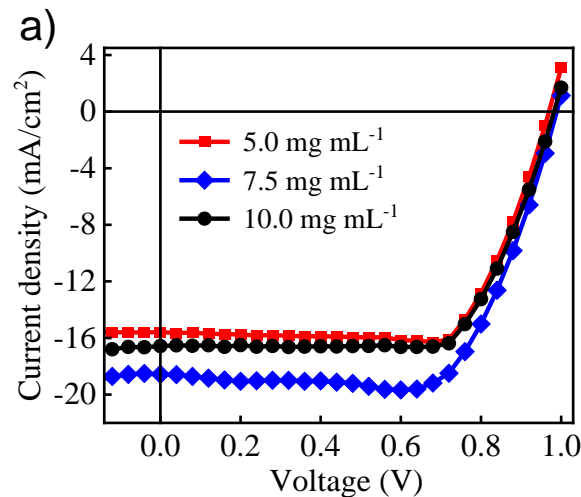


The transparency and thermal stability of CuSeCN films were examined by the deposition of thin film from an aqueous ammonia solution under ambient conditions. The structural, electrical, optical and morphological properties of CuSeCN film were characterized by X-ray diffraction, XPS, FT-IR, cyclic voltammetry, UV-Vis-NIR spectroscopy, and field emission scanning electron microscope, respectively.



(a) Transmission spectra of CuSeCN films on quartz plate after annealing at 100 °C for 10 min.  
 (b) TG and DTG curves of CuSeCN

Low-temperature CuSeCN-based inverted planar perovskite solar cells were fabricated with device architecture ITO/CuSeCN/CH<sub>3</sub>NH<sub>3</sub>PbI<sub>3</sub>/PC<sub>61</sub>BM/BCP/Ag. Further, to examine the effect of the thickness of HTL on device performance, three different concentrations of CuSeCN solution were used for thin film deposition in perovskite solar cells. Maximum power conversion efficiency (PCE) of 13.59 % has been achieved with 7.5 mg mL<sup>-1</sup> CuSeCN solution, as shown in the following figure

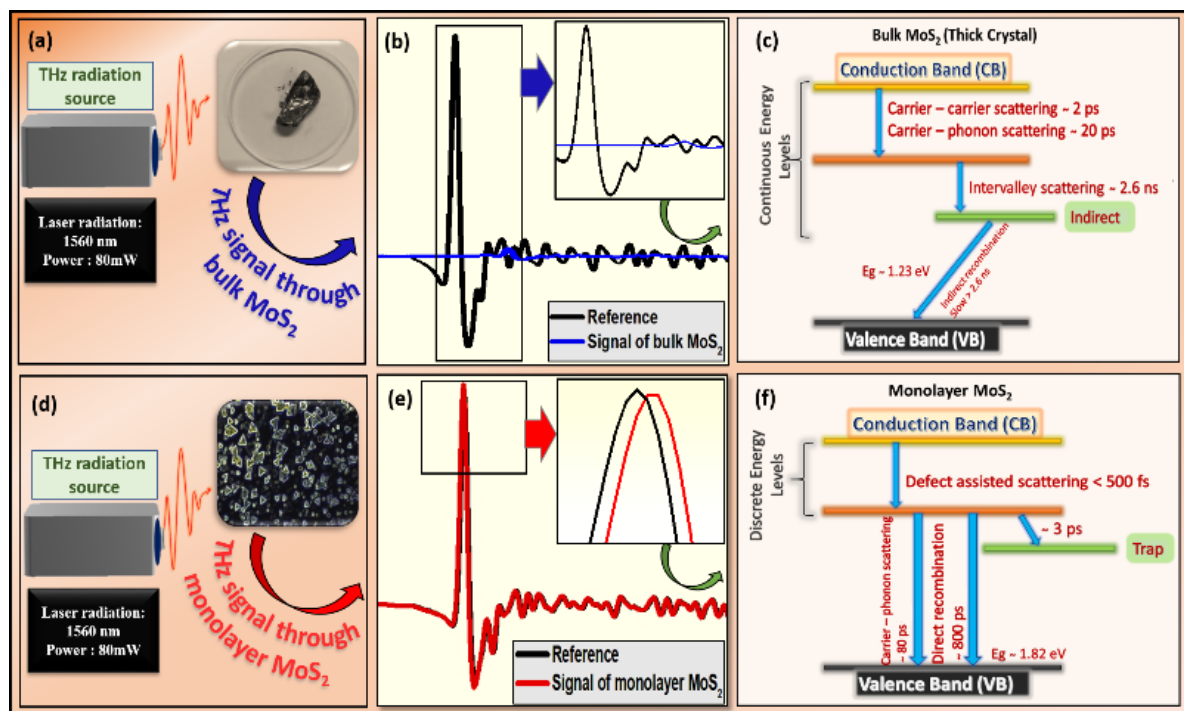


J-V characteristics of PSCs with different thicknesses of CuSeCN under one sun illumination; AM 1.5 G, 100 mW cm<sup>-2</sup>

## Photonic Materials Metrology

- **Probing into Potential Selectivity of Monolayer MoS<sub>2</sub> Quantum Materials for Futuristic Terahertz Applications and its Legitimate Comparison with Bulk MoS<sub>2</sub>**

The vision of modern society and artificial intelligence (AI) rely on higher data transmission rates. The introduction of an underutilized terahertz frequency band is essential for the deployment of sixth generation network connectivity in the coming modern era. In comparison to conventional materials, the newly emerging 2D materials show promising results for real-world applications. In this study, high-quality monolayer MoS<sub>2</sub> was synthesized using an indigenously developed APCVD setup at CSIR-NPL, New Delhi. Furthermore, a comparative plausible optoelectronic mechanism for monolayer MoS<sub>2</sub> as well as bulk MoS<sub>2</sub> has been proposed to explain the role of excitonic carrier dynamics of monolayer MoS<sub>2</sub> and its choice for terahertz application as compared to bulk MoS<sub>2</sub>. The obtained time-domain terahertz results of present studies set a stepping stone to employ the monolayer MoS<sub>2</sub> as potential quantum materials for emerging next generation terahertz communication devices.

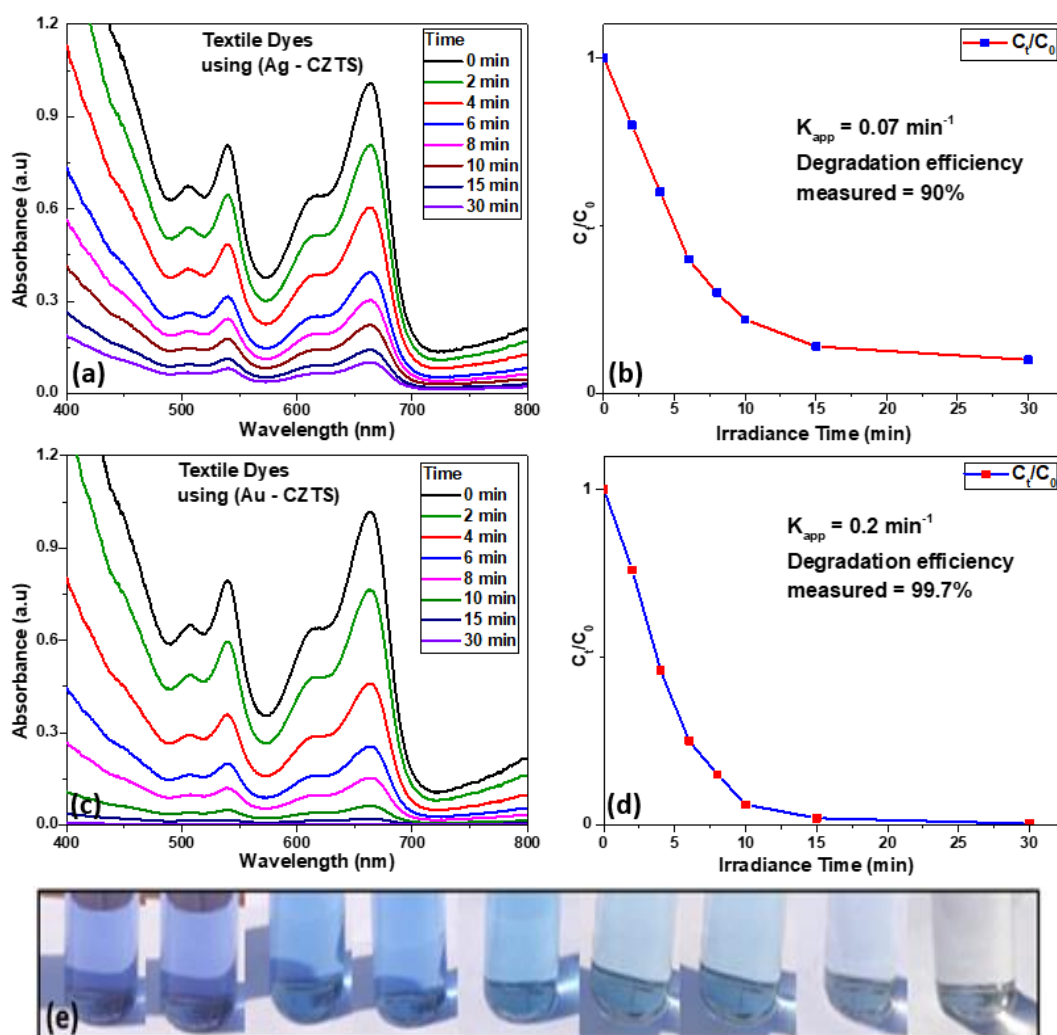


Schematic view of (a) THz signal incident on; (b) THz signal transmitted through; (c) energy level diagram of bulk MoS<sub>2</sub>; (d) THz signal incident on; (e) THz signal transmitted through; (f) energy level diagram of, monolayer MoS<sub>2</sub>.

- **Simple Colloidal Route Ex-situ Synthesis of Non-toxic Au/Ag-Cu<sub>2</sub>ZnSnS<sub>4</sub> (CZTS)**

Photocatalytic degradation of textile pollutants collected from industrial waste & heavy metal removal (Cr (VI) to Cr (III)) tested using Au/Ag-CZTS. The maximum efficiency achieved for textile pollutants is ~ 99.7% with Rate constant ~0.2 min<sup>-1</sup>, and the efficiency achieved for heavy metal reduction is ~70% with Rate constant ~ 0.004 min<sup>-1</sup>.

Technologically, this solution-based synthesis's main benefit is the ease of formation of the colloidal-ink for a scalable film formation on various compatible substrates (rigid/flexible) via the printing route for photovoltaics and photocatalysis application.



Photodegradation studies using UV absorption spectrum for (a) Textile dyes using Ag-CZTS and (b) its corresponding Concentration Vs. Time graph (c) Textile dyes using Au-CZTS and (d) its corresponding Concentration Vs. Time graph (e) Color degradation of Textile dyes

- **An Investigation of Antimicrobial Activity for Plant Pathogens by Green-Synthesized Silver Nanoparticles Using *Azadirachta indica* and *Mangifera indica***

It has been shown that green synthesis, which is essential for production of NPs, using *A. indica* and *M. indica* tree leaf extract is environmentally friendly and cost-effective, with natural capping and reducing agents. AgNPs synthesized from plant extract (*A. indica* and *M. indica*) possessed higher antioxidant activity in concentrations ranging from 50 to 500 mg/mL compared with standard ascorbic acid. The green-synthesized AgNPs showed good antimicrobial activity against plant pathogens. However, the *A*-AgNPs and *M*-AgNPs have not been compared together with *A. alternata*, *A. rolfsii* fungi and *X.*

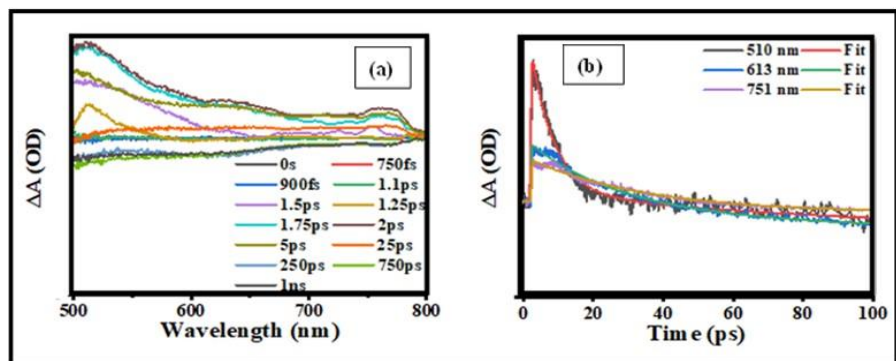
*Oryzae* bacteria. Due to variations in antioxidant and antibacterial levels, these plant extracts demonstrated varying zones of inhibition against microorganisms.



Workflow for green synthesis of nanoparticles using leaf extract

- **Ultrafast Transient Absorption Spectroscopic (UFTAS) and Antibacterial Efficacy Studies of Phytofabricated Silver Nanoparticles using *Ocimum Sanctum* Leaf Extract**

Ag nanoparticles synthesized using *Ocimum Sanctum* plant leaves extract; First-hand report of UFTAS-based studies on AgNPs in presence of Eugenol-*Ocimum Sanctum*; Antibacterial studies of AgNPs against *X. oryzae* bacteria conducted; Non-linear absorption observed in AgNPs through Z-scan open aperture. These highlights the benefits of biosynthesized AgNPs as it shows specific studies of nonlinear



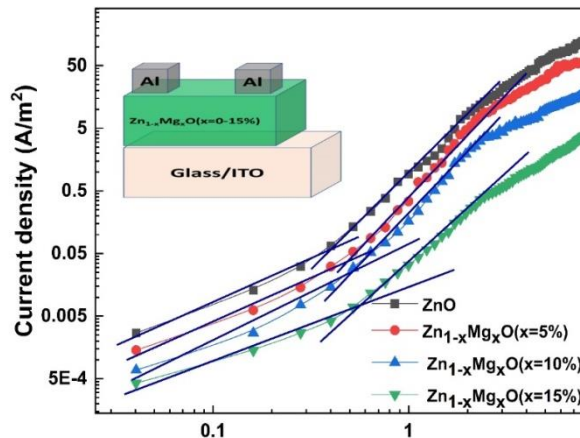
(a) Transient absorption spectra of colloidal AgNPs excitation at 420 nm wavelength is similar to the surface plasmon resonance for varying delay time 0 s to 3 ns. (b) Transient kinetic traces and their corresponding fitting recorded from global analysis at 510, 688 and 758 nm



and charge transfer dynamics, which is further related to antibacterial applications in nanomedicines.

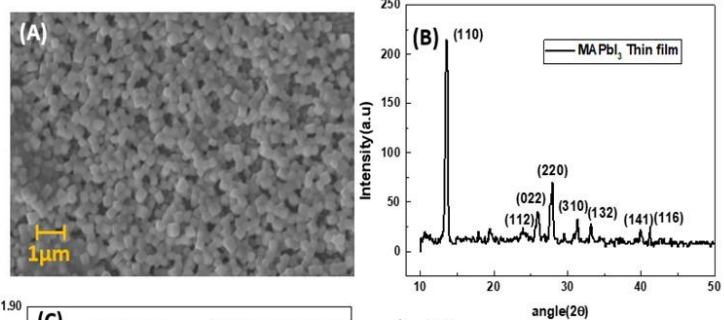
- **Solution-processed Mg-doped ZnO Electron Transport Layer (ETL) for MAPbI<sub>3</sub> Photodetector Application**

The solution-processed Mg-doped ZnO thin film was optimized for application in MAPbI<sub>3</sub> photodetector. The figure shows the current density versus voltage characteristics at different concentrations of Mg-doped thin film devices. The Inset of the figure shows the schematic diagram of the device. There are very clear two regions in the forward bias of the J-V characteristics. At the low bias region the J-V follows ohms law  $J \propto V$  whereas at the high bias region, it follows  $J \propto V^2$ . The conductivity and the trap density were calculated from the ohmic region. Conductivity and mobility both decrease with the increase of Mg loading in the ZnO thin film. There is a minor increase in the trap density with the Mg loading concentration. The ZnO and Mg-doped ZnO thin film was included in the MAPbI<sub>3</sub> photodetector device both devices.

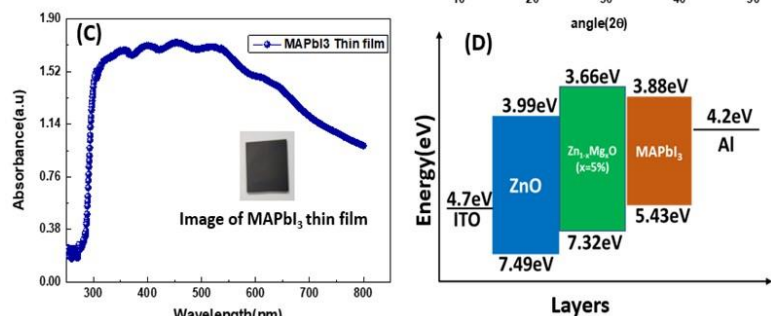


Current density-voltage (J-V) characteristics of the Mg doped ZnO thin film device, inset of the figure is the schematic device diagram with ITO and Al as electrode

Figure (a) shows the SEM images of MAPbI<sub>3</sub> thin films and figure (b) shows the XRD pattern of the MAPbI<sub>3</sub> thin film. All the diffraction planes are almost the same already reported. Hence the required thin film of MAPbI<sub>3</sub> was formed on the substrate.



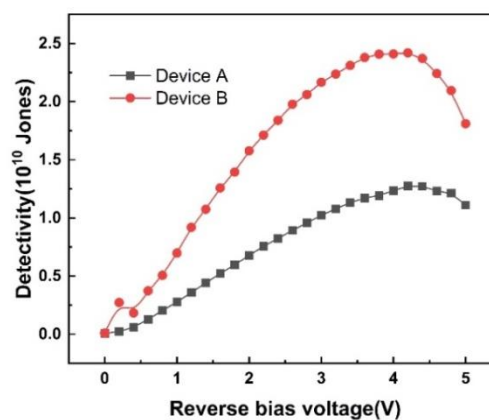
The distribution of grain size over the entire thin film is uniform and of almost equal size. Figure (c) shows the absorption spectra of MAPbI<sub>3</sub> thin film grown on the glass substrate. The strong absorption was observed from 300 nm to 550 nm and from 550 nm to 800 nm the absorption decreased. The Inset



(a) SEM images of MAPbI<sub>3</sub> thin films (b) The XRD pattern of the MAPbI<sub>3</sub> thin film. (c) The absorption spectra of MAPbI<sub>3</sub> thin film grown on the glass substrate. (d) The energy band levels of all the used thin films for photodiode fabrication

of figure (c) shows the image of MAPbI<sub>3</sub> thin film grown on the glass substrate. Figure (d) shows the energy band levels of all the used thin film for photodiode fabrication.

The specific detectivity for both Device A and Device B are shown in Figure. The specific detectivity increases with an applied bias for both the PDs device whereas for above ~4 V the specific detectivity starts decreasing. The specific detectivity for device A and device B upon white light illumination at bias voltage -3 V is  $1.24 \times 10^{10}$ , and  $2.4 \times 10^{10}$  Jones, respectively. The specific detectivity for device B is almost double in comparison to device A. The specific detectivity increases for blue and UV light in device B.



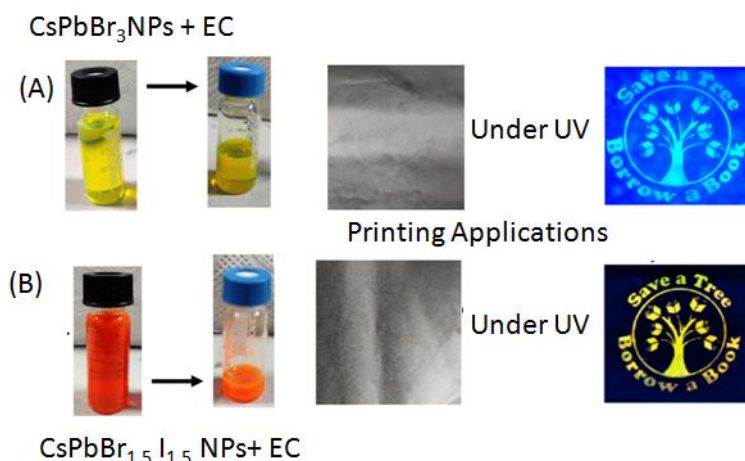
ETL) and device B (ZnMgO as ETL) under the Illumination of white light at different reverse bias voltages

- **Ethylcellulose Encapsulated Inorganic Lead Halide Perovskite Nanoparticles for Printing Applications**

Inorganic lead halide perovskite nanoparticles (NPs) have attracted attention for anti-counterfeiting applications. The fully-inorganic NPs get degraded in polar solvents resulting in poor stability. These also tend to degrade under exposure to high temperatures resulting in obstacles for application in reliable anti-counterfeiting applications.

The encapsulation of perovskite NPs with ethyl cellulose (EC) as a polymer matrix to overcome these obstacles,

using a facile solution blending technique followed by ultra-sonication and characterization was also explored. These NPs demonstrated enhanced photoluminescence intensity, improved color clarity, and considerable stability. Along with organic binders, they can be used in developing printable ink for making patterns. A logo coated with CsPbBr<sub>3</sub> + EC and CsPbBr<sub>1.5</sub> I<sub>1.5</sub> + EC exposed in normal light, and UV light (365 nm) showed a clear image that becomes blue-green and yellow color as shown in the figure.

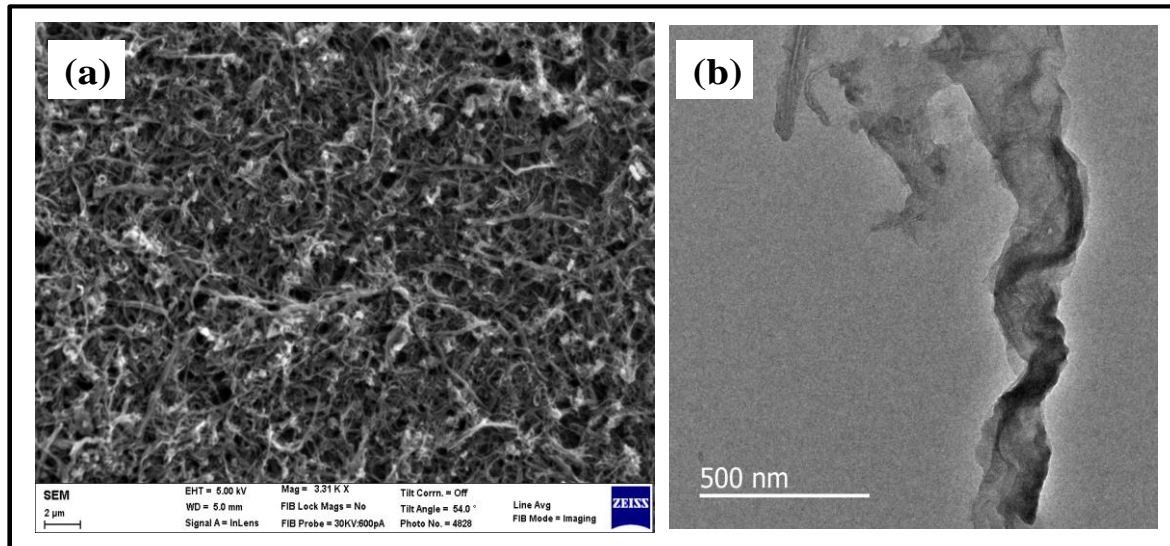


Perovskite nanoparticles, Photograph of the painted paper under ambient light, Trademark pattern of the save tree logo painted by security inks under UV light (A) CsPbBr<sub>3</sub> + EC and (B) CsPbBr<sub>1.5</sub> I<sub>1.5</sub> NPs+ EC

## Advanced Carbon Products and Metrology

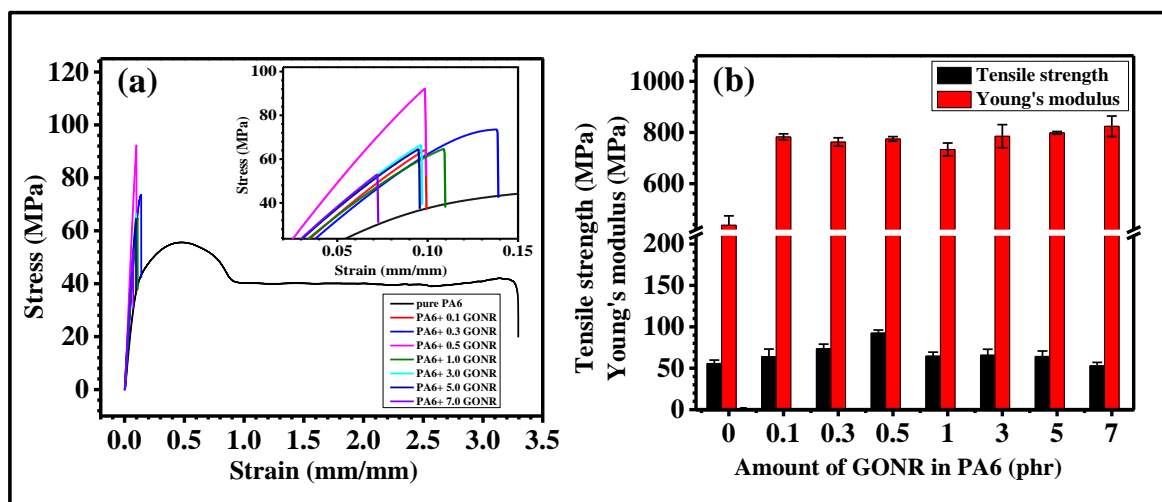
- **Graphene Oxide Nanoribbons (GONR) Reinforced Polyamide-6 Composites**

The oxidative unzipping of in-house prepared long-length MWCNTs resulted in long-length graphene oxide nanoribbon structures (Figure (a) & (b)) which exhibited very good reinforcing capability in polyamide-6 matrix at a significantly low loading.



(a) SEM, and (b) TEM of GONR in powder form

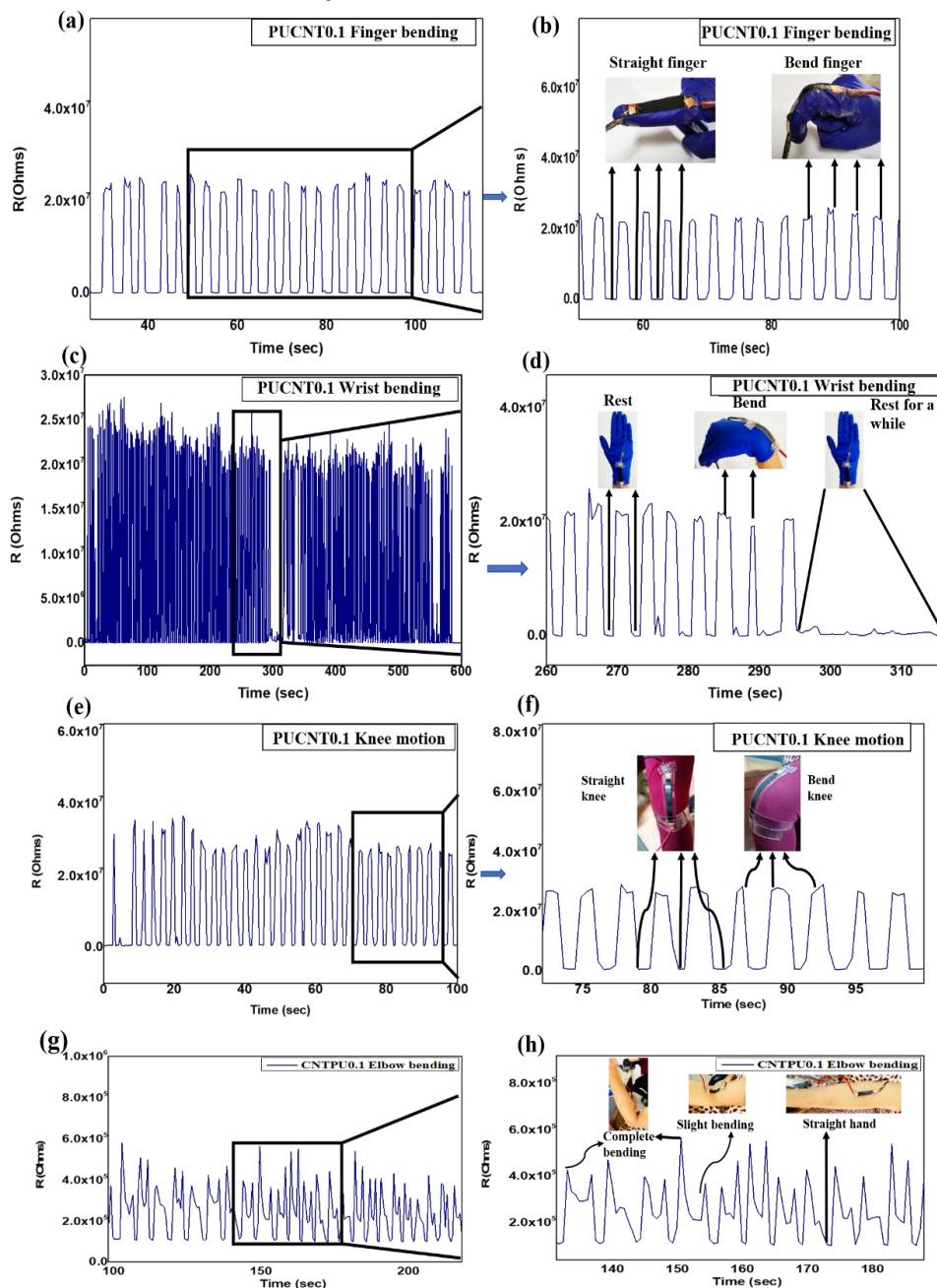
A maximum tensile strength of 92.53 MPa (66% improvement over neat PA6) was exhibited by 0.5 GONR/PA6 composite (Figure (a) & (b)). Moreover, the graphene nanoribbons possessed significant capability as structural reinforcements inside PA6 matrix promising their mechanical applications in different fields.



(a) Stress-strain curves for neat PA6 and varying GONR reinforced PA6 composites, (b) Tensile strength, Young's modulus, and tensile strain values for neat PA6 and GONR/PA6 composites.

- CNTs - Polyurethane Composites Based Strain Sensor for Human Motion Detection**

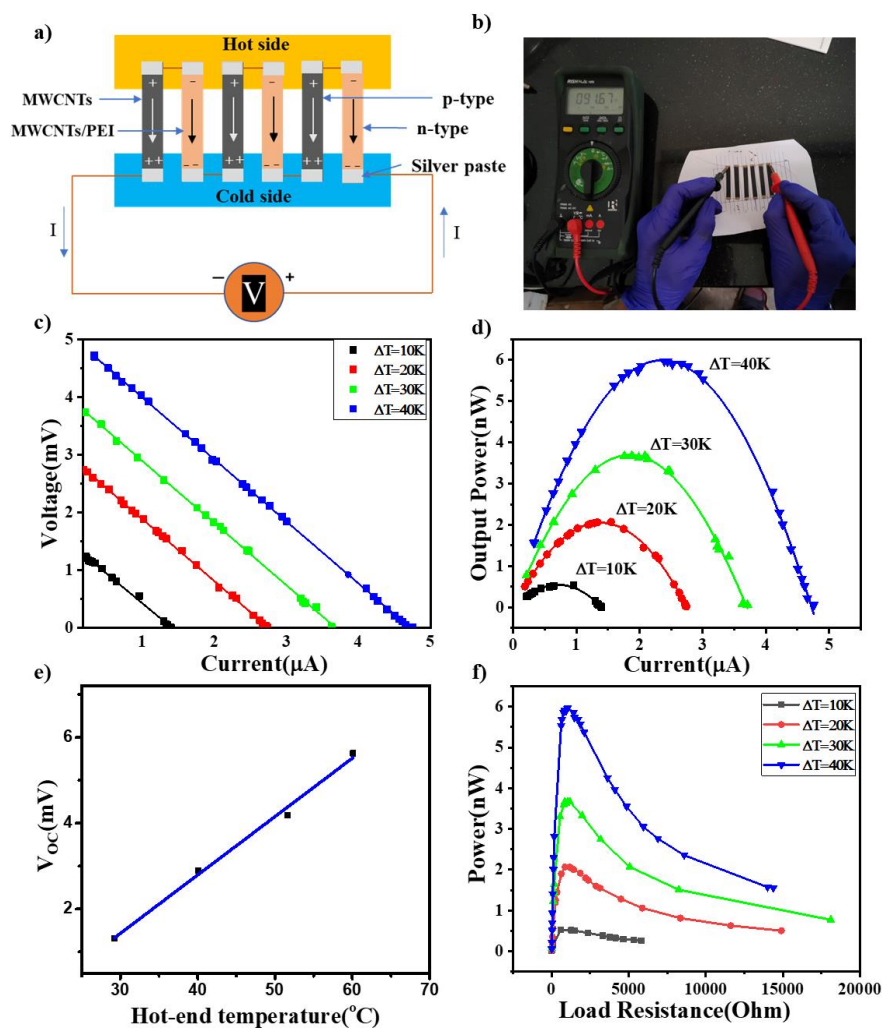
A strain sensor based on 0.1 wt% CNTs-polyurethane composites was developed and demonstrated excellent repeatability in various human motions such as finger bending, wrist motion, knee motion, and elbow motion. The CNT-PU composites can be scaled up to a large scale. Human motion detection is becoming increasingly important in the fields of health and sports, where precise postures and movements are critical for accurate movement and recovery.



Human motion detection: (a, b) Finger bending, (c, d) Wrist motion, (e, f) Knee motion, and (g, h) Elbow motion

- **Carbon Nanotube based Flexible Thermoelectric Materials**

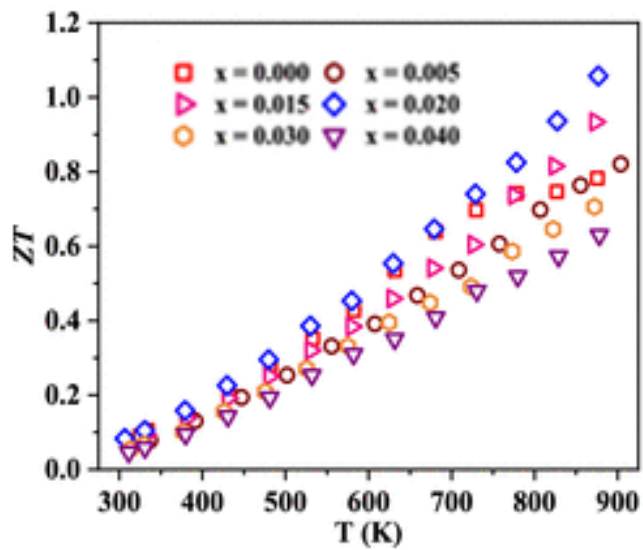
Multifunctional CNT papers/sheets have become desirable materials for flexible wearable thermoelectric devices because of their flexibility, excellent mechanical strength, light weighted and self-supporting nature. As synthesized p-type multiwalled carbon nanotube (MWCNT) paper is treated with polyethyleneimine (PEI) as n-type material to tune its thermoelectric properties. The device was fabricated by p- and n-type segments connected alternatively in electrical series and thermally parallel to get output power. The device's p- and n-type portions have nearly equal power factors of  $0.65$  and  $0.66 \text{ Wm}^{-1}\text{K}^{-2}$  and a Seebeck coefficient of  $12.7 \text{ VK}^{-1}$  with opposite polarity. Further, the thermoelectric device made of 3 p-n pair segments, experimentally observed output power was  $\sim 5.96 \text{ nW}$  at  $\Delta T = 40 \text{ K}$ . These composites-based devices show promising results for energy-harvesting applications and wearable electronic devices.



(a) The TEG module's schematic diagram, (b) 3p-n legs TEG, (c) Load voltage versus current for different  $\Delta T$  ( $\sim 10, 20, 30, 40^{\circ}\text{C}$ ), (d) Output power versus current for different  $\Delta T$  ( $\sim 10, 20, 30, 40^{\circ}\text{C}$ ) (e) Open circuit voltage versus hot-end temperature ( $^{\circ}\text{C}$ ). (f) Power vs load resistance

- Secondary Metallic Phases in Off-Stoichiometric ZrNiSn enhanced the Thermoelectric Performance**

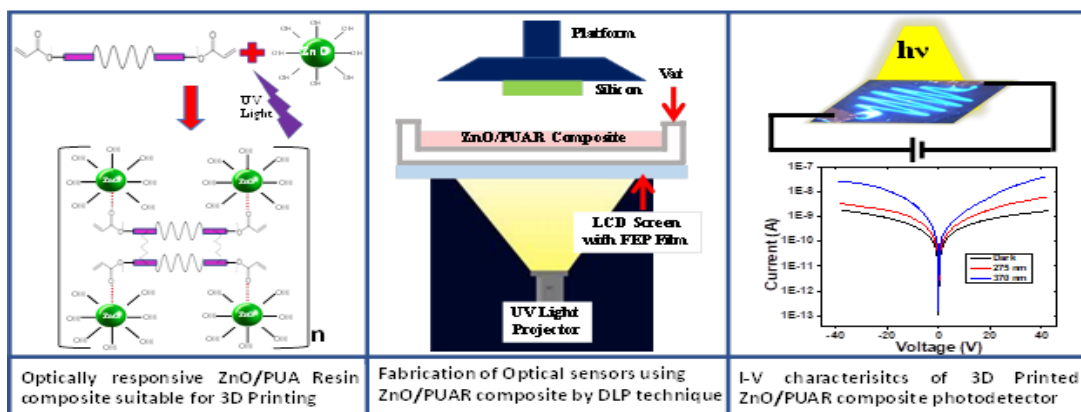
The effect of isoelectronic Ge-doping and excess Ni on the thermoelectric transport of ZrNiSn has been studied. The  $\text{ZrNi}_{1.04}\text{Sn}_{1-x}\text{Ge}_x$  ( $x = 0-0.04$ ) samples have been synthesized employing arc-melting and spark plasma sintering, and were extensively probed for microstructural analysis. It was found that ZrNiSn Half Heusler (HH) phase formed concurrently with the in situ growth of minor secondary phases, i.e., Full Heusler (FH),  $\text{Sn}_{3.5}\text{Zr}_5$ , and  $\text{Ni}_3\text{Sn}_4$ . These minor phases help to enhance the thermoelectric performance of the  $\text{ZrNi}_{1.04}\text{Sn}_{1-x}\text{Ge}_x$  ( $x = 0-0.04$ ) samples. A ZT of  $\sim 1.06$  at  $\sim 873$  K was attained for the composition  $\text{ZrNi}_{1.04}\text{Sn}_{0.98}\text{Ge}_{0.02}$ , which is among the highest for Hf-free ZrNiSn-based HH alloys.



Temperature dependent figure-of-merit (ZT) of  $\text{ZrNi}_{1.04}\text{Sn}_{1-x}\text{Ge}_x$

- 3D Printed ZnO-Polyurethane Acrylate Resin Composite for wide Spectral Photo Response Optical Detectors**

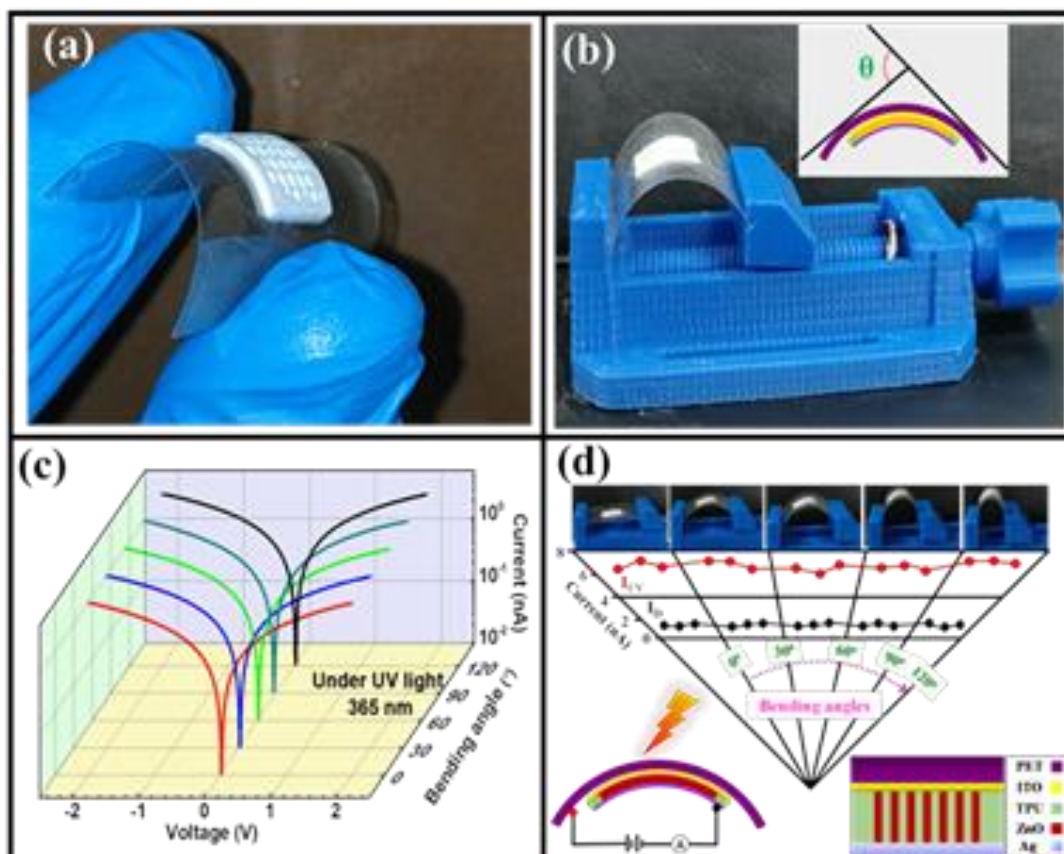
Digital light processing (DLP) 3D printing technique is used for fabrication of photodetectors based on ZnO/PUA resin composites. The detector characteristics are studied in detail for their photoresponse and spectral selectivity. UV-Vis absorbance spectroscopy is done for understanding the wide spectral photo response and band gap calculations. XRD and Raman spectroscopy is done to study the effect of ZnO reinforcement on composite in terms of binding, change in crystallinity, and effect on conductivity. PL spectra of both resin and composite are studied to understand the effect of ZnO loading in bringing out structural defects in PUA polymer chains. Also, the ease of customisation and high throughput possible with the employed 3D printing technique is emphasized for commercial applications.



(a) Optically responsive ZnO/PUA Resin composite suitable for 3 D Printing, (b) Fabrication of Optical sensors using ZnO/PUAR composite by DLP technique, (c) I-V characteristics of 3D Printed ZnO/PUAR composite photodetector

- **3D Printed Lattice Template by Material Extrusion Technique for Fabrication of Pixelated Photodetector**

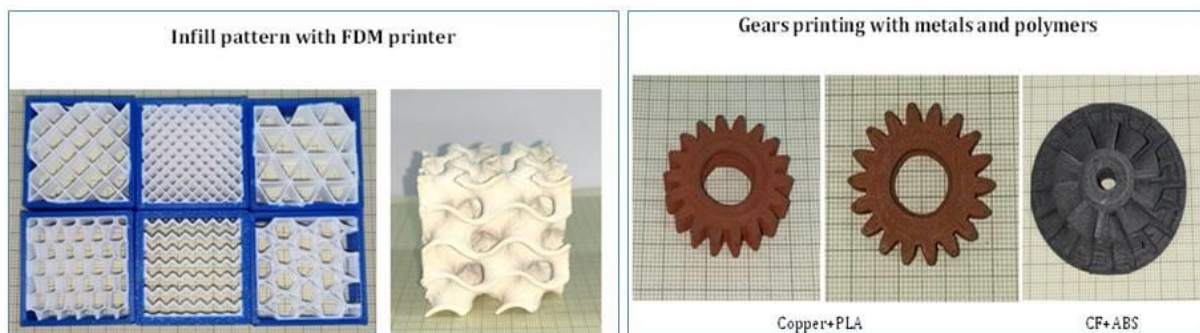
Rigid and flexible, pixelated ultraviolet (UV) photodetector (PD) based on ZnO have been fabricated by material extrusion 3D printing technique, and its photoresponse is studied in an out-of-plane configuration. The infill pattern of the 3D printing technique is exploited for making pixelated and high-resolution photodetectors possible with the FDM technique. These 3D-printed photodetectors are studied for their IV characteristics and time-dependent photoresponse. Different lattice structures are examined to get non-permeable columnar pores for micro vials and reservoirs. The charge-transport mechanism is studied using band diagram analysis of ITO/ZnO and ZnO/Al interfaces for the non-rectifying behavior of IV characteristics. The work has been extended to a flexible photodetector using ITO/PET as a flexible substrate and TPU for making a lattice structure. Furthermore, for commercial applications, the simplicity of the infill pattern for customization of photodetectors with high throughput possible with the FDM 3D printing process is emphasized.



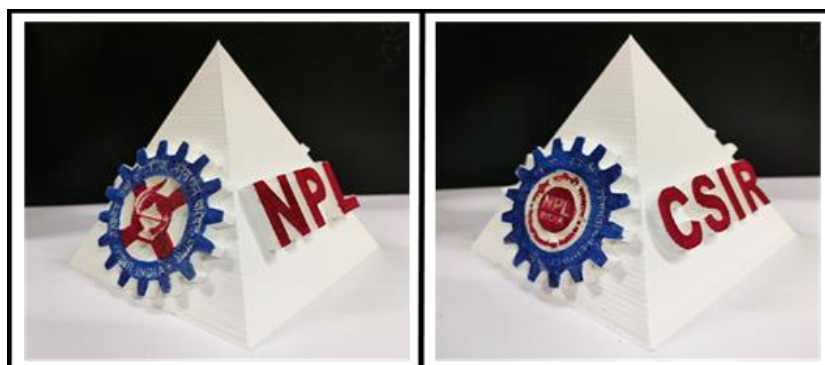
Measurement of ITO/PET flexible photodetector device **(a)** Picture of the device, **(b)** Schematic of bending angle of the device, **(c)** I–V curves of the flexible device for different bending angles with voltage range -2 to +2 V under UV illumination, **(d)** Current of the flexible device with different bending angles under dark and light illumination at a bias voltage of 2 V with bending cycles

- **A Souvenir Developed at CSIR-NPL: A Square Pyramid with CSIR and NPL Logos using FDM 3D Printer**

Additive Manufacturing (AM) is a freeform, direct digital, rapid and additive fabrication of prototypes, tools, patterns, and concept parts as well as functional devices for direct application and service as per ASTM F42 Technical Committee. CSIR-NPL being the NMI of India, can play a pivotal role in collaboration with public and private organizations for establishing all standards related to additive manufacturing and materials. It can provide an unbroken chain of measurements directly with primary standards for physico mechanical properties. It can also standardize AM feedstock for specific applications and component production for industrial acceptance at national and international levels. CSIR-NPL is also mandated to perform industrial research to identify existing standards, establish new standards, and recommend priority areas where there is a demand for standards and research development. CSIR-NPL has been working on additive manufacturing techniques like fused deposition modeling (FDM) for polymer and carbon composites and Vat Photo polymerization using resins. The facilities like FDM and Vat photopolymerization units have been established. An ASTM D638 Test sample by FDM for the standardization of mechanical properties by varying printing parameters and conditions has been generated. Some of the examples are illustrated in the following figure.



To demonstrate the state-of-the-art work done at CSIR-NPL by FDM technique, a souvenir is printed with CSIR and NPL logos and their abbreviations on a square pyramid which represents traceability to standards apex metrology.



A square pyramid with CSIR and NPL logo is printed using PLA polymer by fused deposition 3D printing (FDM) method

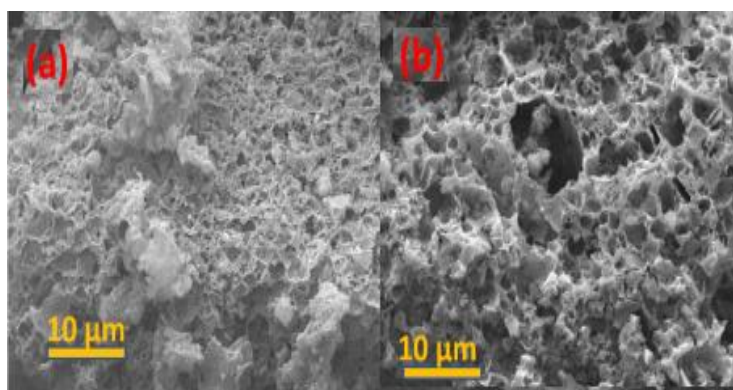


- **Pitch Based Carbon Fiber**

Pitch based carbon fibers are considered as excellent material for various sectors like sports, automotive industries, energy, defence, space, etc. due to high electrical and thermal conductivity along with high tensile strength, high modulus, high temperature tolerance and low thermal expansion. Therefore, research activities have been carried out to develop process technology for spinnable pitch precursor materials, i.e. isotropic coal tar pitch and mesophase pitch for making general purpose carbon fibers (GPCF) and high performance carbon fibers (HPCF), respectively. Then, developed pitch precursors were converted into pitch fibers by using laboratory scale, single hole and continuous melt-spinning set-up and extruder based continuous and multi-filament melt-spinning assembly. These pitch fibers were stabilization at suitable temperatures and carbonized at 1000°C to obtain carbon fibers. There are many steps involved in synthesis process so detailed work has been carried out on optimization of stabilization and carbonization processes to reduce the time and energy consumption without compromising the properties of fibers. Also, the process for making suitable spinnable grade mesophase pitch precursor with required anisotropic or mesophase content has been developed and converted into carbon fiber by varying different processing conditions which will be helpful to establish the facility for making pitch based carbon fibers.

- **Effect of Nitrogen and Sulphur Co-doping on the Surface and Diffusion Characteristics of Date Seed-derived Porous Carbon for Asymmetric Supercapacitors**

A facile transformation of waste date seeds into highly porous activated carbon (D-800) via simple one-pot hydrothermal carbonization followed by KOH activation route was carried out. The SEM is shown in figure (a). The resultant date seeds derived activated carbon was then co-doped with nitrogen



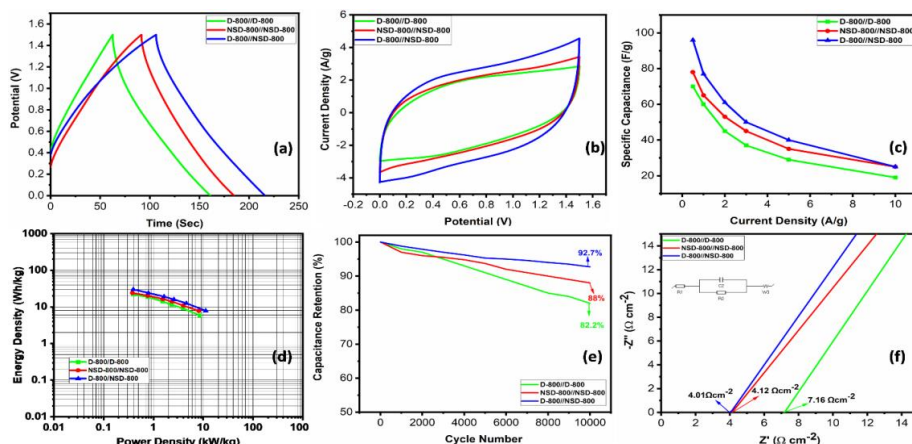
FESEM images of (a) D-800; (b) NSD-800

and sulfur (NSD-800) via effective binary heteroatom

doping method. This leads to an increase in the interconnected pores like framework in the resultant material, which facilitate significant ion storage and fast ion transport (Figure (b)). Heteroatom doping produces a faradaic contribution in addition to the EDLC (electric double layer capacitor) characteristics of the carbon which facilitates the faster diffusion process. Hence, NSD-800 demonstrate promising electrochemical performance achieving a high specific capacitance of 298.5 F/g at 0.5 A/g using 1M H<sub>2</sub>SO<sub>4</sub> electrolyte.

Furthermore, symmetrical and asymmetrical supercapacitor (SC) devices were fabricated using these electrode materials for comparison purpose. It is found that D-800//NSD-800 asymmetric SC device shows superior electrochemical performance as shown by the GCD and CV analysis and capacitance calculations as shown in the following figure (a), (b) & (c) respectively. It delivered an energy density of ~30 Wh/kg

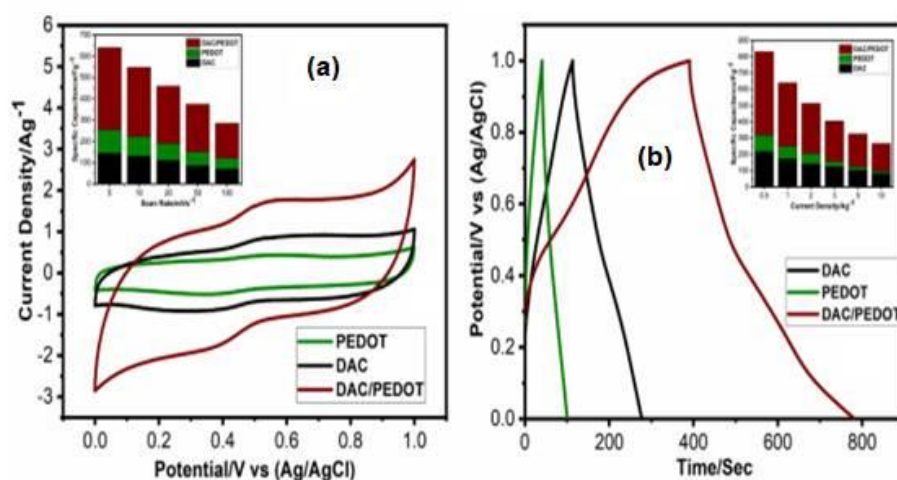
at a power density of 394 W/kg along with extraordinary cyclic stability of 92.7 % after 10000 charge-discharge cycles (Figure (d) & (e)). The EIS Nyquist plots in figure (f) shows the ESR to be nearly 4 ohm/cm<sup>2</sup>.



Comparison of electrochemical performance of symmetric (D-800//D-800 & NSD-800//NSD-800) and asymmetric (D-800//NSD-800) device: (a) GCD curve at 1 A/g, (b) CV curve at 50 mV/s, (c) variation of specific capacitance vs current density, (d) Ragone plot, (e) capacitance retention vs cycle number and (f) Nyquist plot (Inset showing equivalent circuit)

- **Development of Conductive and Porous Date Seed Derived Carbon/PEDOT Composite as Electrode Material**

Conducting polymers like PEDOT has shown convincing performance in super capacitor application, however their poor cyclic stability is a major concern. Coupling conducting polymers with carbon frameworks is seem to be an effective way to mitigate this concern. In this study, binary composite of date seed derived activated carbon (DAC) with poly (3,4-ethylenedioxythiophene) (PEDOT) was synthesized via in-situ chemical oxidation polymerization. CV and GCD of DAC, PEDOT, DAC/PEDOT are shown in the figure with the trends of specific capacitance in the inset. DAC/PEDOT composite electrode shows exception electrochemical performance rendering very high specific capacitance of 512.5 F/g at 0.5 A/g (as calculated by the GCD curve). Further studies are underway to fabricate the device there from.

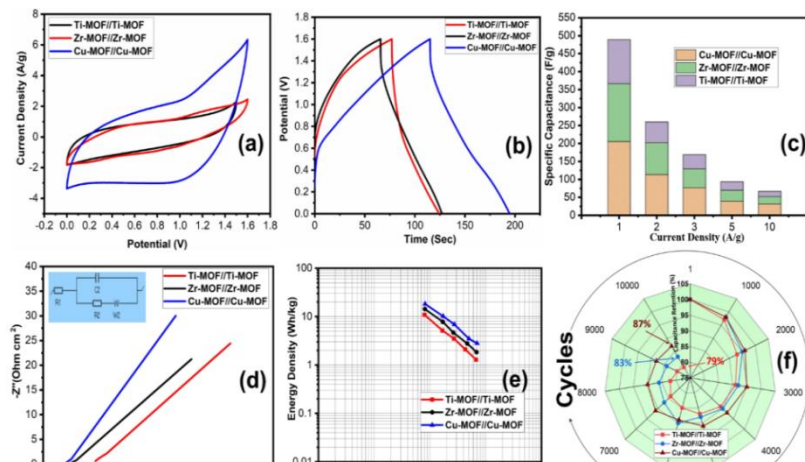


(a) CV and (b) GCD of DAC, PEDOT, DAC/PEDOT; with the trends of specific capacitance (inset)

- Development of Metal-organic Frameworks (MOFs) using Waste PET Bottles and its Application as a Supercapacitor Electrode**

Plastic wastes were transformed into benzene dicarboxylic acid (BDC) through the process of alkaline hydrolysis. The BDC linker so produced was made to react with respective metal salts to produce Cu-MOF, Zr-MOF, and Ti-MOF. The preparation of MOFs was further confirmed using various physio-chemical characterizations.

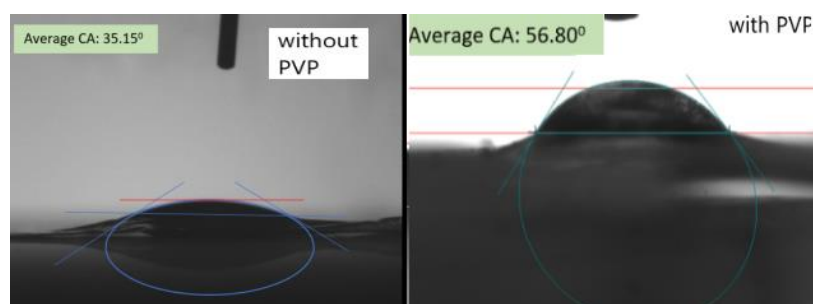
Due to their large surface area and high porosity, MOFs have a significant advantage as supercapacitor electrode material. The MOFs (Cu-MOF, Zr-MOF, and Ti-MOF) produced from plastic wastes (PET bottles) were tested electrochemically in 1M H<sub>2</sub>SO<sub>4</sub> electrolyte using three-electrode setup. Amongst them, Cu-MOF showed higher capacitance (104.8 F/g at 0.5 A/g) and increased diffusion contribution (78.4 %) than its counterparts Zr-MOF (70.5 F/g at 0.5 A/g; 70.4 %) and Ti-MOF (55.5 F/g at 0.5 A/g; 67.5 %). Further, solid-state symmetrical supercapacitor devices have been assembled using all the plastic wastes derived MOFs viz. Cu-MOF//Cu-MOF, Zr-MOF//Zr-MOF, and Ti-MOF//Ti-MOF. The CV, GCD and specific capacitance and ESR of the devices are compared in figure (a), (b), (c) and (d) resp. Among them, Cu-MOF//Cu-MOF symmetric supercapacitor device performed better than the others by rendering energy density of 18.2 Wh/kg at 825 W/kg power density along with a cyclic stability of 87% after 10000 charge-discharge cycles (figure (e) & (f)). These studies open new avenues to utilize waste PET bottles to synthesize high functional MOFs for next generation supercapacitors.



Electrochemical performance comparison of the as assembled solid-state supercapacitor device: (a) CV at 50 mV/s; (b) GCD at 1 A/g; (c) Trends of specific capacitance vs current density; (d) Nyquist plot; (e) Ragone plot; and (f) Cyclic stability

- Improved Hydrophobicity of Biodegradable Calcium Alginate Films for Packaging Applications**

The serious issues posed by the plastic films have motivated the development of calcium alginate (CA) films as a prospective material for packaging purpose. The films were prepared by crosslinking sodium alginate with calcium



Contact angle for the CA films without and with PVP additive

chloride. The polyvinyl pyrrolidone (PVP) has been used as an additive for improved hydrophobicity. Samples were prepared by adding different amounts of PVP, and it was found that PVP-CA film shows better tensile strength (TS) with increasing PVP concentration from 5 % (TS 21 MPa) to 20 % (TS 30 MPa). The synthesized PVP-CA film also found to have remarkable hydrophobicity (contact angle 56°) as compared to that prepared without PVP as shown in the following figure. The biological degradation time of the film (in compost) was nearly 288 hours.

# Bharatiya Nirdeshak Dravya (BND®)

A brief detail of activities performed is described below:

## (A) In-house BND Group

A total of more than 1725 samples were characterized for different groups of CSIR-NPL by using FESEM and EDS techniques. During this period, 11 samples were tested for industry, 8 test reports were prepared and issued to the CFCT section (for using FESEM).

During this period 9 samples were also received and characterized in Outreach program using SEM and EDS. The division welcomes more such external samples for analysis using different modes of characterization available with us.

### • New BND Developed under the In-House BND Program

“Silicon powder BND” (BND® 2024) has been successfully developed at CSIR-NPL under In-House BND Program and released on January 4, 2023. It is intended to be used as a primary standard for line position and line shape calibration for powder X-ray diffraction.



## (B) Chemical & Food BND Section

Release of Elemental standard solution Indian Reference Material (Bharatiya Nirdeshak Dravya, BND®) for Drinking Water

- Indian reference materials is a Certified Reference Material- trademarked and got registered by CSIR-NPL as Bhartiya Nirdeshak Dravya (BND®) for self-reliance and disseminates to support the testing and calibration laboratories for quality assurance at par with the international standards. CSIR-NPL supports the RMPs for the development BNDs to disseminate traceability.
- Bhartiya Nirdeshak Dravya (BND®) of Elemental standard solution of Antimony, BND® 1036, Boron, BND® 1037, Magnesium, BND® 1038 and pH 10 Buffer standard solution, BND®1042, have been developed by RMP Aashvi Technology LLP (ATL), Ahmadabad, Gujarat in collaboration with CSIR-NPL, New Delhi. CSIR-NPL has supported to provide Traceability and ascertaining the property value. These BNDs have been vastly used for the Drinking Water Sector and intended to be used as a primary calibration standard for the quantitative determination of the concern elements, calibration of instruments and validation of method for the quantification/characterization of the measurand.

### **(C) Registration of BNDs with RMPs**

**Registration of New BNDs and successive batches of BNDs with RMPs: (GRAND TOTAL: 76 BNDs):** Following NEW BNDs/successive batches of BNDs were registered during 1<sup>st</sup> April 2022-31<sup>st</sup> March 2023:

➤ **RMP ATL, Ahmedabad:**

BND 1005 (10B), BND 1006 (10B), BND 1007 (7B), BND 1008 (6B), BND 1016 (3B), BND 1017 (3B), BND 1018 (3B), BND 1023 (3B), BND 1024 (4B), BND 1007 (8B), BND 1009 (5B), BND 1021 (5B), BND 1021 (6B), BND 1022 (5B), BND 1029 (5B), BND 1039 (1B), BND 1040 (1B), BND 1005 (11B), BND 1006 (11B), BND 1011 (2B), BND 1012 (2B), BND 1030 (2B), BND 1021 (7B), BND 1021 (8B), BND 1023 (4B), BND 1041 (1B), BND 1042 (1B), BND 1003 (3B), BND 1018 (4B), BND 1019 (4B), BND 1014 (2B), BND 1017 (4B), BND 1020 (2B), BND 1024 (5B), BND 1025 (2B), BND 1015 (3B), BND 1005 (12B), BND 1005 (13B), BND 1006 (12B), BND 1006 (13B), BND 1010 (3B), BND 1013 (3B), BND 1043 (1B), BND 1044 (1B), BND 1027 (2B), BND 1032 (2B)

**(Total: 46 BNDs)**

➤ **RMP GPTP, New Delhi:**

- BND 2206 (1B), BND 2207 (1B), BND 2203 (1B), BND 2208 (1B), BND 2209 (1B), BND 2210 (1B), BND 2211 (1B), BND 2212 (1B), BND 2213 (1B), BND 2214 (1B), BND 2205 (1B), BND 2215 (1B), BND 2216 (1B), BND 2217 (1B), BND 2218 (1B), BND 2219 (1B), BND 2220 (1B), BND 2221 (1B), BND 2222 (1B)

**(Total: 19 NEW BNDs)**

➤ **RMP Jalan & Co., New Delhi:**

- BND 4201A (2B), BND 4202 (2B)

**(Total: 2 BNDs)**

➤ **RMP NCCBM, Ballabgarh:**

- BND 5091 (2B), BND 5051 (2B), BND 5007 (2B), BND 5001 (3B), BND 5004 (2B)

**(TOTAL: 5 BNDs)**

➤ **RMP Pharmaffiliates Analytics & Synthetics Pvt Ltd, Panchkula:**

- BND 9002 (1B), BND 9003 (1B), BND 9004 (1B), BND 9005 (1B)

**(Total: 4 NEW BNDs)**

# Indian Standard Time Division

---

Indian Standard Time Division is responsible for the realization, establishment, custody, maintenance, dissemination and upgradation of the national standards for **Time & Frequency, LF & HF Voltage, Current, Microwave and Magnetic parameters**.

The Time & Frequency Metrology Section is responsible for the highest level of time and frequency measurements in India using ultraprecise satellite links. As one of the mandates, **CSIR-NPL maintains the Indian Standard Time (IST)** based on atomic timescale consisting of bank of Cesium (Cs) atomic clocks, Hydrogen masers, precision measurement devices and ultraprecise satellite links. The traceability of CSIR-NPL timescale generating IST with respect to coordinated Universal Time (UTC) maintained by BIPM is at the level of few nano-seconds (ns). Dissemination of IST via satellite links and network is provided to users as per time synchronization accuracy requirements. Calibration services are provided for atomic clocks, oscillators, stop watches etc. to strategic and industry users as per requirement. In addition, research and development on primary atomic clocks is carried out. India's first Cs fountain clock, with an accuracy of a few parts in  $10^{-15}$ , became operational in 2011 and is being improvised for better stability. A second Cs Fountain is under development. Recently, development of a more accurate clock ( $\approx 10^{-17}$ ) at optical wavelengths based on a single trapped Ytterbium ion (project STIOS) has been initiated.

LF & HF Voltage, Current and Microwave Metrology section maintains LF & HF Voltage, Current, Microwave Power and Phasor Measurement Unit (PMU) parameters of electrical metrology. To maintain the international traceability, a number of international & bilateral intercomparisons under the umbrella of BIPM and APMP have been carried out. At CSIR-NPL, PMU-CAL system traceable to its national standards carries out a comprehensive calibration and testing of PMU as per IS/IEC/IEEE 60255-118-1:2018 standard. It plays a vital role in power distribution sector through the PMU calibration and measurement system.

Electromagnetic (EM) Metrology section comprises of various measurement facilities in frequency range from 1 Hz to 110 GHz of electromagnetic spectrum for devices from household electronic appliances to advanced strategic communication and instrumentation. The section maintains and disseminates various parameters such as attenuation, impedance, insertion loss, microwave power, E-Field and specific absorption rate (SAR), Shielding effectiveness, and dielectric measurements along with advanced Quantum E-Field measurements traceable to Planck Constant, Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel.

## Time & Frequency Metrology Section

- **Development of National Time Scale generating Indian Standard Time**

The "time" is defined in the SI unit as: "One second is the time required for 9192631770 oscillations between doubly split hyperfine ground states of Caesium atoms ( $^{133}\text{Cs}$ )". CSIR-NPL is maintaining "time" with an accuracy of few ns using the ensemble of five Cs

atomic clocks, and four H-Masers with uninterrupted power supply. The “time” at CSIR-NPL is inter-compared with international time scale, UTC, using precise time transfer satellite links. Each and every modern technology being used in area of mobile and internet services, navigation, space technologies, Industry 4.0, cyber security, power and energy, defence, banking, railway, health, weather forecast, and disaster management is getting benefited by the advances in development and dissemination of Indian Standard Time by CSIR-National Physical Laboratory. CSIR-NPL is the Time Keeper of the Nation. CSIR-NPL contributes to generation of International Time Scale, UTC, by International Bureau of Weights and Measurers (BIPM) located in France. CSIR-NPL provides IST to ISRO via satellite links.

Government through the Indian Computer Emergency Response Team (CERT-In) has issued a Directive No. 20(3)/2022-CERT-In dated: 28 April, 2022 to all telecom and internet service providers to synchronize their ICT infrastructure to the NTP servers of CSIR-NPL. Directive requires all service providers, data centres, and Government organisations shall connect to the Network Time Protocol (NTP) Server of National Physical Laboratory (NPL) for synchronisation of all their ICT systems clocks. CSIR-NPL has established stack of NTP servers for the national timing service as per the government directive.

CSIR-NPL undertook the work under the National Mission Project to disseminate Indian Standard Time (IST) through secondary timing ensembles at RRSL Ahmedabad, Bangalore, Bhubaneswar, Faridabad and Guwahati. CSIR-NPL has also undertaken development of Disaster Recovery Center for IST in Bangalore to provide redundancy in generation of Indian Standard Time (IST). CSIR-NPL has setup the internet based NTP service at NIC. CSIR-NPL has indigenously developed the technology of Rubidium Atomic Clock and transferred it to ISRO for Indian NavIC satellites. CSIR-NPL established underground time transfer link utilizing telecommunication dark fibres of Airtel. Total length of the optical fibre is  $\sim 22\text{kM}$  and time has been transferred within an uncertainty of less than 500 picosecond.

CSIR-NPL has started working on redefinition of SI second by doing R&D on an optical clock based on an ultra-narrow transition of a single Ytterbium ion ( $^{171}\text{Yb}^+$ ) confined and laser-cooled within a Radio Frequency (RF) ion Trap.

- **Realization and Maintenance of IST**

CSIR-NPL has a “Primary Timescale” generating UTC(NPLI), which is traceable to the Coordinated Universal Time (UTC) provided by International Bureau of Weights and Measurers (BIPM) located in Sevres, France. UTC(NPLI) is the realization of UTC at NPLI. The IST (i.e., UTC(NPLI) plus 5:30 hours), generated using a bank of caesium clocks and hydrogen masers, has current systematic uncertainty of approx.  $\pm 3$  nanoseconds with respect to UTC. The timescale system generating IST consists of five caesium clocks, one passive hydrogen maser, two active hydrogen maser, measurement system and an international satellite links for clock comparison and traceability link. The caesium clocks provide absolute atomic reference of the time which has exceptional long-term stability, whereas the hydrogen maser has ultimate short-term stability. UTC(NPLI) is realized as the steered output of an Active Hydrogen Maser (AHM). However, the timescale ensemble has five high performance Caesium clocks as well. All Cs clock



output frequencies and steered output from microphase stepper are connected to an automatic switching unit which enables time-based switching of measurement of a pair of clocks through a frequency/phase comparator or a time interval counter.

- **Time Transfer using GNSS (Global Navigation Satellite System)**

The common-view clock signal is a vehicle used to transfer time from one site to another. The time signal embedded in a GNSS signal is the most commonly used source of the common-view clock because of its comprehensive visibility, ease of reception with good signal-to-noise ratio, and insensitivity to propagation effects. CVGNSS time transfer is a one-way method, the signal emitted by a satellite and received by specific equipment installed in a laboratory. Accurate time synchronization ( $\sim 10$  ns) can easily be achieved after estimating all associated systematic uncertainties by the CVGNSS method. Dual-frequency receivers remove the ionospheric delay and improve the time transfer accuracy. Such data is known as GPS P3, which allows clock comparisons with less than a nanosecond statistical uncertainty. CSIR-NPL has multiple dual-frequency GNSS receivers. Recently, two new GNSS timing receivers have been installed and have been calibrated using the travelling GNSS calibrator from Group-1 laboratory, i.e., NICT, Japan, and the internal delays were calculated with respect to NICT G1. With these efforts, the traceability link to UTC was calibrated, and the associated systematic uncertainty improved to  $\pm 2.8$  ns with effect from October 2018. The traceability of IST to UTC is maintained using the CVGNSS method. Additionally, ISRO is provided with traceability to IST using the CVGNSS method as well.

- **Time Transfer using TWSTFT (Two Way Satellite Time and Frequency Transfer)**

TWSTFT is based on exchange of timing signals through a Geostationary (Geo-sat) telecommunication satellite. TWSTFT is potentially one of the most accurate methods for comparing the timescales located geographically under the footprint of that Geo-sat used. With this method, frequencies can be compared with an uncertainty of  $10^{-15}$  @ 1day averaging time, and time scale differences can be compared at the ns level. The high accuracy is obtained by users simultaneously exchanging signals via a Geo-Sat, which will cancel out the delays as the path between the time scales is symmetric.



Outdoor portion of two VSAT's of 2.4m diameter dish antenna each at NPLI. Left one is being used for international link and the right one is used for domestic link

The conventional setup of TWSTFT requires a modem to generate pseudo random noise (PRN) as the time transfer signal, a VSAT (Very Small Aperture Terminal) which generally consists of dish antenna of 1.8 m to 3.6 m, power amplifier, a low noise amplifier and 2.5 MHz band width of satellite transponder for Ku band link.

CSIR-NPL presently has two TWSTFT station links: 1. **TWSTFT link with ISTRAC-ISRO**: To provide UTC time traceability to IRNSS (Indian Regional Navigation Satellite System) CSIR-NPL has a TWSTFT station link with ISTRAC-Bangalore and ISTRAC-Lucknow. The link is operational since 2018 using the GSAT-8 satellite. **TWSTFT link with UTC**: To have a TWSTFT link with PTB Germany which is the pivot of the UTC, an International TWSTFT station is also set up at CSIR-NPL. This setup is upgraded recently and is in the process of establishing the link with 7 International NMIs, including PTB, via Express-80Geo-sat

- **Time Transfer over the Internet (NTP Service)**

NTP is an internet standard protocol that uses a reliable time source, i.e., UTC (NPLI), as a reference for precise synchronization of servers and network devices. NTP servers follow a hierarchy with Stratum 0 as the “Primary Reference Clock” located at the NMIs of the country and can go up to Stratum 15. A primary server (referred to as a stratum 1) is a server that receives a UTC signal directly from an authoritative clock source, e.g., an atomic clock or a GPS signal source. A stratum 2 server receives its time signal from a stratum 1 server, a stratum 3 server from stratum 2 servers, and so on. Clients peer with servers to synchronize their internal clocks to the NTP time signal. The latest version of NTP (NTPv4.0) can maintain time with an uncertainty of less than 50 ms on WAN. However, the absolute level of uncertainty in NTP depends on network conditions. NTP is a highly scalable and fault-tolerant protocol that automatically selects the best of several available time servers. The latest 4th version of NTP comes with several security features, including protection from Kiss of death attacks, supports symmetric and asymmetric cryptographic authentication, panic is disallowed after first clock update upon synchronization, clock discipline algorithm that improves uncertainty, handling of network jitter, and polling intervals, support for the nano kernel implementation that provides nanosecond precision, fast synchronization at startup and after network failures, automatic server discovery etc. Considering the crucial role of time synchronization in cyber security of the nation, the Indian Computer Emergency Response Team (CERT-In) has issued a directive to all service providers, intermediaries, data centers, body corporates, and government organizations to synchronize their ICT infrastructure to any of the NTP servers of the National Informatics Centre (NIC), National Physical Laboratory (NPL), or accurate and standard time sources other than NPL and NIC. Multiple stacks of NTP servers are available at NPL for time dissemination in the public domain with the domain name “time.nplindia.org”. Many customers get benefitted from the NTP services of NPL.

- **Development and Deployment of FonOclock LED IST Displays at CSIR-NPL Reception and Guest House**

Successful deployment of two new LED IST time displays was done at reception of CSIR-NPL Main building and CSIR-NPL Guest House. These displays synchronize to IST within few milliseconds regularly via telephone line. With these two new displays, five Fonoclock based IST synchronized LED time displays within the CSIR-NPL campus are continuously managed.



FonOclock LED screens displaying Indian Standard Time (IST) installed at CSIR-NPL Guest House (left) and at CSIR-NPL Main Reception (right)

## LF & HF Voltage, Current and Microwave Metrology Section

- **Low Frequency Voltage & Low Frequency Current Metrology**

Banks of Multi-Junction thermal converters (MJTC) are used for assigning AC DC transfer difference to the primary standard (MJTC) at 2 Volt and 5mA with the best uncertainty of  $\pm 5$ ppm. Therefore, the thermal transfer standard or thermal converters are designed to cover voltage range of 1mV volts to 1000 volts in the frequency range 10 Hz to 1 MHz with an uncertainty of  $\pm (7$  to 1000) ppm and current range of 1mA to 20 A in the frequency range of 40 Hz to 10 kHz with an uncertainty of  $\pm (10$  to 92) ppm.



- **High Frequency Voltage Metrology**

High frequency (HF) voltage primary standard at NPLI has been realized using a twin resistance coaxial power mount in the frequency range of 1 MHz to 1000 MHz. The rf/dc transfer difference has been assigned at the input reference plane of the primary standard.



The overall uncertainty in assigning RF DC transfer difference has

been estimated to be within  $\pm 0.50\%$  in the frequency range up to 1 GHz. With the establishment of the RF voltage primary standard, one can calibrate and assign the RF DC transfer difference to the transfer standard thermal voltage converters. HF Voltage standard is used to calibrate the RF Voltage meters, high frequency thermal converters using the well-established technique.

- **Microwave Power Metrology**

Coaxial Microcalorimeter system in 2.4mm connector, established as the primary standard of Microwave Power in the frequency range of 1 MHz to 50 GHz is an absolute method based on thermocouple principle for the determination of effective efficiency to the thermocouple sensor. This section provides **apex level calibration services** in microwave power parameter to the industry & user organizations of the country. In order to meet the growing demand for calibration of microwave equipments in this era of continuously growing technology, CSIR-NPL disseminates the traceability of microwave power from 1MHz up to 50 GHz. The absolute value of the effective efficiency has been assigned to the microwave power standard from 1 MHz to 50 GHz using coaxial microcalorimeter and Vector network analyzer. The expanded uncertainty of microwave power primary standard at 50 GHz is  $\pm 1.9\%$ .



- **Phasor Measurement Unit Calibration Metrology**

Today's smart grid relies on phasor measurement units (PMUs) to deliver real-time critical data on the voltage, current, frequency and phase mainly within the power grid. It is mandatory that PMUs must be calibrated from a traceable calibrator system to ensure its consistency, accuracy and reliability. The CSIR-NPL Phasor Measurement Unit Calibration



System (PMU-CAL) is capable of providing perfect solutions for PMU users, manufacturers, electrical power utilities and organizations associated with electrical power transmission. The automated PMU-CAL system fully complies with the IEC/IEEE 60255-118-1:2018 standard. The compliance testing of Phasor Measurement Unit (PMU) from 50V to 150V and 1A to 5A at 50 Hz with a frame rate of 10, 25 and 50 frame/seconds has become possible with the establishment of PMU-CAL system serving the nation through power sector. The CSIR-NPL PMU calibration system has an uncertainty of  $\pm 0.005\%$  to  $\pm 0.010\%$  and generates a wide variety of complex signals, including flicker, harmonics. This feature gives us flexibility to calibrate PMUs by different manufacturers.

### **Electromagnetic Metrology Section**

'Electromagnetic' spectrum is a term used for referring to electromagnetic radiation, for frequency range from 1 Hz to 1020 Hz, which can further be classified into two parts, non-ionizing (one Kilometre to 100 nm) and ionizing (100 nm and up to 1 Å) [1], based on the energy EM wave carry at a particular frequency. Electromagnetic metrology at CSIR-NPL has calibration and measurement capabilities for 1 Hz to 1011 Hz of electromagnetic spectrum. These calibration and measurement capabilities cater to almost all sectors of electrical and electronics industries as well as other interdisciplinary industries such as the automobile sector, biomedical devices, industrial RF heating instrumentation, and many more. Electromagnetic metrological services at apex level in the country cover parts of EM spectrum having day to day interaction in human life. The non-ionizing EM spectrum (1 Hz to 110 GHz) covers area of services from household appliances to advance communication system, defence to strategic sector, electrical and electronics to automobile industry, aviation to naval dockyard, advance material characterization to biological liquids and magnetic fields to electric field generation and measurement as per their broad applications. The Microwave and Magnetic based National Standards and measurement capabilities are realized, established, maintained, and upgraded at CSIR-NPL. These standards are disseminated to reference laboratories across India to provide traceability to various sectors: strategic, defence, manufacturers, testing industries, government regulators and research institutions. Electromagnetic metrology at CSIR-NPL has a unique combination of comprehensive capabilities of various parameters of Electromagnetics such as attenuation, microwave power, E-Field and specific absorption rate (SAR), Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, along with various free space measurements parameters. Upcoming 5G technology is not just a routine technological change but a platform to enable several smart technologies such as smart banking, smart city, smart village, smart healthcare smart automobile and many more. This shows the overall impact of Electromagnetic metrology on country's upcoming technological needs.

Microwave metrology includes parameters such as attenuation, impedance, insertion loss followed by free space microwave measurements such as Electric Filed, SAR, Shielding effectiveness, dielectric measurements along with advanced Quantum E-Field measurements traceable to Plank Constant. Each parameter have their associated primary standards, their calibration and measurement capabilities (CMCs) and their degree of equivalence with the leading NMIs of the world, and associated on-going research for advanced measurements including quantum standards.

Magnetic metrology deals with maintaining and upgrading National Standard related to magnetic parameter like Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, through continuous development. Calibration and testing facility are provided for these parameters to industries and institutions as per ISO/IEC: 17025 guidelines which are traceable internationally. Traceability is maintained and disseminated by means of Calibration of permanent Magnet, Calibration of AC/DC Gaussmeter, Calibration of Magnetic field indicator, Calibration of low field magnetometer, Calibration of Helmholtz Coil, Calibration of Flux meter, Calibration of Turn area of search coil, Testing of AC/DC electromagnet, Power loss measurement of Electrical Steel, Magnetic Radiation Measurement, etc.

In addition to calibration and testing services, training, human resource development and technical consultancy are also being provided.

- **Microwave Metrology**

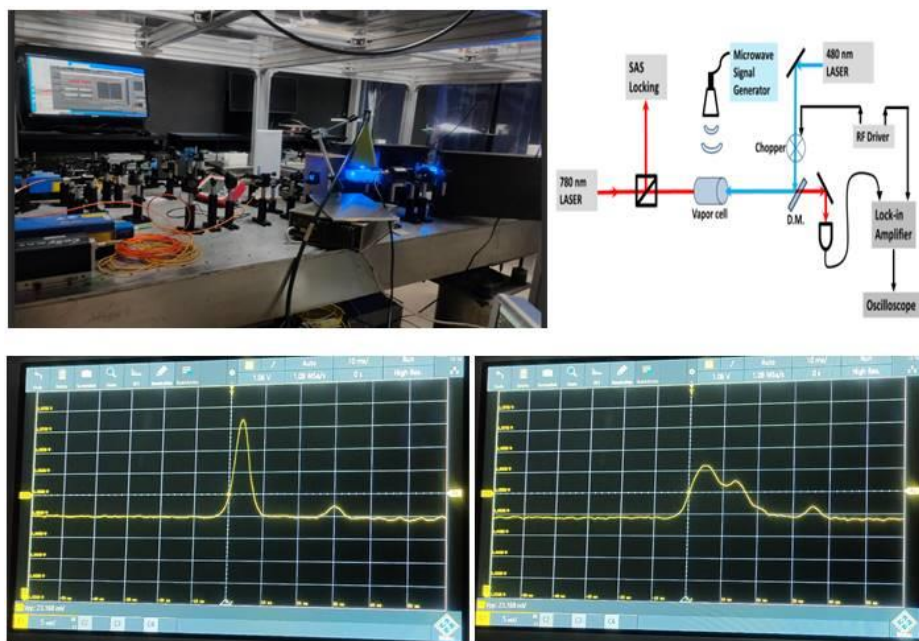
Microwave Metrology at CSIR-NPL exhibits an international degree of equivalence for various measurement parameters such as Microwave Power, Attenuation, Impedance, E-Field, Shielding Effectiveness, Radiated power density, Specific Absorption Rate in the frequency range from 9 kHz to 50 GHz with fifteen registered CMC's and seven international inter-comparisons. Microwave Metrology also engages in Dielectric Material characterization ( $\epsilon$  and  $\sigma$ ) for Lossy Liquids and biological materials by using commercial open ended Dielectric probe, along with VNA (ZNB 8), for frequencies up to 6 GHz as recommended in IEEE-1528 2013 standard. However, the IEEE-1528:2013 standard, is now superseded by the new IEEE/IEC-62209 1528: 2020 standard, which has made few advancements to measurement methods and standards used. The traceability is being established by using multiple reference liquids measured at standard temperatures and inter-comparison. Also, upgradation for this measurement facility for higher frequencies up to 10 GHz to incorporate upcoming 5G frequencies in underway as well.

Electromagnetic metrology section has already completed a technology transfer for “process-know how for Tissue Equivalent liquids as per IEEE-1528 standard” on Sept 24, 2020 and will extend the scope of this by preparation or standard TELs for upcoming 5G frequencies. These TELs are being prepared as per by the new IEEE/IEC-62209 1528: 2020 standard, which require different chemicals from the ones used for previous studies. Also, for BND purpose, the properties of TELs are being measured and recorded at various temperatures in range 10°C to 50°C along with shelf-life study, stability and temperature tolerance studies to be carried out.

CSIR-NPL has partnered with EURAMET consortium for development of calibration methods for probe calibration of time domain probes and arrays for vector SAR measurement systems. These probes measure simultaneous amplitude and phase at much faster rate than the existing SAR measurement systems/probes. In this work, CSIR-NPL plans to establish its own vector SAR assessment facility and provide traceability to vector SAR measurement in the country by allowing technology transfer to different organizations. A Specific Absorption Rate (SAR) evaluation system has been indigenously developed at CSIR-NPL. In this setup E-Field Sensor, Tissue equivalent liquid, Robotic automation (Robotic arm procured from epon) and a controlled GUI

have been indigenously developed. The system is capable to evaluate SAR upto 3W/kg with an expanded uncertainty of  $\pm 0.15\text{W/kg}$  per 1.6W/kg.

Recently, International Bureau of Weights and Measures (BIPM) has decided to redefine all the basic SI units in terms of the physical constants which describe the natural world. The atom-based standards have been accepted worldwide for measurement of time, frequency, gravity, magnetometry, and length. To date, the RF E-field sensing and calibration techniques does not have traceability to physical constants and have complex traceability path. The dependency on the materials under use, limitation of bandwidth of antennae under use, the surrounding parameters at the time of measurement, and the incorrect evaluation of uncertainties are some of the limitations of current techniques which makes measurable quantity vulnerable to the errors. These measurements will help in establishing the quantum communication and quantum sensing calibration facilities at CSIR–NPL for upcoming smart communication devices.



Experimental setup for RF E-field strength measurement using Rydberg atom-based quantum sensor

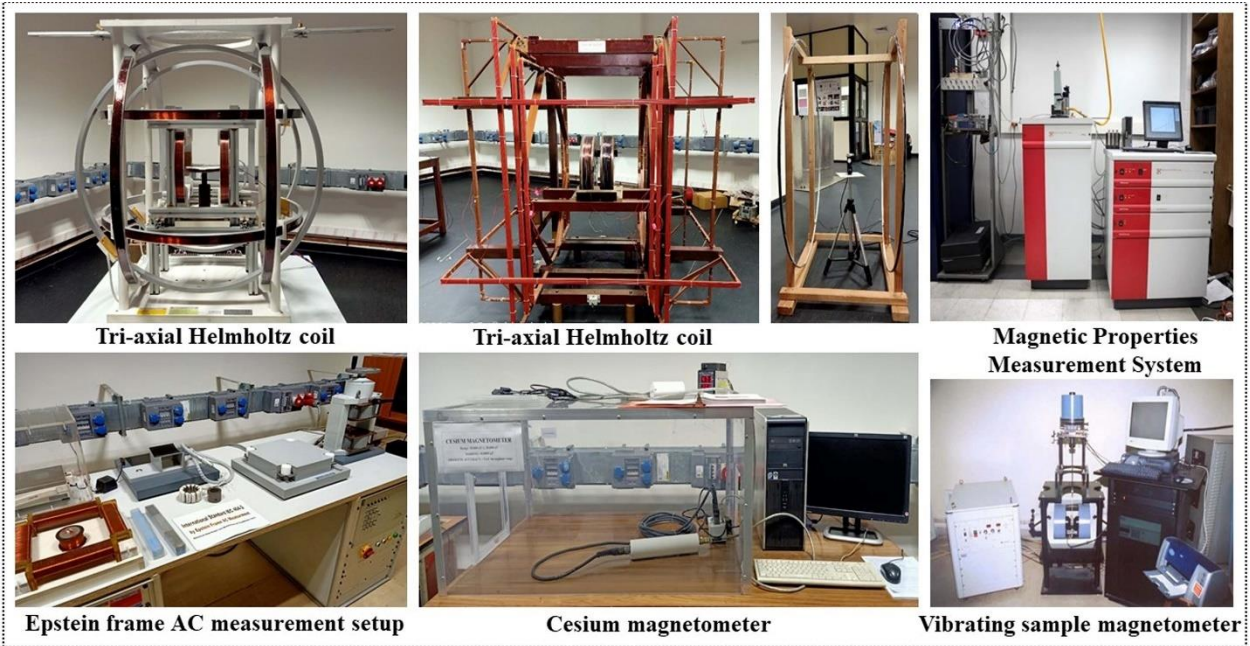
Experimental setup for atom-based E-field sensing is shown in the above figure. The cylindrical cell placed at top of white platforms act as an antenna. At specific conditions mentioned in the absorption profile of probe beam splits in two peaks giving a transparent window at centre of absorption which is known as EIT (Electromagnetically Induced Transparency). The Radio-frequency creates additional interferences resulting in increase in difference between the two split peaks, known as ATS in EIT regime. This behaviour of absorption profile is utilized in RF E-field strength measurement. As the power of incident microwave increases, the split between the two peaks increases.

### Magnetic Metrology Section

This section has significant role in maintaining and upgrading National Standard related to the magnetic parameters such as Magnetic flux Density, Magnetic flux, turn area of search coil, power loss measurement of electrical steel, through continuous development and providing calibration/test services (as per ISO/IEC: 17025 guidelines)

to more than 100 customers (MSME sectors, Large scale industries, Govt. organizations and R&D institutes like Indian Air Force, Air India, Power Grid, CPRI, IDEMI, ERTL, ETDC, ABB, Siemens, Samsung, GE Healthcare, L&T, Adani power, Genus Power, Secure Meters etc.) to improve the quality infrastructure of India.

The section is also responsible for R&D activities regarding magnetic device development and promoting metrological activities.



**Tri-axial Helmholtz coil**

**Tri-axial Helmholtz coil**

**Magnetic Properties Measurement System**

**Epstein frame AC measurement setup**

**Cesium magnetometer**

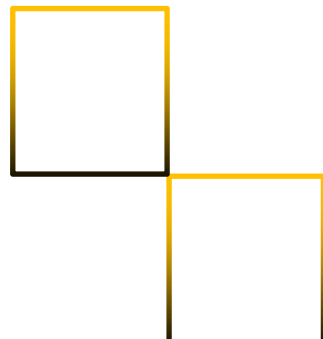
**Vibrating sample magnetometer**





**ANNUAL  
REPORT  
2022-23**

**Directorate**



## Directorate

---

This division encompasses Planning, Monitoring Evaluation and Outreach; Industrial Liaison Group; Centre for Calibration & Testing; Workshop; International Science and Technology Affairs Group; Human Resource Development Group; Administration; Quality Management System; Rajbhasha Unit; Knowledge Resource Centre; Finance & Accounts Store; Purchase Section; Works & Services.

### **Planning, Monitoring Evaluation and Outreach**

CSIR-NPL undertakes projects sponsored by various external agencies such as the Ministry of Science & Technology, MNRE, DST, etc. The department is involved in the planning, monitoring and evaluation of the various types of GAP, FTT, FCP, HCP, SSP, CLP & Mission Mode projects. The details of External Cash Flow i.e., money received from these agencies to carry out specified project is regularly recorded and monitored by PME against the target established by the Institute. Registration of all projects and allotment of specific identity in terms of a Project No. is made at PME, soon after the money for the project is received, along with in-principle approval. Projects are registered in different modes viz FTT, mission mode, Sponsored research, Grant-in-Aid, Collaborative and CNP. The total number of projects registered in different modes during 2022-23 is 45. In the year 2022-23, four new GAP projects have started worth Rs. 1.41 Crores, while one new CSIR Funded project has taken off, costing Rs.15.60 Lakh. A grant of Rs. 1.07 Crores in the seventeen continuing GAP projects was received.

Apart from this, PME also attends to technical queries, Parliament Questions, and technical audit, as well as assists Director in liaising with CSIR-HQ, Management Council (MC) and Research Council (RC) on project related matters. In 2022-23, PME has successfully conducted 02 Research Council, and 20 Scientific/Project Review Meetings. PME has processed 1014 indents worth Rs. 79.70 Crores.

### **Business Development Group (BDG)**

The Business Development Group (BDG) serves as an interface between CSIR-NPL and Government/Public/Private Organizations/Industries/Universities, etc. BDG facilitates the utilization of the CSIR-NPL knowledgebase by licensing the technologies/know-how to the Industries and other stakeholders. BDG plays an active role in showcasing technologies and know-how developed by CSIR-NPL to the stakeholders on various platforms including the CSIR-NPL website. BDG also facilitates consultancy, technical, and research services to the clients in time-bound project mode for utilization of expertise available within CSIR-NPL regarding the development of new products/processes and improvement of the Quality System in the country. Apart from this, BDG also processes the registration of the new Bharatiya Nirdeshak Dravya (BNDs) along with the handling of traceability and dissemination charges. One of the important roles of BDG includes the execution and signing of MoUs/Agreements/NDAs with the clients (Indian Industries, Institutes, Research Organizations, Reference Material Producers (RMPs), etc) for the purpose. In addition, BDG is highly involved in managing S&T outputs, including the

generation of various reports to be sent to various stakeholders including CSIR-Head Quarters.

The details of the technology/know-how licensed, MoUs/agreements signed, projects undertaken, registration of new BNDs and traceability and dissemination charges received during this period are as follows:

### Technical Services Projects (TSP)

Sl No	Project Title	Client	Project cost (Rs) (including GST)
1	On-Site Metrological Characterization of Vibration Machine	Phoenix Contact (India) Pvt. Ltd, A-58/2 Okhla Industrial Area, Phase-II, New Delhi-110020	3,54,000/-
2	Sound Transmission Loss and Sound Absorption Coefficient Testing of the Dry Type Acoustic partition panels	M/s Sound Works, Nirmala Toilet, 2nd Floor, No. 14, 4th Cross Road, Wilson Garden, Bengaluru, Bengaluru Urban, Karnataka-560027	4,72,000/-
3	To measure the electromagnetic field near geopathic & non-geopathic stress lines (To be identified by client within NPL premises)	M/s Syenergy Environics Limited, Time Square Building, 3rd Floor, B Block, Sushant Lok Phase-1, Gurugram-122002, Haryana	2,36,000/-
4	On-site Performance Evaluation of Semi Anechoic Chamber as per ISO 3745 Standard	M/s Envirotech Systems Limited, 346 347, Ecotech 1 Extension, Kasna, Gautam Buddha Nagar, Uttar Pradesh-201308	3,54,000/-

### Sponsored R&D (SSP)

Sl No	Project Title	Client	Project cost (Rs) (including GST)
1	Development of Mono-/Bi-invisible Fluorescent Pigments and visible/invisible fluorescent Security Threads/Fibres for Anti-counterfeiting Technology	Aron Universal Limited, 25/1, 2nd Phase, Jigani Industrial Area, Jigani, Bangalore (South), Karnataka-560105	5,16,84,000/-

**Registration Charges for Bharatiya Nirdeshak Dravya (BND) from Reference Material Producers (RMPs)**

Sl No.	Client	Project Title	Money received (Rs) (including GST)
1	M/s Jalan and Company, C-16, Lajpat Nagar-II, New Delhi, Delhi-110024	Registration charges for BND 4203, BND 4204, BND 4205, BND 4206, BND 4207, BND 4208, BND 4209, BND 4103, BND 4104, BND 4105, BND 4106, BND 4107 and BND 4108	1,53,400/-
2	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1005 (10th Batch), BND 1006 (10th Batch), BND 1007 (7th Batch), BND 1008 (6th Batch), BND 1016 (3rd Batch), BND 1017 (3rd Batch), BND 1018 (3rd Batch), BND 1023 (3rd Batch), BND 1024 (4th Batch)	1,06,200/-
3	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1007 (8th Batch), BND 1009 (5th Batch), BND 1021 (5th Batch), BND 1021 (6th batch), BND 1022 (5th batch), BND 1029 (5th Batch)	70,800/-
4	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5091 (2nd Batch)	11,800/-
5	Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1039 and BND 1040 (Both New BNDs)	23,600/-
6	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1005 (11th Batch), BND 1006 (11th Batch), BND 1011 (2nd Batch), BND 1012 (2nd Batch) and BND 1030 (2nd Batch)	59,000/-
7	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1021 (7th Batch), BND 1021 (8th Batch) and BND 1023 (4th Batch)	35,400/-
8	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5051 (2nd Batch)	11,800/-
9	M/s Aashvi	Registration charges for BND 1041	23,600/-

	Technology LLP, Ahmedabad, Gujarat-380004	(NEW BND) and BND 1042 (NEW BND)	
10	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5001 (3rd Batch) and BND 5004 (2nd Batch)	23,600/-
11	National Council for Cement and Building Materials (NCB), Ballabgarh, Faridabad, Haryana 121004	Registration charges for BND 5007 (2nd Batch)	11,800/-
12	Global PT Provider Pvt. Ltd., New Delhi, Delhi- 110020, India	i) Registration charges for 10 new BNDs: BND 2206, BND 2207, BND 2208, BND 2209, BND 2210, BND 2211, BND 2212, BND 2213, BND 2214 & BND 2215 (All New BND's)  ii) Registration charges for 7 new BNDs: BND 2216, BND 2217, BND 2218, BND 2219, BND 2220, BND 2221, & BND 2222 (All New BND's)	2,00,600/-
13	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration of successive batches of three existing BNDs for BND 1003 (3rd Batch), BND 1018 (4th Batch) and BND 1019 (4th Batch)	35,400/-
14	M/s Jalan and Company, C-16, Lajpat Nagar-II, New Delhi, Delhi- 110024	Registration charges for BND 4201A (2nd Batch) and BND 4202 (2nd Batch)	23,600/-
15	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration of successive batches of five existing BNDs for BND 1014 (2nd Batch), BND 1017 (4th Batch), BND 1020 (2nd Batch), BND 1024 (5th Batch) and BND 1025 (2nd Batch)	59,000/-
16	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	Registration charges for BND 1015 (3rd Batch), BND 1005 (12th Batch), BND 1005 (13th Batch), BND 1006 (12th Batch), BND 1006 (13th Batch), BND 1010 (3rd Batch) and BND 1013 (3rd Batch)	82,600/-
17	Pharmaffiliates Analytics & Synthetics Pvt Ltd.,	Registration charges for BND 9002 (New BND), BND 9003 (New BND), BND 9004 (New BND) & BND 9005	47,200/-

	Panchkula, Haryana 134109, India	(New BND)	
18	M/s Aashvi Technology LLP, Ahmedabad, Gujarat-380004	i) Registration charges for BND1043 (New BND) and BND 1044 (New BND) ii) Registration charges for BND1027 (2nd Batch) and BND 1032 (2nd Batch)	i) 23,600/- ii)23,600/-

**Traceability and Dissemination Charges for Bharatiya Nirdeshak Dravya (BND) from Reference Material Producers (RMPs)**

Sl No.	Client	Project Title	Money received (Rs) (including GST)
1	SUMS Techno Labs Private Ltd, Ballari (Bellary), Karnataka-583201	Traceability & Dissemination charges received from stock sale of 2 Bhartiya Nirdeshak Dravyas (BND) from 31-March-2021 to 31-March-2022	1,180/-
2	Global PT Provider Pvt. Ltd., Okhla Industrial Area, Phase-I, New Delhi, Delhi-110020	Traceability & Dissemination charges received from stock sale of 2 Bhartiya Nirdeshak Dravyas (BND) from 01-April-2021 to 31-March-2022	4,419/-
3	National Council for Cement and Building Materials, Delhi-Mathura Road (NH-2), Ballabgarh, 121004 Haryana	Traceability & Dissemination charges received from stock sale of Bhartiya Nirdeshak Dravyas (BND) from 17-Dec-2021 to 31-Mar-2022	4,30,760/-
4	National Council for Cement and Building Materials, Delhi-Mathura Road (NH-2), Ballabgarh, 121004 Haryana	Traceability & Dissemination charges received from stock sale of Bhartiya Nirdeshak Dravyas (BND) from 01-Apr-2021 to 16-Dec-2021	5,55,545/-
5	M/s Aashvi Technology LLP, Shahibag, Ahmedabad, Gujarat-380004, India	Traceability & Dissemination charges received from stock sale of Bhartiya Nirdeshak Dravyas (BND) from 01/04/2021 to 30/11/2021	8,50,780/-
6	M/s Aashvi Technology LLP, Shahibag, Ahmedabad, Gujarat-380004, India	Traceability & Dissemination charges received from stock sale of Bhartiya Nirdeshak Dravyas (BND) from 01/12/2021 to 31/03/2022	6,87,704/-

### Licensing of Technology/Know-How

Sl. No.	Name of the technology/Know-how	Name of the client	Date of licensing
1	Know-how titled "Ultrasonic Pulse Velocity Tester Device with Threshold Error Correction", Lumpsum : Rs 5.88 Lakh including GST; Non-Exclusive; Duration: 5 years	M/s SRK Instruments, Prashanth Nagar, Miyapur, Hyderabad-500049, Telangana	24-Aug-2022

### Agreements/MoUs/NDA etc signed by CSIR-NPL

Sl. No.	Name of the company/Industry/Organization	Signing date
1	Agreement with Global PT Provider Private Limited, F-89/22, Okhla Industrial Area, Phase-1, New Delhi-110020 for " <b>Development and/or production of Bharatiya Nirdeshak Dravyas (BND™ : Indian Reference Material)</b> "	28-Jun-2022
2	Agreement with M/s SRK Instruments, Shop #A6, Aliens Elite, Prashanth Nagar, Miyapur, Hyderabad-500049, Telangana for licensing of know-how " <b>Ultrasonic Pulse Velocity Tester Device with Threshold Error Correction</b> "	24-Aug-2022
3	Agreement with Aron Universal Limited, 25/1, 2 <sup>nd</sup> Phase, Jigani Industrial Area, Jigani, Bangalore (South), Karnataka-560105, India for sponsored project " <b>Development of mono/bi-invisible fluorescent pigments and visible/invisible fluorescent security threads/fibres for anti-counterfeiting technology</b> "	19-Sep-2022
4	Agreement with Pharmaffiliates Analytics & Synthetics Private Limited, Panchkula, Haryana-132113 for " <b>Development and/or production of Bharatiya Nirdeshak Dravyas (BND®R : Indian Reference Material)</b> "	04-Jan-2023

## Centre for Calibration and Testing Centre

CFCT acts as an interface for connecting metrological activities of NPLI to Industries & Govt. agencies for National Growth, Quality Control & Trading. Currently, CFCT is supporting more than 4000 clients from industries, national laboratories, and government organizations from all over the country and abroad including SAARC nations. CFCT supports all customer care-related queries and deals with the customers with utmost care to serve the Nation. CFCT plays an essential role in creating awareness about the importance of metrology related activities. Also, at CFCT, we have provided most of the information online so that our esteemed customers can freely access it. These services include CTBR Form, Calibration and Testing Charges, Specimen Copy of Calibration & Test Certificates, and Payment Related Information with terms and conditions of instruments handling etc.

The following table shows the list of some of the users availing the calibration and testing services from CSIR NPL through CFCT.

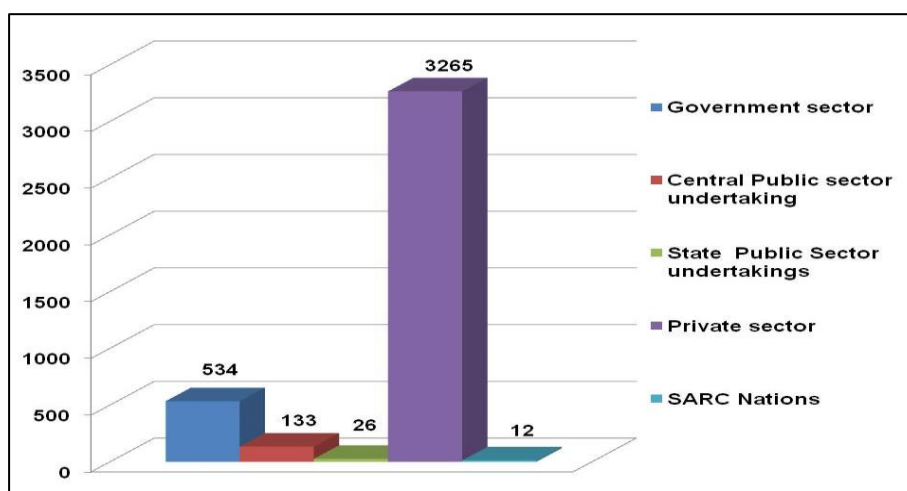
S.No	Organization	List of users/clients
1	Government/ PSU	DRDO, ISRO, Election Commission of India, CPCB, Indian Railways, Indian Airforce, Air India, BSF, BIS, Legal Metrology, DAE, CPRI, HAL, BHEL, BEL, GAIL, ONGC, IOCL, HPCL, Indian oil, State Electricity Boards, NTPC, Delhi Jal board, MSME Testing Centres, Ordinance Factory, Steel Authority of India and Scientific Institutes/Labs, Universities etc.
2	Private Sector/Industries	Tata Steel; Mysore Paints & Varnish; CK Birla Group; GE power systems; ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Adani Electricity; Binani Cement; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej & Boyce Mfg. Co. Ltd; Havells India; Honda Cars; J.K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen & Toubro; Maruti Suzuki; Philips India; Rapid Metro Rail Gurgaon; Samsung India; Honda Siel; Surya Roshni, Wipro consumer care & lighting; Orient Electric; ITC, Halonix Technologies, Astra lighting; Bharat Forge; Tektronix India; Fluke Technologies etc.
3	SAARC Nations	Nepal Bureau of Standards & Metrology (MBSM), Bangladesh Standards and Testing Institution (BSTI), Measurement Units, Standards and Services Department, Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Maldives Standards and Metrology Unit



The following table shows the outcome of the calibration and testing services from CSIR-NPL through CFCT for the past 10 years.

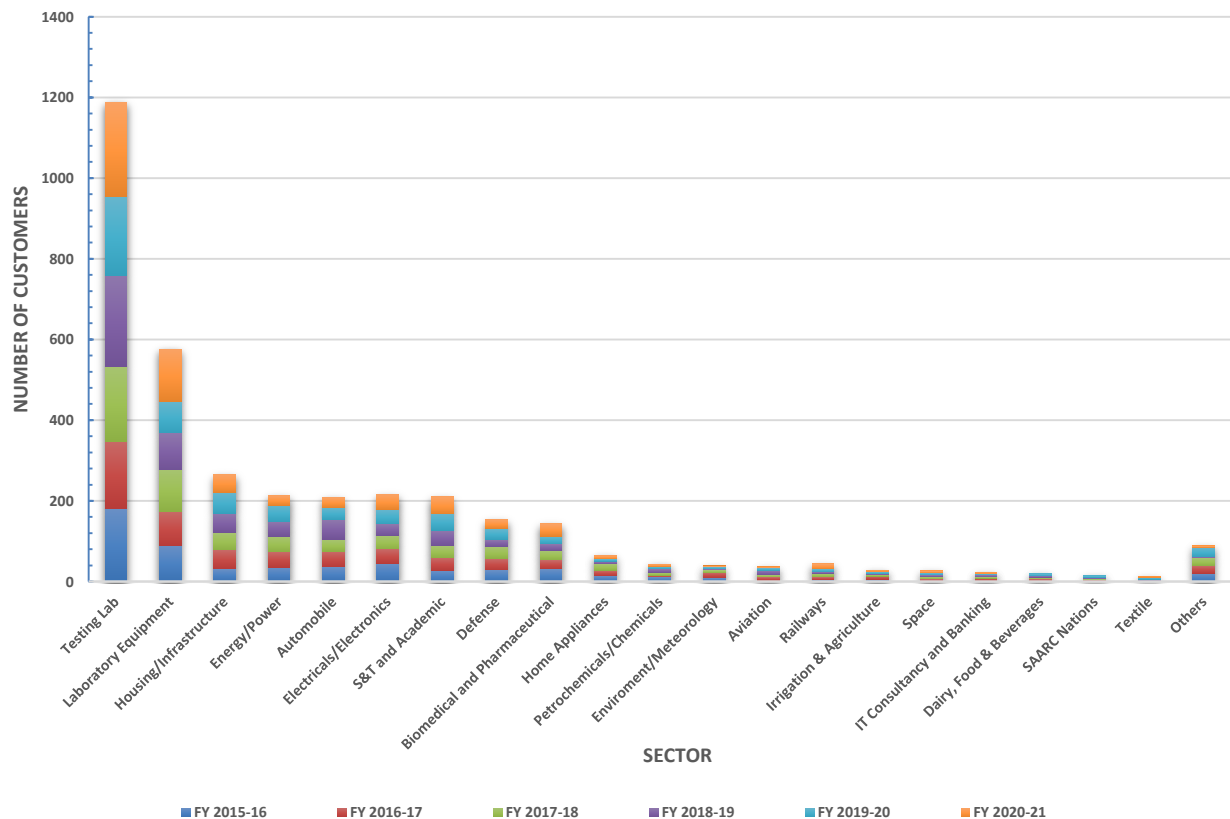
S.No.	Financial Year	Total Earnings in Rs. Crores	Certificates Issued	Cases Generated
1	2013-14	6.5	2784	1396
2	2014-15	7.1	2760	1267
3	2015-16	7.2	2758	1284
4	2016-17	7.4	2539	1172
5	2017-18	7.6	2638	1098
6	2018-19	11.1	2601	1264
7	2019-20	11.4	2348	1145
8	2020-21	10.2	2014	1126
9	2021-22	11.3	2151	1241
10	2022-23	13.6	2741	1390

Below illustrated figure shows metrological services provided by CSIR-NPL through CFCT to various organizations and sectors. The beneficiaries of these metrological services include government ministries, regulatory bodies, public sector undertakings, private industries, MSMEs, strategic sectors, S&T organizations, etc. In addition, CSIR-NPL has been supporting the NMIs of neighbouring countries, especially those belonging to South Asian Association for Regional Cooperation (SAARC) nations.



CSIR-NPL provides calibration and testing services through CFCT to several stakeholders

The following figure shows the sector-wise distribution of metrological services of CSIR-NPL through CFCT for 2015-16 to 2020-21. CFCT data analysis in terms of metrological services provided to vital sectors, which contribute to the knowledge economy and knowledge society. These are categorized into the following twenty sectors: automobile, aviation, biomedical and pharmaceutical, dairy, food & beverages, defense, electrical/electronics, energy/power, environment metrology, home appliances, housing/infrastructure, irrigation & agriculture, IT consultancy & banking, laboratory equipment, petrochemicals & chemicals, railways, S&T and academic, space, testing laboratories, textile, SAARC nations, and others.

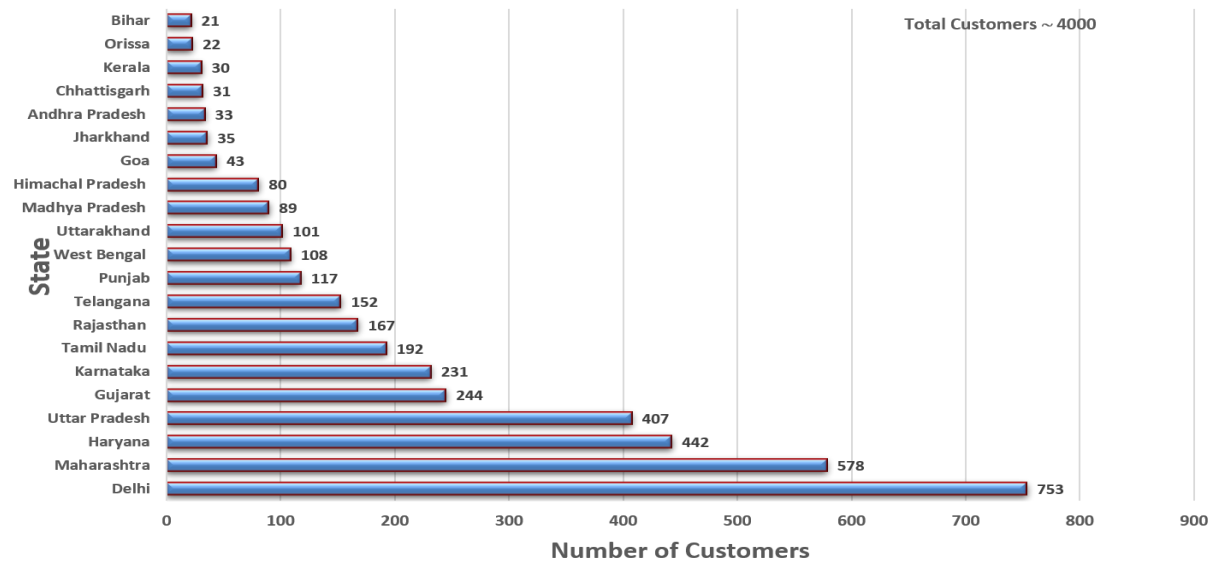


### Sector-wise distribution of Metrological Services of CSIR-NPL for 2015-16 to 2020-21

The “other” category includes data that could not fit into the above-mentioned specialized categories. The testing labs and laboratory equipment are the top sectors. This is quite expected because the NABL accredited laboratories across the country need to obtain the mandatory metrological traceability to SI units through CSIR-NPL. It is understood that, most of the government ministries have their own secondary testing and calibration laboratories to ensure the conformity assessments for their regulations as well as for products manufactured in India or imported. Since these secondary laboratories are spread across the country, the state regulators approach these local laboratories for calibration and testing. This also explains why the number of state PSUs that approach CSIR-NPL is relatively lower in number, as observed in above figure. These secondary laboratories have their traceability to the SI units through CSIR-NPL.

The other major sectors which obtain measurement traceability to SI units from CSIR-NPL through CFCT are automobiles, biomedical and pharmaceutical, defense, home

appliances, housing/infrastructure electrical and electronics, energy/power, S&T and academic, aviation, railways and space. The measurement traceability to sectors like diary, food & beverages, environment/ metrology, IT consultancy & banking, textile etc. though not significant at present in availing the facilities of CSIR-NPL, but possibilities exists that they may be using secondary calibration and testing laboratories. However, it must be ensured that all sectors utilize measurement *values traceable to SI units* for quality assurance.



### Sector-wise distribution of metrological services of CSIR-NPL

As measurement traceability is linked to economic growth, organizations in the various states of India, availing the CSIR-NPL facilities are plotted. A total of 21 states data was analysed. New Delhi is frontrunner, which is expected as most of the government bodies and industries approach CSIR-NPL due to its proximity. The case with Haryana also, being an adjoining state. Otherwise, the ranking in measurement traceability to SI units through CSIR-NPL and the industrial growth appears to be correlated well. According to RBI's recent report, states like Maharashtra, Tamil Nadu, Gujarat, Utter Pradesh and Karnataka have high rate of industrial growth while north-eastern states have lowest industrial growth. Therefore, to improve the economy of the country, among many other parameters, the respective state governments should be encouraging industries and MSMEs to ensure the measurement traceability for industrial growth through manufacturing of products of international quality.

### Central Workshop

Central Workshop of the CSIR-National Physical Laboratory provides technical services related to design, drawing and development of new experimental setups/instruments, fabrication of high-precision components, repair and maintenance of existing instruments/setups required by the various section of the laboratory. In addition, this facility also provides inside campus mechanical maintenance and other related work etc.

During the period under report, 505 jobs in the workshop were done. These jobs include fabrication of the accessories and components, vacuum sealing of quartz ampoules, cutting of quartz tubes & glass beakers, fitting of ring tubes. These are used for calibration, testing, and other R&D and non-R&D activities. The photos of some of the jobs fabricated in the Central Workshop are illustrated below.



(a) Metallic Plate



(b) Graphite Rod



(c) U-Holder



(d) Repair of Trolley



(e) Double Sided rod for Street Light



(f) Acrylic Box

### Contribution of Central Workshop to support different R&D Activities

#### International Science and Technology Affairs Group (ISTAG)

International Scientific Collaborations are assisting scientists to share their ideas & papers for developing new technologies & bridging the gap between them for the service of mankind. ISTAG group facilitates the overseas visits of scientific and technical personnel of the laboratory to get acquaintance & learn new techniques. It advises scientists to participate in International Conferences, Seminars, and Summer Schools. It helps the scientists to get prestigious international fellowships. This group also urges the scientists to avail bilateral exchange programme. The total number of visits conducted by the CSIR-NPL scientists/technologists was 24 during 2022-23. ISTAG also conducts PRC meetings for foreign deputations of Regular Staff. This year, 08 PRC Meetings were organized. The group also encourages and facilitates the visits of young students to abroad. This year, 09 students visited abroad to attend International conferences/seminars/ workshops and others for research oriented programmes. It also organizes the visit of foreign delegations at CSIR-NPL. International experts are also invited to deliver talks and lectures at CSIR-NPL. The total number of foreign delegations that visited CSIR-NPL was 09 during 2022-23. The scientific staff is

motivated to avail sabbatical leave/study leave. Arranging training programmes for international candidates is also the job of this group. This group also handles international collaborative projects, bilateral exchange programme and MOU.

### **Human Resource Development Group**

- **Ph.D. Registration and other Support to Research Fellows**

One of the most prominent activities of the CSIR-NPL is to provide help and support to Research Fellows (JRFs / SRFs), starting from the time they join CSIR-NPL till the time they leave CSIR-NPL. This includes their placement in a suitable Division / Group and helping them in getting Hostel accommodation, if required. This also includes their Ph.D. registration, assessment for continuance /up-gradation, deputation to attend conferences, etc.

From 1<sup>st</sup> April 2022 to 31<sup>st</sup> March 2023, 36 research fellows (JRFs/SRFs) joined CSIR-NPL and AcSIR Ph.D. Programme, resulting in a total strength of Research Fellows (JRFs+SRFs) in CSIR-NPL is 335 as on 31.03.2023.

- **Organization of Student's Training at CSIR-NPL**

CSIR-NPL provides training to students pursuing M.Sc./M.Tech./MCA, or their equivalent degree programmes, at different educational institutions, spread all across the country, in the areas of research activities being carried out at CSIR-NPL. The primary objective is to provide the students a feel and importance of the various activities and motivate them towards scientific research as a career.

From 1<sup>st</sup> April 2022 to 31<sup>st</sup> March 2023 total of 116 students were provided training oriented towards the fulfilment of their academic degree requirements in different areas of research under the guidance of senior scientists.

ECF Generated: 6,93,840/-

- **Deputation of CSIR-NPL Staff Members to Attend Conferences / Similar Events**

CSIR-NPL encourages and supports its staff members, including the floating members like JRFs, SRFs, PAs, RIs, RAs, SRAs, etc., to attend and present papers at national / international conferences / symposia / seminars / workshops, organised by different agencies in areas relevant to research activities being carried out at CSIR-NPL. This is primarily meant to enable the staff members to put their views and research results before the leading national / international experts and interact with them on the latest developments in their research areas.

From 1<sup>st</sup> April 2022 to 31<sup>st</sup> March 2023 , 168 cases of CSIR-NPL scientists and other staff members, including research scholars, were nominated to participate in various conferences / similar events and training courses held nationwide.

- **Skill Development Programme in CSIR-NPL**

Under the Skill Development Programme - total training programmes 22, total participants 731.

ECF Generated: 11,68,200/-

- **Jigyasa Programme with Kendriya Vidhyalaya Sangathan**

We are planning to establish virtual labs under Jigyasa Programme.

- **Institutional Visits**

During 2022-23, CSIR-NPL has organized 22 visits for various colleges/schools. A total of 1057 visitors explored various facilities of the laboratory.

### **Quality Management System**

The Quality Management System (QMS) of the CSIR-NPL (NPLI) is responsible for implementing and fulfilling the requirements of IS/ISO/IEC 17025: 2017 and IS/ISO 17034: 2016 standards at CSIR-NPL. At present, there are 28 sub-divisions covered under QMS. QMS coordinated the annual internal audits of the various sub-divisions and follow-up of corrective actions taken for closure of Non-conformances (NCs) to ensure the continuing suitability, adequacy, and effectiveness of policies and objectives of the quality system.

QMS provided the necessary inputs and information as required by the Asia Pacific Metrology Programme (APMP) Technical Committee for Quality System (TCQS) from time to time. QMS also prepared the Annual Report (November 2021 - October 2022) of QMS of NPLI by taking the inputs from the respective sub-divisions and submitted it to APMP TCQS for APMP General Assembly (GA) 2022. Mr. M. A. Ansari, Quality Manager, and Mr. Goutam Mandal, Deputy Quality Manager, attended and presented the QMS Annual Report of NPLI in the APMP TCQS meeting held during 9th & 10th November 2022 on the activities related to QMS, including participation in international inter-comparisons.

Under an MoU signed between CSIR-NPL (NMI of India) and Bhabha Atomic Research Centre (BARC, Designated Institute of India for Ionizing Radiation) in October 2020 for providing guidance to the Radiation Standard Section (RSS), BARC on a quality system based on IS/ISO/IEC 17025: 2017 and also for conducting peer review so that BARC can publish Calibration and Measurement Capabilities (CMCs) on Ionizing Radiation in the International Bureau of Weights and Measures (BIPM) Key Comparison Database (KCDB). Scientists of QMS of CSIR-NPL conducted about 15 online meetings during the period with Scientists of RSS, BARC for the preparation of the Quality Manual and Procedure Manuals of BARC through detailed discussions. Preparation of the Quality Manual and Procedure Manuals is complete. A team of scientists from CSIR-NPL visited RSS, BARC from 18th to 20th July 2022 for verification of the implementation of the quality system.

QMS of CSIR-NPL is also teaching a subject titled "Quality Control and Management" for a one-year course, "Post Graduate Diploma in Precision Measurement and Quality Control (PGD-PMQC)" under AcSIR to Engineering/Science graduate students.

QMS has provided training on "IS/ISO/IEC 17025: 2017 and Internal Audit (General Requirements for the Competence of Testing and Calibration Laboratories)" to ~ 20 participants (Scientists and Technical Officers) of CSIR laboratories organized by CSIR-NPL during 5<sup>th</sup> to 8<sup>th</sup> July 2022.

### **Knowledge Resource Centre**

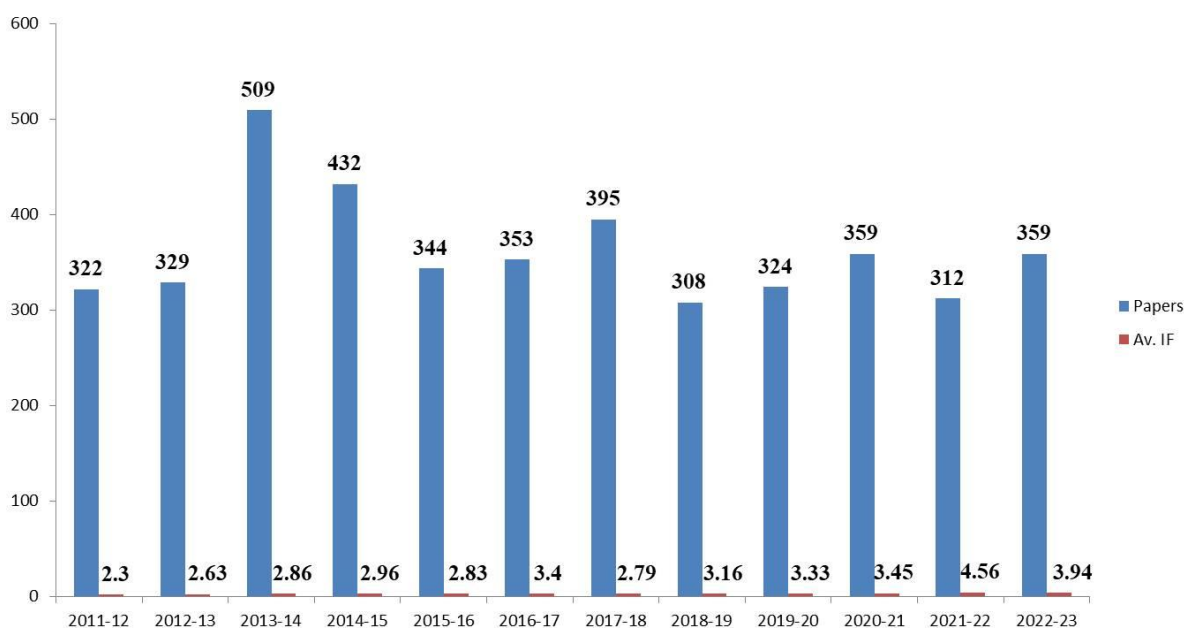
In CSIR-NPL the umbrella term 'Knowledge Resource Centre (KRC)' comprises Library and IT related activities under its domain.

As far as library and information support is concerned, KRC, over the years, has developed a rich collection of scholarly books and journals, especially in the field of physics and related sciences. During the current year, KRC subscribed to numerous scholarly journals and added a variety of books in both English and Hindi languages to enrich its textual collection. Regarding the services offered, KRC serves the CSIR-NPL community with services like Electronic Document Delivery service, Inter- Library Loan service, Reference service, Literature Search service, etc. Further, towards improving the quality of science produced by the lab in terms of research publications, NPL-KRC offers content similarity check with the help of the recommended software 'iThenticate'. In addition to the printed content, the centre also offers online access to full-text journals from distinct publishers through the National Knowledge Resource Consortium (NKRC). The NKRC facilitates access to the electronic content from publishers like ACS (American Chemical Society), AIP (American Institute of Physics), APS (American Physical Society), IOP (Institute of Physics), OSA (Optical Society of America), IEEE, RSC (Royal Society of Chemistry), Springer, Taylor & Francis etc. KRC also provides access to the Indian Standards. Additionally, the library has initiated the procurement of recommended standards in accordance with the requisitions from the CSIR-NPL researchers. Also, during the period, renovations of the Library Reading Hall and staff sitting rooms was completed, along with the installation of a new AC unit in the Reading Hall.

The shift in technology achieved with the automation of KRC activities and installation of improved routers helped in attracting the R & D personnel in large number to optimize the use of the available resources. Further, to promote free worldwide access to the intellectual outputs of CSIR-NPL in the form of journals articles, research papers, conference papers, technical reports, preprints, and other scholarly communication, NPL-KRC has established the Institutional Repository (IR@NPL) <http://npl.csircentral.net/> and till date, around 3800 records have been added. Further, the library provides the services of specialized academic writing tools such as Grammarly and iThenticate. Additionally, the Library is actively engaged in maintaining the CSIR-NPL website and managing the institute's social media presence. Also, NPL-KRC is participating in the CSIR project for a Central Website for all CSIR labs. Moreover, in response to the demand for licensed scientific software, NPL-KRC has acquired licenses for the software 'Origin', ensuring its availability to CSIR-NPL researchers in alignment with the recommendations of the respective scientific divisions.

Apart from the library related activities, NPL-KRC also provides IT facilities to cater to the computing and communication needs of the laboratory. Data Center services are running 24x7 with an in-house setup of various Linux based servers. Internet connectivity has been implemented using 100Mbps through National Knowledge Network (NKN). A gigabit fiber optics backbone network solution is running at various locations across the CSIR-NPL campus and providing CAT6 based ethernet LAN to connect approximately one thousand network based devices i.e. computers, servers, laptops, IP cameras, attendance machines. The gateway security solution has been set up, which includes a Unified Threat Management (UTM) system for multi-level firewall, anti-virus, etc. A Radio Link is established between NPL-Campus and NPL-Colony for JRF Hostel Network. JRF hostel is equipped with a complete wireless technology solution and devices such as Omni Directional/Directional antennas and various Wi-Fi devices in different modes and configurations. Email services of the laboratory are facilitated using NIC mail services at email.gov.in

### Papers Published by the CSIR-NPL in SCI Journals



### राजभाषा यूनिट

राजभाषा यूनिट दिन-प्रति-दिन के सरकारी कार्यों में राजभाषा हिन्दी के प्रगामी प्रयोग को बढ़ाने का कार्य करती है। राजभाषा यूनिट का मुख्य उत्तरदायित्व संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबंधों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/अधिकारियों/कर्मचारियों को अवगत कराना, अनुपालन कराना एवं अनुपालन हेतु सहायता प्रदान करना है।

राजभाषा यूनिट के उत्तरदायित्व:



### 1. कार्यान्वयन:

- संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबन्धों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/ अधिकारियों/कर्मचारियों को अवगत कराना, अनुपालन कराना एवं अनुपालन हेतु सहायता प्रदान करना ।
- प्रत्येक तिमाही में निदेशक, एन पी एल की अध्यक्षता में राजभाषा कार्यान्वयन समिति की बैठक का आयोजन, कार्य सूची एवं कार्यवृत्त तैयार करना। बैठक में लिए गए निर्णयों पर अनुवर्ती कार्रवाई करना।
- हिन्दी दिवस/ हिन्दी मास तथा प्रत्येक तिमाही में हिन्दी कार्यशालाओं/व्याख्यानो का आयोजन करना ।
- राजभाषा विभाग, गृह मंत्रालय, भारत सरकार से प्राप्त वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने हेतु निरंतर प्रयास व उचित कार्रवाई करना।
- संसदीय राजभाषा समिति के निरीक्षण सम्बन्धी कार्य तथा समिति को दिए गए आश्वासनों को पूरा करने हेतु कार्रवाई करना।
- प्रत्येक वर्ष विज्ञान विषयों पर हिन्दी में राष्ट्रीय संगोष्ठी का आयोजन।

### 2. प्रशिक्षण एवं प्रकाशन:

- हिन्दी प्रशिक्षण (प्रबोध, प्रवीण एवं प्राज्ञ पाठ्यक्रम) ।
- हिन्दी टंकण/आशुलिपि एवं कम्प्यूटर पर हिन्दी में कार्य करने का प्रशिक्षण दिलाना ।
- प्रत्येक छःमाही में हिन्दी समीक्षा पत्रिका का प्रकाशन ।
- प्रयोगशाला की वार्षिक रिपोर्ट तथा अन्य महत्वपूर्ण प्रकाशनों में हिन्दी अंश का संपादन ।

### 3. अनुवाद:

- प्रयोगशाला में प्रयुक्त सभी प्रपत्रों (फार्मों), मानक मसौदों का द्विभाषीकरण ।
- हिन्दी अनुवाद कार्य ।
- राष्ट्रीय भौतिक प्रयोगशाला के वार्षिक प्रतिवेदन के महत्वपूर्ण अंशों का हिन्दी अनुवाद ।
- प्रयोगशाला की वेबसाइट का हिन्दी अनुवाद ।

### कार्मिक:

- |                           |                |
|---------------------------|----------------|
| • श्री जय नारायण उपाध्याय | हिन्दी अधिकारी |
| • श्री विजय सिंह          | निजी सचिव      |
| • श्रीमती विद्यावती       | एमटीएस         |

### प्रयोगशाला द्वारा राजभाषा की प्रगति के लिए उठाए गए कदम एवं प्रयास

- प्रत्येक तिमाही में निदेशक, एन पी एल की अध्यक्षता में राजभाषा कार्यान्वयन समिति की बैठक में वार्षिक कार्यक्रम में निर्धारित लक्ष्यों को प्राप्त करने हेतु चर्चा एवं उनकी समीक्षा की जाती है तथा बैठक में लिए गए निर्णयों पर अनुवर्ती कार्रवाई की जाती है ।
- संघ सरकार की राजभाषा नीति, राजभाषा अधिनियम के उपबन्धों तथा आदेशों से प्रयोगशाला के वैज्ञानिकों/अधिकारियों/कर्मचारियों को अवगत कराया जाता है, अनुपालन कराया जाता है एवं अनुपालन हेतु सहायता प्रदान की जाती है ।
- हिन्दी दिवस/हिन्दी पखवाड़ा/मास मनाया जाता है। इस दौरान विभिन्न प्रतियोगिताओं का आयोजन किया जाता है, जिसमें प्रयोगशाला के सभी अधिकारी/कर्मचारी भाग लेते हैं और उन्हें नकद पुरस्कार द्वारा प्रोत्साहित किया जाता है ।
- प्रत्येक तिमाही में प्रयोगशाला के अधिकारियों/कर्मचारियों हेतु हिन्दी कार्यशालाओं/व्याख्यानो का आयोजन किया जाता है । इन कार्यशालाओं के माध्यम से स्टाफ सदस्यों को हिन्दी में अधिक-से-अधिक कार्य करने हेतु प्रेरित एवं प्रोत्साहित किया जाता है । टेबल-वर्कशाप के माध्यम से व्यक्तिगत रूप से चर्चा की जाती है एवं कठिनाइयों का समाधान किया जाता है ।

- प्रत्येक वर्ष विज्ञान विषयों पर हिन्दी में एक/दो दिवसीय राष्ट्रीय संगोष्ठी का आयोजन किया जाता है। वैज्ञानिकों द्वारा शोध पत्र हिन्दी में प्रस्तुत किए जाते हैं। राष्ट्रीय संगोष्ठी की सारांश पुस्तिका हिन्दी में प्रकाशित की जाती है, जिससे विज्ञान शोध सम्बन्धित जानकारी हिन्दी में आम जन तक पहुंचती है।
- प्रयोगशाला के अधिकारियों/कर्मचारियों को केन्द्रीय हिन्दी प्रशिक्षण संस्थान से हिन्दी प्रशिक्षण (प्रबोध, प्रवीण एवं प्राज्ञ पाठ्यक्रम) दिलाया जाता है। कम्प्यूटर पर हिन्दी में कार्य करने का प्रशिक्षण दिलाने हेतु कार्यक्रम आयोजित किए जाते हैं।

### स्वच्छता पखवाड़ा, 2022

भारत सरकार द्वारा जारी दिशा—निर्देशों के अंतर्गत प्रयोगशाला में दिनांक 09 मई, 2022 से 15 मई, 2022 तक 'स्वच्छता पखवाड़ा' का सफल आयोजन किया गया। राजभाषा हिन्दी के प्रगामी प्रयोग हेतु दिनांक 04 मई, 2022 को निम्नलिखित 02 प्रतियोगिताओं का आयोजन किया गया :

- वाद - विवाद प्रतियोगिता:-
  - डा. मनोज कुमार, वरिष्ठ वैज्ञानिक ने प्रथम पुरस्कार प्राप्त किया।
  - सुश्री आरती भारद्वाज, शोध छात्रा ने द्वितीय पुरस्कार प्राप्त किया।
  - सुश्री शिखा श्रीवास्तव, शोध छात्रा ने तृतीय पुरस्कार प्राप्त किया।
- काव्य पाठ प्रतियोगिता:-
  - श्री गौरव वर्मा, शोध छात्र ने प्रथम पुरस्कार प्राप्त किया।
  - सुश्री शिखा श्रीवास्तव, शोध छात्रा ने द्वितीय पुरस्कार प्राप्त किया।
  - श्री अंकित गुप्ता, शोध छात्र ने तृतीय पुरस्कार प्राप्त किया।

इन दोनों प्रतियोगिताओं में कुल 45 स्टाफ सदस्यों (वैज्ञानिक/अधिकारी/कर्मचारी) व शोध छात्रों ने भाग लिया। 'स्वच्छता पखवाड़ा' के समापन समारोह में विजेता प्रतिभागियों को निदेशक महोदय द्वारा नगद पुरस्कार एवं प्रमाण पत्र पुरस्कृत किया गया।

### प्रयोगशाला के वैज्ञानिक/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए कार्यशाला

#### • **छुट्टी यात्रा रियायत एवं राष्ट्रीय पेंशन प्रणाली : अद्यतन नियमावली**

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार के दिशा निर्देशों का अनुपालन सुनिश्चित करते हुए हिन्दी के प्रगामी प्रयोग में उत्तरोत्तर वृद्धि हेतु प्रयोगशाला के वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों के लिए प्रत्येक तिमाही में हिन्दी कार्यशाला आयोजित की जाती है।

उपर्युक्त के संदर्भ में प्रयोगशाला के सभी वैज्ञानिक/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए " छुट्टी यात्रा रियायत एवं राष्ट्रीय पेंशन प्रणाली : अद्यतन नियमावली" विषय पर दिनांक 14 दिसम्बर, 2022 को हिन्दी कार्यशाला आयोजित की गयी। इस कार्यशाला में "छुट्टी यात्रा रियायत एवं राष्ट्रीय पेंशन प्रणाली विषय पर दो (02) व्याख्यान दिए गए। इस कार्यशाला में लगभग 70 वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों ने भी भाग लिया।

अतिथि वक्ता श्री गुंजन गांधी, उप-निदेशक, रक्षा मुख्यालय, प्रशिक्षण संस्थान, नई दिल्ली ने "छुट्टी यात्रा रियायत एवं राष्ट्रीय पेंशन प्रणाली : अद्यतन नियमावली" विषय पर महत्वपूर्ण एवं ज्ञानवर्धक व्याख्यान दिया।

हिन्दी कार्यशाला के अंत में धन्यवाद प्रस्ताव श्री जय नारायण उपाध्याय, हिन्दी अधिकारी ने किया। कार्यशाला में दिए गए व्याख्यान की वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों ने बहुत सराहना की।

- **राजभाषा नियमों के आलोक में तिमाही प्रगति रिपोर्ट कैसे भरें**

भारत सरकार के दिशा निर्देशों का अनुपालन सुनिश्चित करते हुए हिन्दी के प्रगामी प्रयोग में उत्तरोत्तर वृद्धि हेतु प्रयोगशाला के वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों के लिए प्रत्येक तिमाही में हिन्दी कार्यशाला आयोजित की जाती है।

उपर्युक्त के संदर्भ में प्रयोगशाला के सभी वैज्ञानिक/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए "राजभाषा नियमों के आलोक में तिमाही प्रगति रिपोर्ट कैसे भरें" विषय पर दिनांक 15 जून, 2022 को हिन्दी कार्यशाला आयोजित की गयी। इस हिन्दी कार्यशाला में "राजभाषा नियमों के आलोक में तिमाही प्रगति रिपोर्ट कैसे भरें" विषय पर व्याख्यान दिए गए। इस हिन्दी कार्यशाला में लगभग 40 वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों ने भी भाग लिया।

अतिथि वक्ता श्री संजय चौधरी, हिन्दी अधिकारी, सीएसआईआर – सीआरआरआई नई दिल्ली ने 'राजभाषा नियमों के आलोक में तिमाही प्रगति रिपोर्ट कैसे भरें' विषय पर महत्वपूर्ण एवं ज्ञानवर्धक व्याख्यान दिया।

हिन्दी कार्यशाला के अंत में धन्यवाद प्रस्ताव श्री जय नारायण उपाध्याय, हिन्दी अधिकारी ने किया। 'राजभाषा नियमों के आलोक में तिमाही प्रगति रिपोर्ट कैसे भरें' विषय पर आयोजित कार्यशाला में दिए गए व्याख्यान की वैज्ञानिकों/तकनीकी अधिकारियों/कर्मचारियों को प्रेरित एवं प्रोत्साहित किया।

#### हिन्दी दिवस तथा हिन्दी माह समापन समारोह-2022

राजभाषा विभाग, गृह मंत्रालय, भारत सरकार द्वारा जारी कार्यालय ज्ञापन सं. 11034/02/2019-राभा समिति, दिनांकित 31.07.2020 के अनुसरण में हिन्दी पखवाड़ा/ माह आयोजन संबंधी निर्देशों को ध्यान में रखते हुए प्रयोगशाला में 16 अगस्त, 2022 से 14 सितम्बर, 2022 तक 'हिन्दी माह' मनाया गया। प्रयोगशाला के सभी स्टाफ सदस्यों को अपना अधिक से अधिक कार्य हिन्दी में करने के लिए प्रेरित एवं प्रोत्साहित करने के उद्देश्य से निम्नलिखित प्रतियोगिताएं ऑफलाइन (कोविड-19 प्रोटोकॉल के तहत) माध्यम से आयोजित की गयीं।

क्रम सं.	प्रतियोगिता का नाम	दिनांक
1.	लोकोक्ति पल्लवन प्रतियोगिता	16.08.2022
2.	वाद विवाद प्रतियोगिता	18.08.2022
3.	चित्राधारित कथा लेखन प्रतियोगिता	23.08.2022
4.	हिन्दी टंकण प्रतियोगिता	25.08.2022
5.	सरकारी कामकाज में टिप्पण /आलेखन मूलरूप से हिन्दी में कार्य/डिक्टेशन	31.08.2022
6.	काव्य पाठ प्रतियोगिता	02.09.2022
7.	सामान्य ज्ञान-विज्ञान प्रतियोगिता	06.09.2022

दिनांक 14.09.2022 को हिन्दी दिवस तथा हिन्दी माह समापन समारोह का आयोजन किया गया। कार्यकारी निदेशक महोदय ने कार्यक्रम का शुभारंभ आशीर्वचन से किया। उन्होंने हिन्दी दिवस के अवसर पर उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए ज्ञान-सृजन विषय पर अत्यन्त सारगर्भित व्याख्यान दिया।

एनपीएल में राजभाषा गतिविधियों के बारे में श्री सुरेन्द्र कुमार, प्रशासन नियंत्रक महोदय ने संक्षिप्त ब्यौरा प्रस्तुत किया। साथ ही, उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित किया।

डॉ. सुशील कुमार ,मुख्य वैज्ञानिक ने अतिथि वक्ता का परिचय प्रस्तुत किया तथा अपने सम्बोधन में कहा कि वर्तमान वैज्ञानिक परिदृश्य में हिन्दी सहित भारतीय भाषाओं को वाणिज्य-व्यापार तथा विज्ञान साहित्य के सृजन व प्रसार हेतु भाषायी माध्यम बनाया जाना आवश्यक है। जन-जन की भाषा हिन्दी सहित भारतीय भाषाओं में सर्वसुलभ वैज्ञानिक उपलब्धियों तथा ज्ञान-विज्ञान से जुड़ी मूलभूत बातों को आम जन तक पहुंचाने के लिए सार्थक प्रयासों की आवश्यकता है ।

इस पावन अवसर पर मुख्य व्याख्यान अतिथि वक्ता प्रसिद्ध कवि ,**कला समीक्षक,लेखक, अनुवादक** श्री प्रयाग शुक्ल जी ने **‘भारतीय भाषाएं और हिन्दी’** विषय पर दिया।उन्होंने अपने विस्तृत ज्ञानकोश/अनुभवकोश से अनेक उदाहरण के द्वारा भारतीय भाषाओं /साहित्य और हिन्दी के सम्बन्धों के साथ साहित्य की सरसता और जीवंतता का प्रमाण दिया। साहित्य,इतिहास,भूगोल आदि अनेक क्षेत्रों से उदाहरण देकर यह बताया कि हिन्दी भाषा में साहित्य सृजन की अपार संभावनाएं हैं। अपने सम्बोधन के अंत में **“धम्मक – धम्मक”** नामक स्वरचित बाल-कविता का पाठ किया।

समारोह के अंत में हिन्दी माह के दौरान आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 45 विजेता प्रतिभागियों को माननीय कार्यकारी निदेशक महोदय व मुख्य अतिथि के करकमलों से पुरस्कार व प्रमाण-पत्र प्रदान किए गए। स्वागत, कार्यक्रम का संचालन व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिन्दी अधिकारी, एनपीएल द्वारा किया गया।



डॉ. संजय रंगनाथ धकाते, कार्यकारी निदेशक,एनपीएल संबोधित करते हुए



मुख्य अतिथि को सम्मानित करते हुए कार्यकारी निदेशक



मुख्य अतिथि श्री प्रयाग शुक्ल जी व्याख्यान देते हुए



विजेता प्रतिभागियों को पुरस्कार प्रदान करते हुए मुख्य अतिथि व अधिकारीगण

### विश्व हिन्दी दिवस, 2023

राष्ट्रीय भौतिक प्रयोगशाला में राजभाषा यूनिट द्वारा **विश्व हिन्दी दिवस, 2023** (दिनांक 10 जनवरी, 2023) का आयोजन किया गया। प्रयोगशाला में स्टाफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने के लिए प्रोत्साहित एवं प्रेरित करने के उद्देश्य से दिनांक 05 जनवरी को दो प्रतियोगिताओं का आयोजन किया गया।

क्रम सं.	प्रतियोगिताएं	दिनांक
1.	आशु भाषण प्रतियोगिता	05 जनवरी, 2023
2.	काव्य पाठ प्रतियोगिता	05 जनवरी, 2023

इन सभी प्रतियोगिताओं में प्रयोगशाला के स्टाफ सदस्यों/शोध छात्र-छात्राओं ने अत्यधिक रूचि प्रदर्शित करते हुए उत्साहपूर्वक भाग लिया।

### कार्यक्रम

- |    |  |   |  |
|----|--|---|--|
| 1. | स्वागत   | : | श्री जय नारायण उपाध्याय  |
| 2. | कार्यक्रम शुभारंभ/सम्बोधन  | : | निदेशक महोदय   |
| 3. | विश्व हिन्दी दिवस के बारे में  | : | श्रीमती वीना जैन, वरिष्ठ प्रशासन नियंत्रक                            |
| 4. | आमंत्रित अतिथि का परिचय व संबोधन                                       | : | डा. सुशील कुमार, मुख्य वैज्ञानिक                                     |
| 5. | मुख्य अतिथि द्वारा व्याख्यान<br>(विषय: हिन्दी की वैश्विकता और जनसंचार) | : | प्रो. महेन्द्र पाल शर्मा, हिन्दी विभाग,<br>जामिया मिल्लिया इस्लामिया |
| 6. | पुरस्कार वितरण   | : | मुख्य अतिथि/मंचासीन गणमान्य  |
| 7. | धन्यवाद प्रस्ताव   | : | श्री जय नारायण उपाध्याय  |

हर साल 10 जनवरी को 'विश्व हिंदी दिवस' के रूप में मनाया जाता है। इस दिन को विश्व में हिंदी भाषा के प्रचार-प्रसार के लिए जागरूकता फैलाने के उद्देश्य से मनाया जाता है। इस वर्ष की हिंदी दिवस की थीम है **'हिंदी को जनमत की भाषा बनाना, बगैर उनकी मातृभाषा की महत्ता को भूले।'**

अंग्रेजी के मशहूर समीक्षक और निबंधकार ईएम फास्टर ने अपनी पुस्तक आस्पेक्ट्स ऑफ नॉवेल में बड़ी बात कही है। उन्होंने साहित्य के बारे में कहा है कि जिस साहित्य की जड़ें जितनी स्थानीय होंगी, वह उतना ही अंतरराष्ट्रीय हो सकता है।

इस पावन अवसर पर कार्यकारी निदेशक डॉ संजय रंगनाथ धकाते महोदय ने विश्व हिंदी दिवस की अनेक हार्दिक शुभकमनाएं दीं। उन्होंने कहा कि आज फीजी, मॉरीशस, गयाना, सूरीनाम, यूरोप, अमेरिका, नेपाल आदि देशों में हो रही हिंदी-सेवा से वैश्विक परिदृश्य में हिंदी का एक नया व प्रबल चित्र उभर रहा है। हिंदी भाषा देश-विदेश में आधुनिक चुनौतियों को लांघते हुए विश्वव्यापी बन रही है। स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिंदी का प्रयोग करने के लिए प्रेरित एवं प्रोत्साहित करते हुए ज्ञान-सृजन विषय पर अत्यन्त सारगर्भित व्याख्यान दिया। सम्बोधन के अंत में विश्व हिंदी दिवस के अवसर पर आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 10 विजेता प्रतिभागियों को माननीय कार्यकारी निदेशक महोदय ने हार्दिक बधाई दी।

श्रीमती वीणा जैन, वरिष्ठ प्रशासन नियंत्रक ने बताया कि विश्व में हिंदी का विकास करने और एक अंतरराष्ट्रीय भाषा के तौर पर इसे प्रचारित-प्रसारित करने के उद्देश्य से विश्व हिंदी सम्मेलनों की शुरुआत की गई और प्रथम विश्व हिंदी सम्मेलन 10 जनवरी 1975 को नागपुर में आयोजित हुआ था। इसीलिए इस दिन को विश्व हिंदी दिवस के रूप में मनाया जाता है।

आमंत्रित अतिथि के परिचय के साथ ही हिंदी का वैश्विक परिदृश्य विषय पर डा. सुशील कुमार, मुख्य वैज्ञानिक ने हिंदी भाषा की गरिमामयी वैश्विक उपस्थिति पर सारगर्भित व्यख्यान दिया।

आमंत्रित अतिथि प्रोफेसर महेन्द्रपाल शर्मा, हिंदी विभाग, जामिया मिल्लिया इस्लामिया ने हिंदी की वैश्विकता और जनसंचार विषय पर अपने सम्बोधन में कहा कि वर्तमान परिदृश्य में हिंदी सहित भारतीय भाषाओं को विज्ञान/प्रौद्योगिकी तथा वाणिज्य-व्यापार आदि सहित तकनीकी शिक्षण हेतु भाषायी माध्यम बनाया जाना आवश्यक है।

समारोह के अंत में विश्व हिंदी दिवस के अवसर पर आयोजित की गयी प्रतियोगिताओं में भाग लेने वाले 10 विजेता प्रतिभागियों को मुख्य अतिथि /मंचासीन गणमान्य माननीयों ने हार्दिक बधाई दी व पुरस्कार प्रदान किए।

स्वागत, कार्यक्रम का संचालन व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिंदी अधिकारी, एनपीएल द्वारा किया गया।



प्रयोगशाला के वैज्ञानिक/तकनीकी अधिकारियों/स्टाफ सदस्यों के लिए कार्यशाला

दिनांक 21 फरवरी 2023 को 'अंतरराष्ट्रीय मातृभाषा दिवस के अवसर पर कार्यशाला का आयोजन किया गया। इस कार्यशाला में मुख्य अतिथि द्वारा श्री देवेन्द्र मेवाड़ी, प्रसिद्ध विज्ञान लेखक व संचारक ने 'मातृभाषा जीवन का आधार है' विषय पर रोचक व प्रेरक व्याख्यान दिया। उन्होंने मातृभाषा की महत्ता को विस्तारपूर्वक समझाया व प्रतिभागियों को कार्यालयीय कार्यों सहित अन्य कार्यों को मातृभाषा में संपादित करने हेतु प्रेरित किया।

**कार्यक्रम विवरण:**

1. स्वागत : श्री जय नारायण उपाध्याय
2. कार्यक्रम शुभारंभ/सम्बोधन : निदेशक महोदय
3. अंतरराष्ट्रीय मातृभाषा दिवस के बारे में : श्रीमती वीना जैन, वरिष्ठ प्रशासन नियंत्रक
4. आमंत्रित अतिथि का परिचय व संबोधन : डा. एस आर धकाते, मुख्य वैज्ञानिक
5. मुख्य अतिथि द्वारा व्याख्यान : श्री देवेन्द्र मेवाड़ी, प्रसिद्ध विज्ञान लेखक व संचारक  
(विषय: मातृभाषा जीवन का आधार है)
6. धन्यवाद प्रस्ताव : श्री जय नारायण उपाध्याय

स्वागत, कार्यक्रम का संचालन व धन्यवाद ज्ञापन श्री जय नारायण उपाध्याय, हिन्दी अधिकारी, एनपीएल द्वारा किया गया। इस कार्यशाला/व्याख्यान में प्रयोगशाला के लगभग 55 वैज्ञानिकों/अधिकारी/कर्मचारियों ने भाग लिया।

## Major R & D Projects during 2022-23

The major projects of value >50 Lakhs are listed below

Sl. No	Project Title	Funding Agency	Contract Value (in lakhs)	Amount Received during 2022-23
1	Study of seasonal variation of ozone precursor in relation with surface ozone over Delhi, a mega city	Physical Research Laboratory (A Unit of Dept. of Space, Govt. of India)	135.32	NIL
2	A system to generate a common synchronised clocks using CVGNSS with an uncertainty of few ns at geographically disturbed sensor nodes	Defence Electronics Research Laboratory ( DERL) Ministry of Defence	95.00	NIL
3	Implementation of IST service using NPL controlled remote oscillator system for national knowledge Network at National Informatics Centre	National Informatics Centre Services Inc. ( NICSII )	94.36	47.17
4	Carbonaceous Aerosols Emissions, Source Apportionment and climate effects	Ministry of Environment, Forest and Climate Change (MoEF)	274.672	NIL
5	National Primary Standard facility for cell calibration	Ministry of New and Renewable Energy( MNRE)	1788.50	NIL
6	Growth and study of highly conducting delafossite single crystal: Device application in metrology	DST	89.00	NIL
7	Megacity Delhi atmospheric emission quantification assessment and impacts (Delhi Flux)	Ministry of Earth Sciences(MoES)	198.28	NIL
9	Creation of Testing and Calibration Facility for LED and LED based Lighting at NPL India as per National/International Standards	Bureau of Energy Efficiency(BEE)	2025.00	NIL



10	Studies of stabilization of ferromagnetism in MnX(X=Al,Ga) binary alloy thin films by ion beam irradiation	DST	80.49	22.23
11	Production of Certified Reference Materials- Bharatiya Nirdeshak Dravya (BND)	Ministry of Commerce & Industry, Department of Commerce	1627.00	NIL
12	Establishment of type testing calibration and certification facility for online continuous Emission Monitoring System (OCEMS) and Continuous Ambient Air Quality Monitoring System (CAAQMS)	Ministry of Environment, Forest & Climate Change (MoEF) Govt. of India	5660.00	NIL
13	Advanced Single Photon Detector & Establishment of Single Photon Defection Based Quantum Standard for QuEST	DST	578.14	5.81
14	Bulk preparation of p-type and n-type materials for excitonic solar cells	DST	58.24	NIL
15	Design and Development of flexible large area(156x156 mm <sup>2</sup> ) modified perovskite mini modules	DST	98.83	NIL
16	GCRF South Asian Nitrogen Hub (SANH)	UK Centre for Ecology and Hydrology (UKCEH)	153.13	NIL
17	Establishment of recaptacles for the preservation of the original constitution of India in New Parliament Building	Lok Sabha Secretariat Parliament House	56.00	32.00

## Awards & Achievements

---

### Distinguished National/ International Award

- **Prof. Venugopal Achanta**, Director, CSIR-NPL, was elected as a Member of the International Committee for Weight and Measures (CIPM) (Nov. 2022).



- **Prof. Venugopal Achanta**, Director, CSIR-NPL, conferred a Fellow of the Indian National Science Academy (INSA)  
[https://www.insaindia.res.in/scroll\\_news\\_pdf/felcit22.pdf](https://www.insaindia.res.in/scroll_news_pdf/felcit22.pdf)
- **Dr. N Vijayan**, Sr. Principal Scientist, CSIR-NPL, received the MRSI Medal during IUMRS-ICA 2022 at IIT Jodhpur (19-23 Rd Dec. 2022).



- “EMSI-Excellence in Microscopy Award” conferred to **Dr. Jai Shankar Tawale** for his excellent contribution to electron microscopy and allied fields in the materials science category on the occasion of the International Conference on Electron Microscopy EMSI-2023 at Delhi University (8-10 Feb. 2023).



- **Dr. Anshul Varshney** has been selected for BRICS Young Scientist Forum Conclave - 2022 held at Xiamen, China (29 Aug. - 1 Sept. 2022).

### Best Paper Award

- Akash Kumar Singh, P. K. Siwach and H. K. Singh received **Best Poster Award** at National Science Day, CSIR-NPL for the paper 'Insulator-Metal Characteristics of VO<sub>2</sub> Films Grown on Si (100) by RF Sputtering of V<sub>2</sub>O<sub>5</sub> Target' (28 Feb. 2023).
- Arpit Malik, S.G. Aggarwal, S. Ohata, T. Mori, P.R. Sinha, M. Singh, K. Singh, D. Soni, M. Koike, Y. Kondo received **Best Poster Award** for the poster 'A Novel Approach for Calibrating the Mass Absorption Cross Section of Commonly Used Black Carbon Photometer' at National Science Day, Poster Symposium' proceeding , CSIR-NPL (28 Feb. 2023).
- Ashish Bhatt received **Best Poster Award** for poster presentation on 'Development of Pd-C Eutectic Fixed-Point Cell for the Thermocouple Scale Realization up to 1600 °C at CSIR-NPL' to at AdMET-2023 at BARC (24 - 25 Mar. 2023).
- Baban Kr., Shankar G. Aggarwal, Prashant Patel, Khem Singh, Daya Soni, V. N. Ojha, received **Best Poster Award** for the poster 'Design and Development of a Virtual Impactor for Bioaerosol Sampling' at National Science Day, Poster Symposium' proceeding , CSIR-NPL (28 Feb. 2023).
- Bheem Singh, Sudhanshu Gautam, Vishnu Aggrawal, Rahul Kumar, J.S. Tawale, S. C. Roy and Sunil S. Kushvaha received **Best Poster Award** at National Science Day,

CSIR-NPL, for the paper 'Growth of Bi<sub>2</sub>Se<sub>3</sub> thin film on flexible Mo foils for Photoelectrochemical water splitting application' (28 Feb. 2023).

- Bheem Singh, Yogesh Singh, Sudhanshu Gautam, N. Khatun, Vishnu Aggrawal, Rahul Kumar, S. C. Roy, V. N. Singh and Sunil S. Kushvaha received **Best Oral Presentation Award** at 2nd International Conference on Advanced Materials and Nanotechnology (ICAMN2022) for the paper 'Sb<sub>2</sub>Se<sub>3</sub> thin film on flexible metal foils for PEC water-splitting applications' (22 – 24 Dec. 2022).
- Bipul Kumar Pradhan, Roopa, Prashant Tyagi, Amit Kumar Mauraya, Sunil Singh Kushvaha and M. Senthil Kumar received **Best Paper Award** for oral presentation in ICNOC – 2022, for the paper entitled, "Laser MBE Growth and Ultraviolet-Light Stimulated Electron Field Emission Properties of Nano-Crystalline GaN Films on Metal Foil" (28 - 30 Nov. 2022).
- Chitra, Dheeraj Sah, Parveen Saini, Rebecca Yang, Chander Kant, Kalpana Lodhi, Sushil Kumar received **Best Oral Presentation** for 'Development of Recycling Processes for Polymeric Layers from Waste Silicon Solar Modules' at National Conference on Advances in Solar Energy Materials (ASEM-2023) at BHU, Varanasi (16-18 Mar. 2023)
- चित्रा, धीरज साह, प्रवीण सैनी, कल्पना लोधी, चंद्र कांत, सुशील कुमार received **Best Poster Award for** अपशिष्ट सिलिकॉन सौर फोटोवोल्टिक मॉड्यूल से एथिलीन विनाइल एसीटेट (ईवीए) के लिए रीसाइक्लिंग प्रक्रियाओं का विकास, अपशिष्ट से संपत्ति: उपयोगी उत्पादों के लिए अपशिष्ट पदार्थों का पुनर्चक्रण पर राष्ट्रीय सम्मेलन-2022 at CSIR-NPL (Sept. 2022)
- Komal, Daya Soni, Khem Singh, Shankar G. Aggarwal received **Best Poster Award** for the poster 'Method Validation for gas chromatography technique for greenhouse gas (CH<sub>4</sub> & CO<sub>2</sub>) monitoring using gravimetrically prepared primary reference gas mixtures' at National Science Day, Poster Symposium' proceeding , CSIR-NPL (28 Feb. 2023).
- Manoj Sehrawat received **Best poster Award** on Floating catalyst chemicals vapour deposition derived grapheneted CNT aerogel in e-Workshop on Advances on Science & Technology of Graphene-2022 (Graphene-2022) organized by Indian Carbon Society in collaboration with CSIR-NPL, New Delhi (1-2 Nov. 2022).
- Neha, Athira Raveendran, Rahul Saha, Parveen Saini, received **Best Poster Award** for 'Anticorrosion properties of polyaniline/nanocrystalline cellulose composite' in International Conference on Corrosion and Coatings (i3C)- 2022 organized by the Indian Institute of Metals (IIM) Jamshedpur Chapter in association with Tata Steel, CSIR-NML & NIT Jamshedpur (07-08 Dec. 2022).
- Reena Yadav, Animesh Pandey, Mandeep Kaur, V.P.S. Awana and Sudhir Husale received **Best Poster Award** on National Science Day-2023, in the Physics, Engineering and materials category, for the poster 'Detection and manipulation of elusive quasiparticles for quantum technology' (28 Feb. 2023).

- Ruchi Kumari Sharma, Avritti Srivastava, Premshila Kumari, B.P. Singh, Pathi Prathap, Sanjay K. Srivastava received **Best Oral Presentation Award** for the paper presentation on ‘Improved Surface Passivation of Organic/Silicon Hybrid Solar Cells via Incorporating PEDOT:PSS-GO Composite as Hole Transport Layer’ in e-Workshop on Advances on Science & Technology of Graphene-2022 (Graphene-2022) organized by Indian Carbon Society in collaboration with CSIR-NPL, New Delhi (1-2 Nov. 2022).
- Sumit received **Best Poster Award** in ADMET 2023 for ‘Design and development of a low noise current source for 100 g Kibble Balance’ (24-25 Mar. 2023).
- Vinod, Anuj Krishna, Kiran, Shubi, N. Vijayan received **Best Oral Presentation Award** for paper ‘Single Crystal of an organic scintillation material N-Phenylanthranilic Acid: Potential Candidate for Non-Linear Optical Applications’ at International Conference on Crystal Growth and Spectroscopy (ICCGS-2022) organized by Department of Physics, St. Joseph's College, Trichy (29 - 31 Aug. 2022)

### Editorial Board of Reputed Journals/ Editor of Book

- Sangeeta Sahoo continued to be an Editorial Board Member for the journal “*Scientific Reports*” under the banner of Nature Publishing Group (NPG).
- *Permittivity and Its Applications*, Nova Publishers, NY, USA, 2022, Doi:10.52305/NVBF3091, Edited by Parveen Saini, CSIR-NPL, New Delhi, India
- *Emerging Applications of Carbon Nanotubes and Graphene*, 2023, USA, Taylor & Francis, CRC Press, ISBN, No. 9781032140155, Edited by Bhanu Pratap Singh and Kiran M. Subhedar
- Anshul Varshney has been appointed as Editor of *IETE Journal of Research*.
- Naveen Garg wrote a book entitled *Environmental Noise Control: The Indian Perspectives in an International Context* published by Springer Nature, Switzerland.

### Book Chapters

- Baloria V., Yadav A., Singh P., Gupta G., “Semiconductor Oxide based Chemiresistive Gas Sensors”, in book Carbon Nanomaterials and Their Nanocomposite-Based Chemiresistive Gas Sensors; Applications, Fabrication, and Commercialization., S. Dhall (Editor), Elsevier, 133-163.
- Jeevan Jyoti, B.P. Singh, M.Sandhu, S.K. Tripathi, “Recent Escalations in MXenes: From Fundamental to Applications, In: Singh, D.K., Singh, S., Singh, P. (eds) Nanomaterials. Springer, Singapore. [https://doi.org/10.1007/978-981-19-7963-7\\_8](https://doi.org/10.1007/978-981-19-7963-7_8) NVBF3091 .
- Kiran M. Subhedar, Bhanu Pratap Singh, “Introduction to Carbon Nanotubes and Graphene and their Emerging Applications”, in book Emerging Applications of Carbon Nanotubes and Graphene, Taylor & Francis, CRC Press, No. 9781032140155. NVBF3091 .

- Pallvi Dariyal, Manoj Sehrawat, S.R. Dhakate, Bhanu Pratap Singh, “Carbon Nanotubes and Graphene for Conducting Wires”, in book Emerging Applications of Carbon Nanotubes and Graphene, Taylor & Francis , CRC Press, No. 9781032140155. NVBF3091 .
- Parveen Saini, “Dielectric Properties and EMI Shielding Behaviour of Conducting Polymer based Hybrids and Composites”, in book Permittivity and Its Applications, Nova Publishers, NY, USA, 2022, Doi:10.52305/NVBF3091 .
- Singh P., Gupta G., “Recent developments in thin film deposition using the magnetron sputtering technique” in book Advances in Materials Science Research, M.C. Wythers (Editor), Nova Science Publishers, USA, 56 (2022) 197-242.
- Sushant Sharma, Reena Goyal, Mamta Rani, Sanjay R. Dhakate, Bhanu Pratap Singh, “Carbon Nanotubes and Graphene for Ballistic Protection”, in book Emerging Applications of Carbon Nanotubes and Graphene, Taylor & Francis , CRC Press, No. 9781032140155 NVBF3091 .
- Sudhanshu Gautam and Sunil Singh Kushvaha, “Bi2Se3 Topological Insulator Thin Films for Various Device Applications” in book Nanomaterials for Innovative Energy Systems and Devices, Z. H. Khan (Editor), Springer, Singapore (2022), 143-172.

## Other

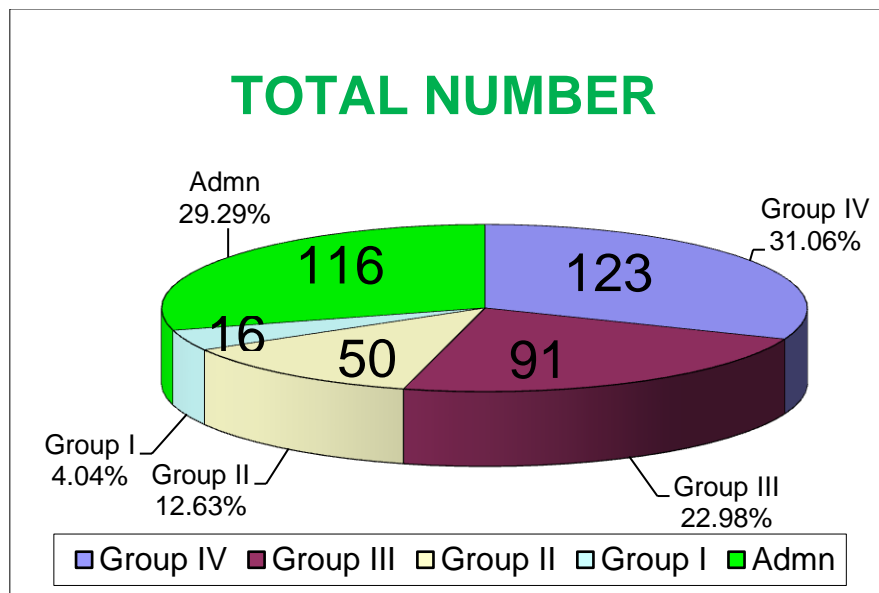
- **Enhancing Precision in Power Grid Operations: CSIR-NPL provides Traceability to PGCIL's Phasor Measurement Unit Calibration System**

In a significant stride towards strengthening the accuracy and reliability of power grid operations of the country, CSIR-NPL has extended its expertise to provide traceability to the Phasor Measurement Unit (PMU) Calibration System at Power Grid Corporation of India (PGCIL), Manesar. This strategic collaboration ensures that all PMUs tested by PGCIL are now seamlessly traceable to the national standards of the country. This traceability to the national standards signifies a commitment to maintaining the highest level of precision in power grid measurements of the country.



## Staff, Patents, Reports & Financial Outflow

- Regular Staff in Position as on 31.03.2023**



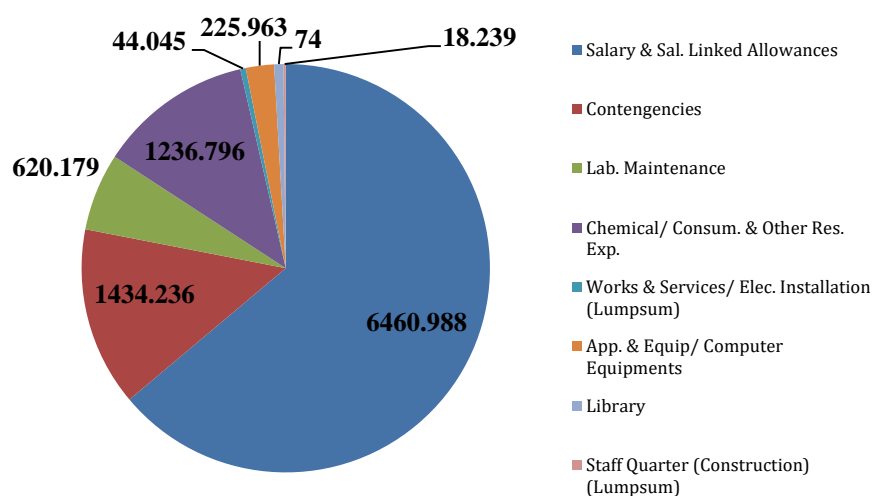
- New Recruitments (2022-23)**

S. No.	Name	Designation	Date of Joining
NIL			

- Patents & Reports**

- Patents Applications filed in India:02
- Patents Applications filed Abroad: 01
- Patents Granted in India:07
- Copyrights: 02

- Budget flow (in Lakh)**



## Patents & Copyright list

### Filed in India

SNo	Title	Inventors	Provisional Filing Date	Complete Filing Date	Application No.
1	IONIC-ASYMMETRIC ALIPHATIC DIAMINE TERMINATED RYLENEDICARBOXIMIDE ORGANIC ELECTRONIC MATERIALS	Rachana Kumar, Samya Naqvi, Mehak Ahuja, Komal Bhardwaj, Rajiv Kumar Singh, Asit Patra, Sushil Kumarss	---	02-Sep-22	202211050720
2	ELECTROMAGNETIC ACOUSTIC TRANSDUCER FOR RESIDUAL STRESS DETECTION IN MATERIALS	P K Dubey, Sanjay Yadav, Bishan Kumar	---	02-Mar-23	202311014140

### Filed in Foreign Countries

SNo	Title	Inventors	Country	Complete Filing Date	Application No.
1	ULTRASONIC PULSE VELOCITY TESTER DEVICE WITH THRESHOLD ERROR CORRECTION	PREMSHANKAR KEDARNATH DUBEY, SANJAY YADAV, PIYUSH	US	28-Sep-22	17/936018

### Granted in India

SNo	Title	Inventors	Provisional Filing Date	Complete Filing Date	Application No.	Grant Date	Patent No.
1	Mixed flow relative humidity generator	Hari Kishan, Bhikham Singh, Ashok Kumar, Shiv Dutt Sharma	---	07-Dec-12	3769DEL2012	06-Jul-22	400876
2	Boron doped manganese antimonide as a useful permanent magnet material	Singh Nidhi, Pulikkotil Jiji Thomas Joseph, Gupta Anurag, Anand Kanika, Dhar Ajay, Budhani Ramesh Chandra	17-Oct-13	24-Sep-14	3078DEL2013	25-Jul-22	401985
3	Multi-states nonvolatile opto-ferroelectric memory element and its process thereof	Ashok Kumar, Hitesh Borkar, Vaibhav Rao, Monika Tomar, Vinay Gupta	---	14-Jan-16	201611001338	29-Nov-22	412765
4	Sunlight sensitized blue long afterglow phosphor: A Commercial process for the preparation thereof	Divi Haranath, G. Swati, Singh Nahar	---	21-Feb-18	201811006559	01-Dec-22	413430
5	Electromagnetic interference (emi) shielding nanocomposites with enhanced absorption based on superparamagnetic particles decorated porous carbon	Saini Parveen, Kotnala Ravinder Kumar, Barala Sunil Kumar, Arora Manju, Pant Rajendra Prasad	19-Sep-13	19-Sep-14	2754DEL2013	31-Jan-23	419794
6	Light weight high electromagnetic	Singh Bhanu Pratap, Garg	24-Jun-11	21-Jun-12	1793DEL2011	07-Mar-23	424358



	interference (emi) shielding material based on carbon nanotubes reinforced polymer composites	Parveen, Pande Shailaja, Mathur Rakesh Behari, Saini Parveen, Dhawan Sundeep Kumar					
7	A low cost compact mixed flow relative humidity generator	Ashok Kumar, Hari Kishan, Bhikham Singh	---	14-Dec-12	3859DEL2012	23-Mar-23	426520

### Copyrights

S No	Reference Number	Copyright Title	Filed/Granted	Filed/Granted
1	035CR2022	Control and Automation Software for Calibration and Testing of Blood Pressure Measuring Devices	P K Dubey, Rahul Kumar, Ashok Kumar, Sanjay Yadav	Filed
2	036CR2022	Software for commercial ultrasonic flaw detector based five axes immersion C-Scan testing system	P K Dubey, Kalpana Yadav, Sanjay Yadav, Rahul Kumar	Filed

**CSIR-NPL: The National Metrology Institute of India**  
**Member, BIPM and Signatory CIPM-MRA**

---

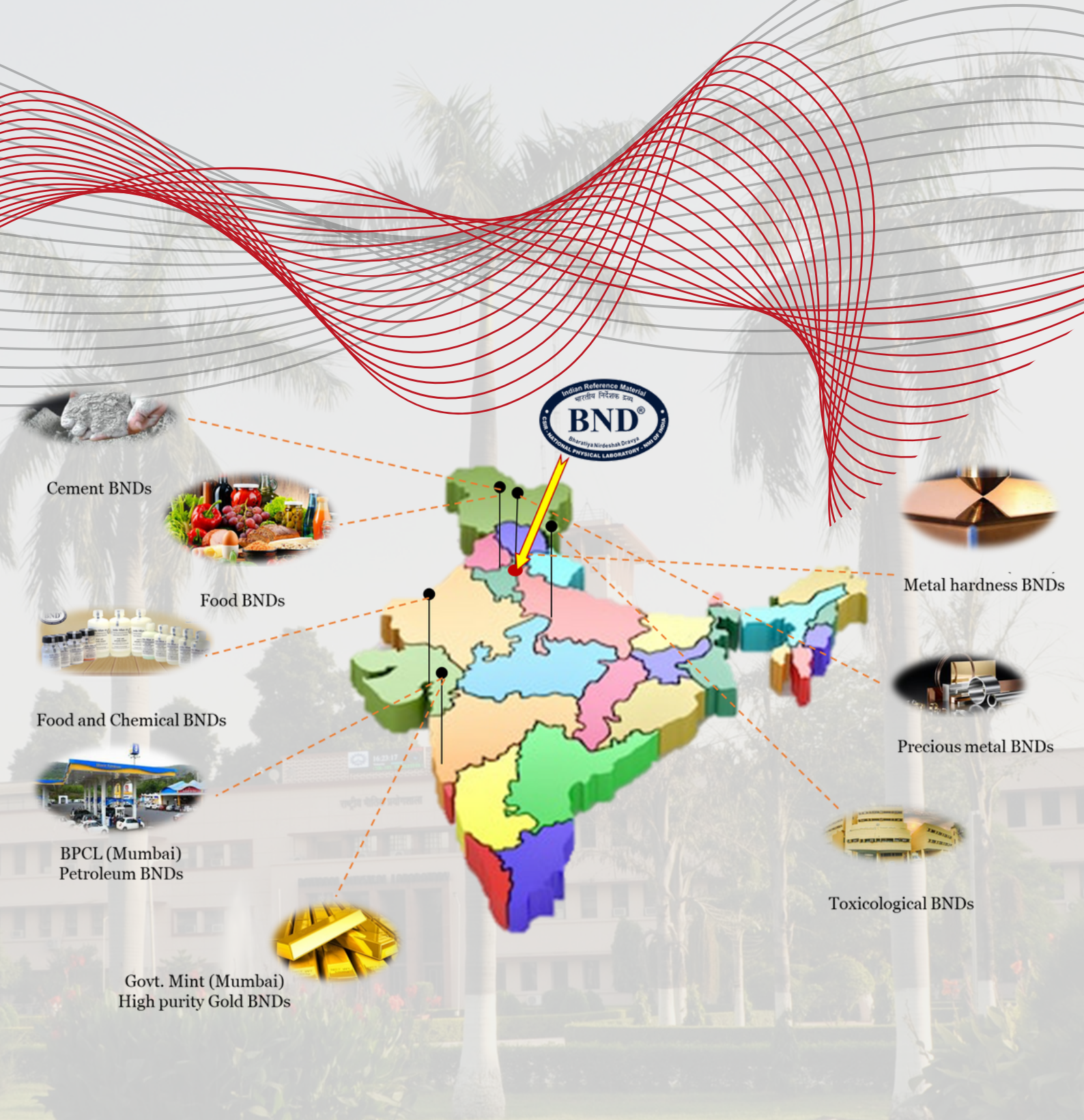
**Director, CSIR-NPL**

Tel.: +91-11-45609201, 45609301

Email: [director@nplindia.org](mailto:director@nplindia.org)

**Editing, Compiling and Publication**

- Mr. Ashish Ranjan, Senior Principal Scientist (Chairman)
- Dr. Abhishek Sharma, Principal Scientist (Convener)
- Dr. Dilip Dhondiram Shivagan, Senior Principal Scientist (Member)
- Dr. Sunil Singh Kushvaha, Principal Scientist (Member)
- Dr. Arun Kumar Upadhayaya, Senior Principal Scientist (Member)
- Dr. Bipin Kumar Gupta, Principal Scientist (Member)
- Dr. Sanjay Kumar Srivastava, Senior Principal Scientist (Member)
- Dr. Nirmalya Karar, Senior Principal Scientist (Member)
- Dr. Avni Khatkar, Scientist (Member)
- Dr. Rajesh, Chief Scientist (Member)
- Dr. Abhishek Kumar Yadav, Technical Officer (Member)



Cement BNDs



Food BNDs



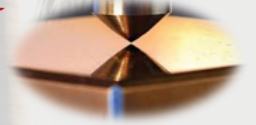
Food and Chemical BNDs



BPCL (Mumbai)  
Petroleum BNDs



Govt. Mint (Mumbai)  
High purity Gold BNDs



Metal hardness BNDs



Precious metal BNDs



Toxicological BNDs

सी. एस. आई. आर. - राष्ट्रीय भौतिक प्रयोगशाला  
**CSIR-NATIONAL PHYSICAL LABORATORY**  
**DR. K.S. KRISHNAN ROAD, NEW DELHI-110012**



Website: <https://www.nplindia.org>



सि.एस.आई.आर.  
CSIR  
भारत का नवाचार इंजन  
The Innovation Engine of India