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NIM HIGHLIGHTS

中国计量科学研究院
National Institute of Metrology,China

Editor's Note:

This edition is a compilation of selected content from the Chinese version of 2025 NIM Highlights, which is expected to be interesting to international readers from the metrology community.

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Acknowledgements:

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CONTENTS

01

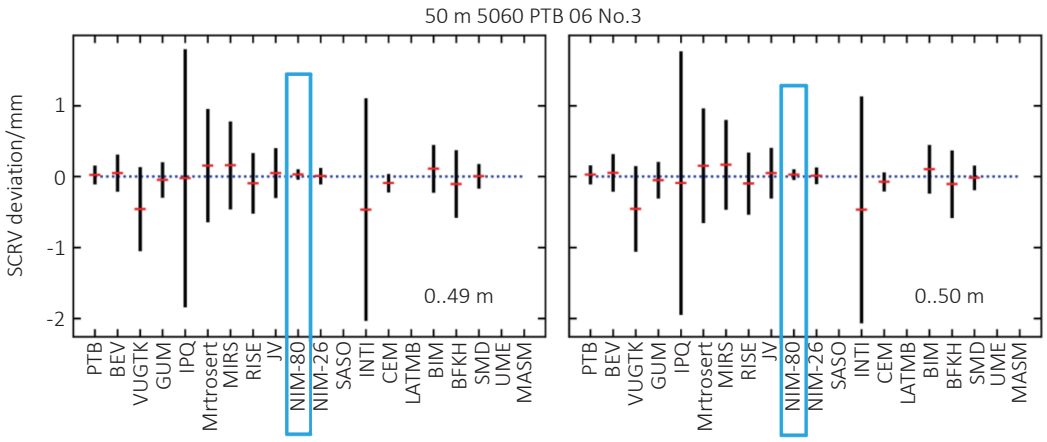
New / Renewed National Primary Standards and National Certified Reference Materials in 2025

National Primary Standard for Indoor Large-Scale Length Comparator

A length measurement standard with a wide measuring range and micrometer-level accuracy is critical to the traceability of large-scale instruments such as laser trackers and laser interferometers in the aerospace. NIM established a National Primary Standard for Indoor Large-scale Length Comparator.

National Primary Standard for
Indoor Large-scale Length Comparator

With techniques including three independent laser interferometers arranged in spatial paths to eliminate Abbe error, real-time air refractive index correction over an 80-meter distance, and precision control of an ultra-long air-bearing guideway, the primary standard achieves an expanded uncertainty of U=Q[0.05 μm, $3\times10^{-8}L$] (k=2) within the range of 80 meters. It participated in the steel tape international comparison (EURAMET.L-S2.3.n01) and obtained good comparison results.



The Steel Tape International Comparison (EURAMET.L-S2.3.n01)

The national primary standard offers calibration services for sectors including aerospace and precision instrument manufacturing, and supports technical collaboration and traceability system development in large-scale measurement.

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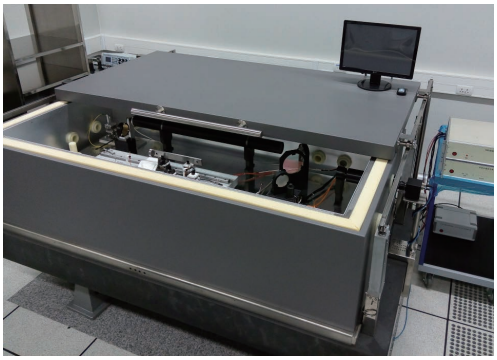
National Primary Standard for End Standards

In the field of precision manufacturing, end length measurement is widely used for dimensional calibration in measurement laboratories and quality control on industrial sites. To meet the traceability requirements for nanometer-level accuracy of end standards, NIM developed the National Primary Standard for End Standards.

The standard employs phase-shifting interferometry to automatically obtain interference fractions, and determines the measured length using the exact fractions method. It enables absolute interferometric measurement of gauge blocks in the range of (0.1 - 1000) mm, with an expanded uncertainty of 15 nm+7.5×10^{-8} L (k=2). The standard participated in the international key comparison for interferometric measurement of gauge blocks (CCL-K1), and the results demonstrated its international equivalence.

Gauage Blocks Measurement



National Primary Standard for End Standards

The standard ensures the accuracy of the source values for end standards in China, providing traceability for end standard measurement and supporting the high-end manufacturing industry.

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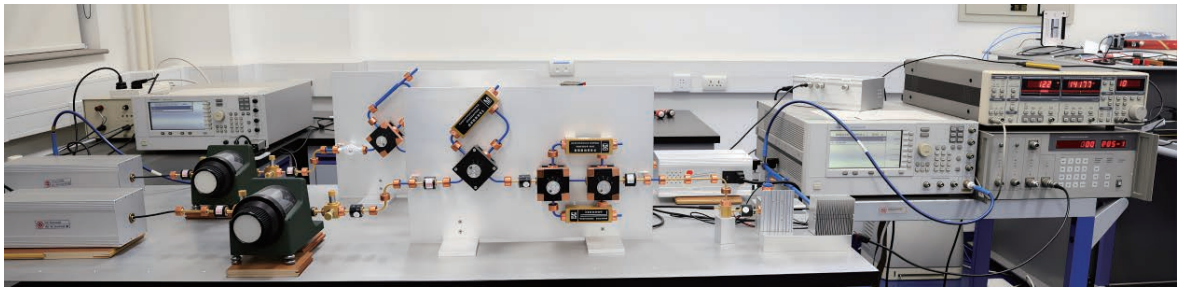
National Primary Standard for (50 – 110) GHz Attenuation



National Primary Standard for (50 – 110) GHz Attenuation

Attenuation is one of the fundamental parameters in radiofrequency and microwave metrology. NIM developed an attenuation national primary standard covering the frequency band of (50 – 110) GHz.

A hybrid dual-channel method and a local oscillator phase noise cancellation technique were proposed and applied, achieving a dynamic range of 80 dB with an expanded uncertainty better than 0.1 dB (k=2).

The standard enables traceability of attenuation across a broad bandwidth and a wide measurement range, underpinning performance improvements for various millimeter-wave equipment applied in communications, detection, and autonomous driving.

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National Primary Standard for Optical Radiant Power

Optical radiant power is a core quantity in photometry and radiometry. High-accuracy measurements of radiant power underpin climate change monitoring, satellite remote sensing calibration, photovoltaic device evaluation, and LEDs and display performance evaluation. NIM developed the National Primary Standard for Optical Radiant Power based on spectral cryogenic radiometer.

National Primary Standard for Optical Radiant Power

The standard overcame multiple technical challenges, including power stabilization of broadband light sources and absolute spectral responsivity calibration in the visible-to-infrared range. It also resolved difficulties in absolute optical power measurement, such as window transmittance effects and low signal-to-noise ratios in spectral signals. The achieved expanded uncertainty of optical radiant power measurements was (0.02 - 0.08)% (k=2).

The standard has served ground-based calibration for China's Fengyun series meteorological satellites and photovoltaic module power traceability. It also supports on-orbit radiometric calibration of space remote sensors, power efficiency evaluation in photovoltaic and LED applications, and performance characterization of novel photodetectors.

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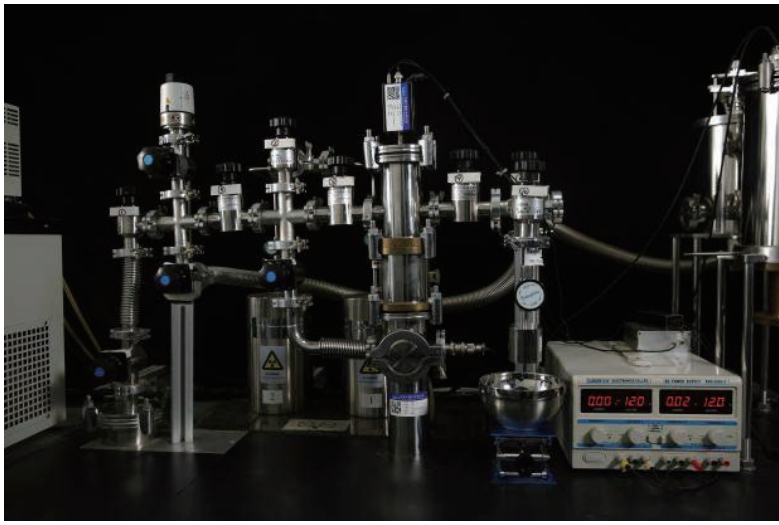
National Primary Standard for Activity of Radioactive Gas

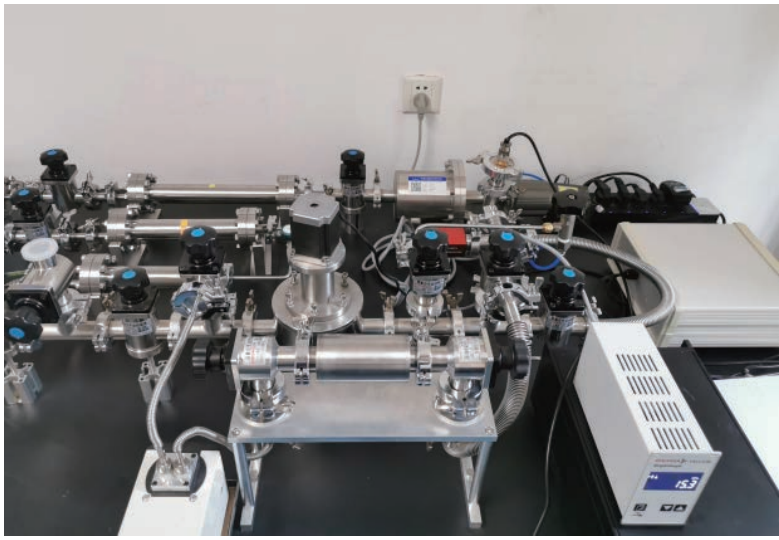
Gaseous radionuclide activity measurement is applied in nuclear safety, environmental protection and atmospheric science. NIM established the National Primary Standard for Activity of Radioactive Gas, consisting of two measuring systems: a defined solid-angle gas activity measuring apparatus and an internal gas proportional counting gas activity measuring apparatus.

The defined solid-angle gas activity measuring apparatus adopted the absolute measurement technique of defined solid-angle with condensed radon sources. For radon gas (^{222}Rn), a naturally occurring carcinogen, the relative expanded uncertainty of activity measurement was 0.51% - 0.60% (k=2). The internal gas proportional counting gas activity measuring apparatus adopted the absolute measurement method via length-compensated internal gas counters. For gaseous fission effluent nuclides such as krypton (^{85}Kr) and xenon isotopes (^{133}Xe, ^{135}Xe, etc.), the relative expanded uncertainty of activity measurement ranged from 1.4% to 3.0% (k=2).

The standard provides traceability for activity measurements of radioactive gases in nuclear safety and radiation protection applications.



Defined solid-angle gas activity measurement apparatus



Internal gas proportional counting gas activity measurement apparatus

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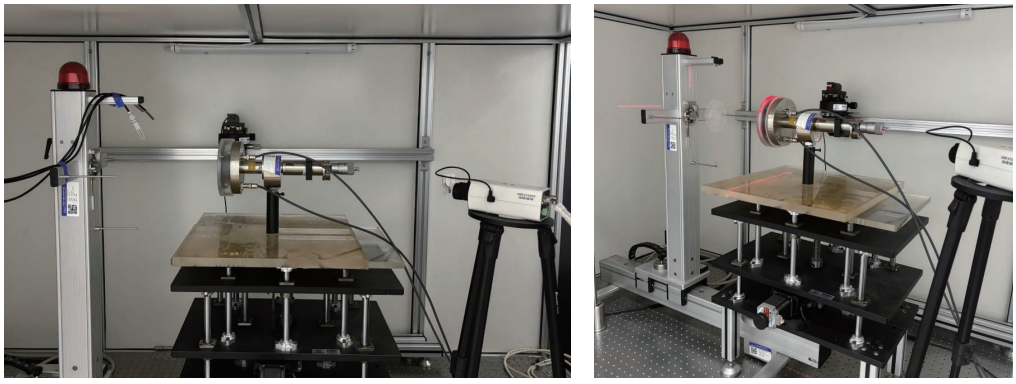
National Primary Standard for Beta Radiation Tissue Absorbed Dose

Beta radiation poses potential hazards to human tissue. To provide traceability of tissue absorbed dose for beta radiation, NIM developed the National Primary Standard for Beta Radiation Tissue Absorbed Dose.

The standard mitigates the volume effect interference associated with the "large cavity" problem. By employing an extrapolation chamber with a variable cavity volume, in conjunction with a stable radiation field and a precision weak current measurement system, the standard accurately determines the tissue absorbed dose with an expanded uncertainty of 2.4% to 2.8% (k=2). The standard participated in the EURMET.RI (I)-S16 international comparison, demonstrating good equivalence with the international reference values.



National Primary Standard for Beta Radiation Tissue Absorbed Dose

The National Primary Standard provides a technical foundation for quantity value dissemination, and supports dosimeters performance rating and dose quality control in medical plaque brachytherapy.

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National Certified Reference Materials for Atomic-Level Line Width

To establish an atomic-scale metrological traceability system, NIM developed line width reference materials with atomic-level uncertainty, which were approved as the first-class National Certified Reference Materials.

This achievement employed a novel secondary method (silicon lattice spacing) of realizing the metre for dimensional nanometrology, and constructed a cross-environment traceability chain for silicon lattice spacing from lossy resolvability to non-lossy non-resolvability. For application scenarios such as transmission electron microscopy (TEM), scanning electron microscopy (SEM) and scanning probe microscopy (SPM), NIM developed both planar and three-dimensional nano line width reference materials, achieving a best expanded uncertainty as low as the atomic level (<1 nm).

The reference materials meet the needs for traceability of line width measurements in atomic-scale manufacturing.

National Certified Reference Materials for Atomic-level Line Width

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02

Technical Advancements

NIM's Strontium Optical Lattice Clock Steers International Standard Time

International standard time provides a single, uniform time reference facilitating international telecommunications, navigation, scientific research, and commerce. Optical clocks were planned to replace cesium atomic clocks to redefine the SI second thanks to their superior frequency uncertainties. As part of this redefinition process, several optical clocks around the world have been approved to calibrate the international standard time.

The strontium optical lattice clock NIM-Sr1, developed by NIM, was approved to steer the international standard time in 2025 with a relative uncertainty of 3.1×10^{-16}. The optical clock passed rigorous review by the experts of the Consultative Committee for Time and Frequency (CCTF). The BIPM published the calibration data of NIM-Sr1 in the 454th Circular T.

It marked the first time that an optical clock developed in China had been approved to participate in steering the international standard time. This will lead more Chinese optical clocks to engage in the cooperation in international atomic time. NIM now has a total of three primary and secondary frequency standards (PSFSs) contributing to the international standard time, including NIM-Sr1. The PSFSs are capable of independently calibrating China Standard Time (CST), which provide solid support for research and industry in China.

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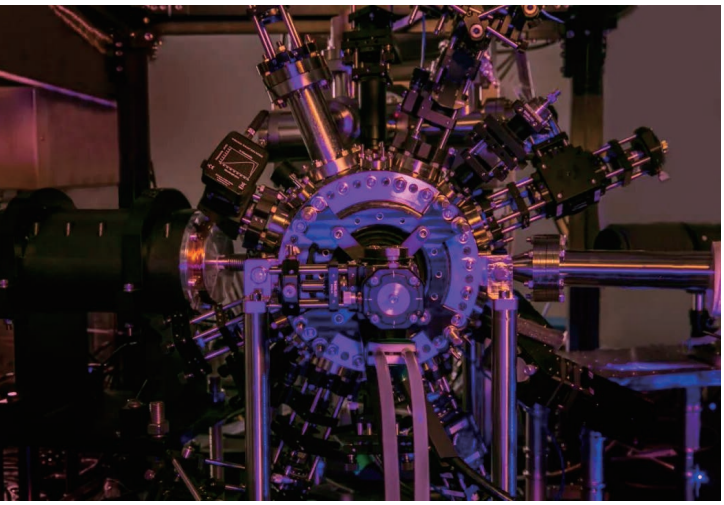
Publication: *Metrologia*, 2021 58:035010
https://doi.org/10.1088/1681-7575/abf33e



The strontium optical lattice clock NIM-Sr1

From Static to Dynamic, from Classical to Quantum: New Breakthroughs in Gravity Measurement at NIM

Dynamic gravimetry is a key technology underpinning marine resource exploration, geoscience research, and assisted navigation. Traditional calibration methods suffer from dependence on static environments and difficulty in adapting to complex marine operating conditions. NIM has overcome the technical challenges of high-frequency free-fall release, high-speed data processing, and carrier motion compensation. NIM researchers have developed a cam-driven laser interferometer-type field calibration device for marine gravimeters and conducted offshore dynamic trials. The trials verified the feasibility of the 1 mgal field calibration technical scheme, which will support field calibration of marine gravimeters in the future.

High-precision quantum gravimeters have demonstrated significant application value in resource exploration, earthquake early warning, and cutting-edge navigation. However, due to the lack of unified international standards, the global market lacks an instrument performance evaluation framework and mutual recognition agreements for products, hindering global industrial collaboration and the deployment of the technology at scale. NIM's gravity measurement research team jointly with partners from France, proposed the international standard proposal *Quantum technologies—Performance evaluation and test methods for absolute quantum gravimeters based on free-falling cold atoms*, which has been officially approved for development by the IEC/ISO Joint Technical Committee 3 (IEC/ISO JTC3). This standard will systematically specify the performance parameters and test methods for quantum gravimeters based on the principle of free-falling cold atoms, filling a gap in international standards in this field and supporting the development and application of quantum gravimeters.

Photo of the marine gravimeter field calibration device during offshore testing

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Publication: *IEEE Joint International ITAIC*, Pages 131-138, 2023

https://doi.org/10.1109/ITAIC58329.2023.10408977

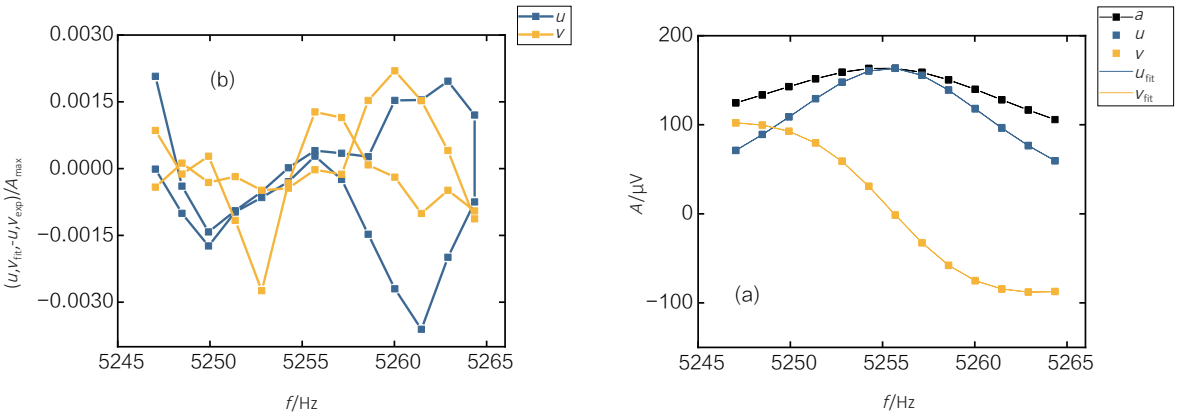
The World's First Integrated Measurement System of Primary Acoustic Gas and Radiometric Thermometers with Same Temperature Source

Thermodynamic temperature serves as the fundamental source for establishing the International Temperature Scale (ITS). In the range from 400 K to 1300 K, there is a global lack of overlapping and cross-validated measurement data obtained by both contact and non-contact primary thermometry, which constitutes a key technical obstacle to the revision of the ITS.

NIM has developed a globally unique experimental apparatus that integrates both acoustic gas and radiometric primary thermometers with the same temperature source, suitable for thermodynamic temperature measurements from 400 K to 1300 K. This achievement resolved the challenges of temperature and pressure control at high temperatures, and coupling problem of size-of-source effect with blackbody cavity. It enabled the measurement of the resonator's internal dimensions with an accuracy of 10^{-6} at 1300 K. In addition, the developed relative spectral responsivity measurement system based on supercontinuum laser extended the out of band limit by a factor of 100 compared with conventional light source.

This work achieved, for the first time internationally, simultaneous measurements using both acoustic gas and radiometric primary

Integrated primary acoustic gas and radiometric thermometer with same temperature source



Acoustic measurements at 809 K and 565 kPa

methods at the same temperature source over the range of 400 K to 1300 K. lt is expected to provide the necessary T-T90 data to improve the temperature scale in the future.

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Publication: *Philosophical Transactions of the Royal* Society A, 2026, 384 (2312): 20240454.

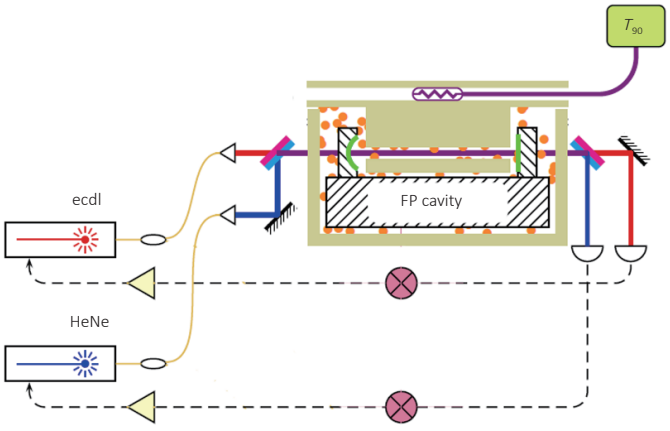
https://doi.org/10.1098/rsta.2024.0454

Two-Color Method Realizing Primary Measurement of Quantum Pressure

Measuring pressure using light is a promising research direction for establishing quantum pressure standards. However, over the past decade, the deformation of optical resonant cavities under pressure contributing the most significant uncertainty, has been a major obstacle to a fully primary standard. A joint study performed at NIST by researchers from NIM and NIST has effectively resolved this challenge.

This work innovatively employed two laser beams at different wavelengths, i.e. 633 nm and 1542 nm, for simultaneous measurements, achieving, for the first time, a primary measurement of pressure based on quantum properties of helium. The relative standard uncertainty at 5 atmospheres was 5.7×10^{-6}, with a deviation of 2.2×10^{-6} from the mechanical pressure standard, which can be seen as a new test for the quantum electrodynamic (QED) theory at the level of 2 parts per million.

The work, published in *Physical Review Applied*, has laid a key technical foundation for the establishment of a quantum pressure standard.



Schematic of coupling two laser beams at 633 nm and 1542 nm to a Fabry-Perot cavity

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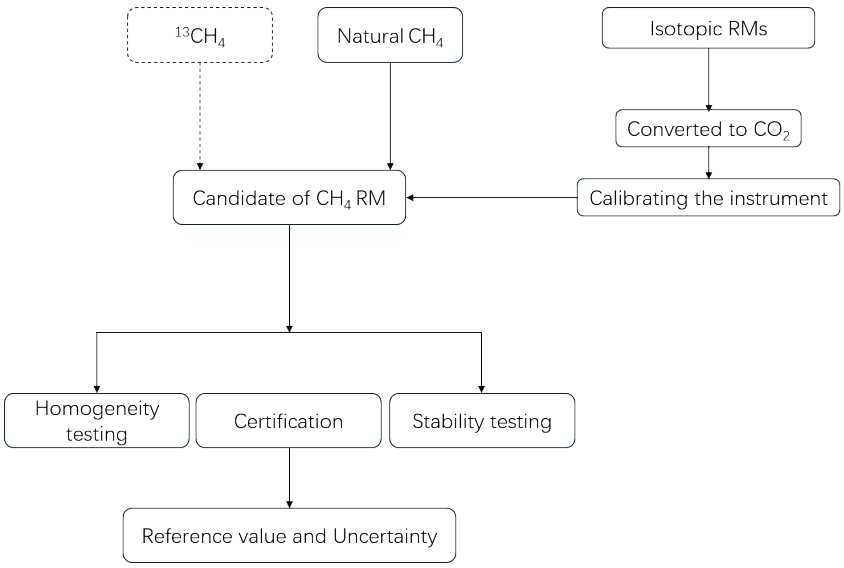
Publication: *Physical Review Applied*, 23 (2025) 064041.
https://doi.org/10.1103/z9zz-lqzh

NIM Achieves Breakthrough in Developing Methane Isotope Reference Materials

Methane is one of the important greenhouse gases (GHGs). Carbon stable isotope technology is commonly used internationally to trace the sources of atmospheric methane and to investigate the methane production mechanisms in deep-sea environments. This technology relies on methane isotopic reference materials to calibrate the measurement system. However, there is currently no internationally available methane isotopic reference material.

NIM has successfully developed a synthesis technique based on the weighing method for methane isotopic reference materials with varying isotope ratios, and established a certification technique for methane isotopes based on the freeze concentration, chromatographic separation, and oxidation conversion methods. Using the techniques, the team developed 4 pure methane and 2 methane in air isotopic reference materials with the expand uncertainty of lower than 0.2 ‰ (k=2).



Schematic of methane isotopic reference material development

The techniques can be used to develop methane isotopic reference materials with varying concentrations and isotopic ratios, providing metrological support for methane isotope measurement in the atmosphere and deep–sea environments.

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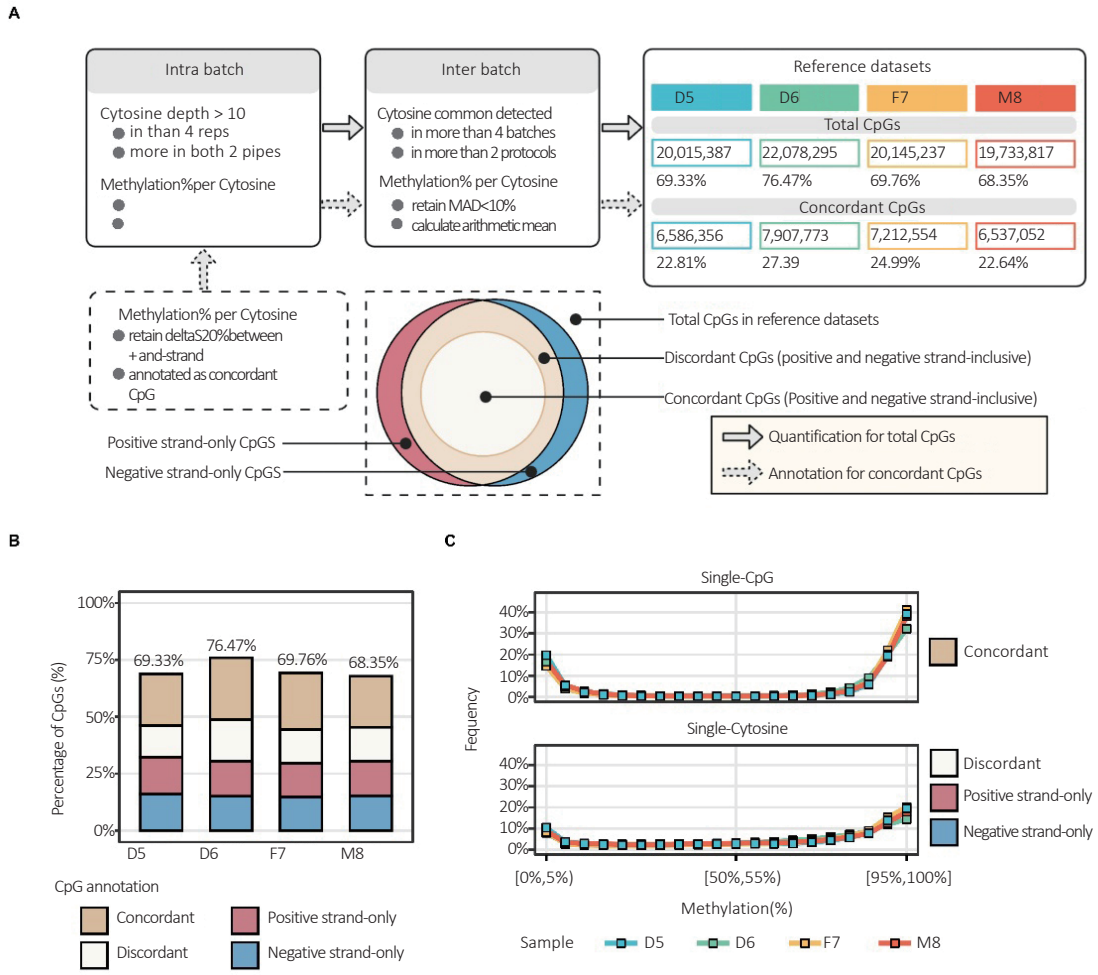
Publication: *Chemical Reagents*, 48 (2026) 81-87

https://doi.org/10.13822/j.cnki.hxsj.2025.0146

NIM Establishes Genome-Wide Quantitative DNA Methylation Reference Datasets

DNA methylation (5mC), as a crucial epigenetic modification, holds significant value for the development of disease biomarkers. However, due to variations in experimental protocols, sequencing platforms, and analytical pipelines, methylation sequencing has long suffered from cross-platform inconsistencies, which severely hinders the clinical translation of this technology.

To address this challenge, NIM, utilizing the certified Quartet DNA reference materials, comprehensively applied three international mainstream technologies including WGBS, EM-seq, and TAPS to conduct cross-laboratory DNA methylation sequencing, successfully generating 108 high-depth datasets. By integrating rigorous quality control and a consensus voting framework, the team



Construction of genome-wide methylation quantification reference datasets

established genome-wide quantitative methylation reference datasets at single-cytosine levels for the first time.

Published in *Nature Communications*, this study systematically elucidated the core contributions of strand-specific measurement biases and site-specific sequencing depths to improving quantitative accuracy. These findings provide technical support and an internationally equivalent traceable benchmark for the standardized performance evaluation, analysis pipeline calibration, and high-level quality control of emerging epigenomic technologies.

Contact: Dr. DONG Lianhua
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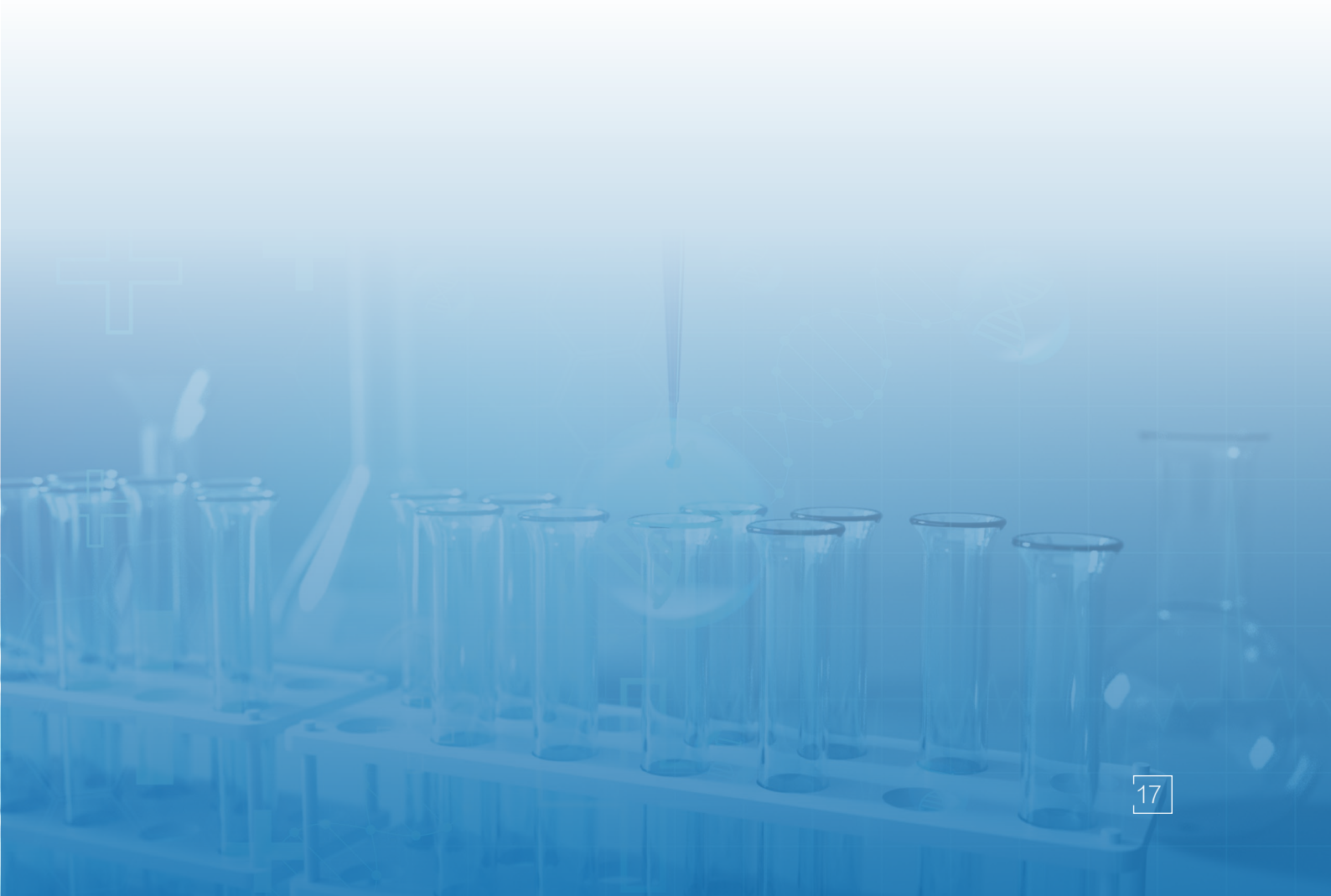
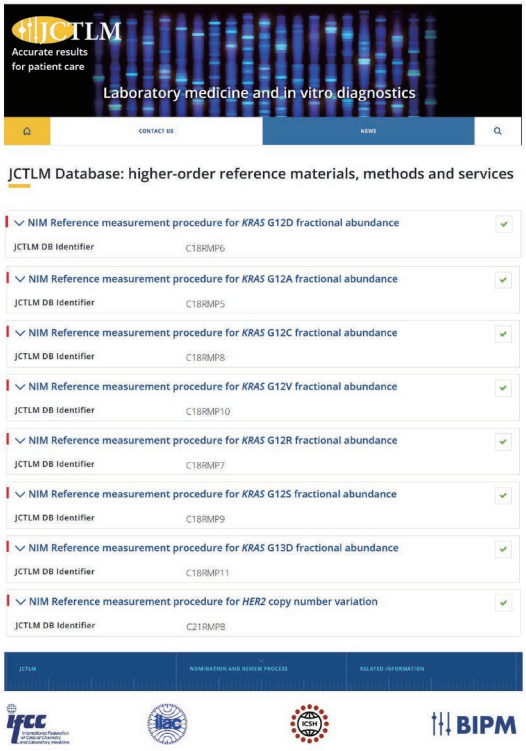
Publication: *Nature Communications*. 2025, 16 (1): 9202.
https://doi.org/10.1038/s41467-025-64250-z



NIM Developed Measurement Procedures for Cancer Gene Mutations Recognized by JCTLM as Higher-Order Reference Measurement Methods

In molecular diagnostics, the accurate measurement of gene mutations is crucial for guiding targeted cancer therapies and disease prognosis. However, the absence of a unified metrological benchmark has created severe technical bottlenecks, leaving genetic testing data untraceable and incomparable, which significantly restricts international harmonization and mutual recognition of testing data.

NIM has innovatively established a system of higher-order reference measurement methods for cancer hotspot mutations based on single-molecule amplification technology. With absolute quantification of mutant and wild-type nucleic acid molecules, this approach achieved the accurate measurement of somatic hot-spot mutations associated with malignancies such as breast and lung cancers.



JCTLM High-order Reference Methods Established by NIM

Eight reference measurement procedures (RMPs) developed by the NIM team, covering seven *KRAS* gene mutation fractional abundances and *HER2* copy number variation, have been officially included in the JCTLM database as higher-order reference methods, thereby anchoring global consistency and mutual recognition of testing data in oncology diagnostics.

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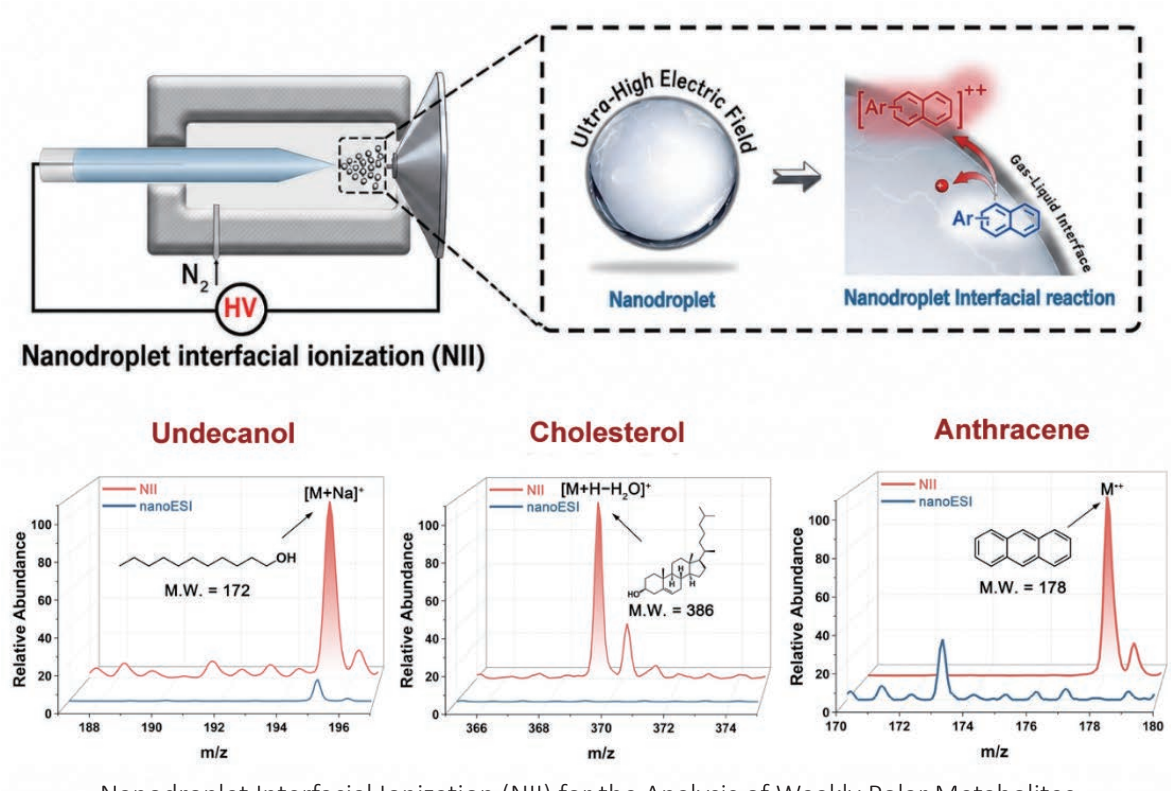
Publication: *Analytical and Bioanalytical Chemistry*. 2023, 415 (4) : 725-733.
https://doi.org/10.1007/s00216-022-04466-w

Highly Sensitive Detection of Weakly Polar Metabolites by Nanodroplet Interfacial Ionization Coupled with Mass Spectrometry

Metabolomics can serve as a real-time dynamic molecular guide for early disease screening and precision medication. In single-cell metabolomics analysis, weakly polar and non-polar compounds such as lipids and steroids are difficult to be detected by conventional mass spectrometry due to low ionization efficiency and significant matrix interference, which has constrained the comprehensive characterization of cellular metabolism.

To address this technical bottleneck, the Mass Spectrometry Laboratory of NIM, has developed a nanodroplet interfacial ionization (NII) technique based on nanodroplet interfacial reactions. This technique enhances the ionization efficiency of trace weakly polar



Nanodroplet Interfacial Ionization (NII) for the Analysis of Weakly Polar Metabolites

compounds by one to two orders of magnitude and significantly suppresses matrix interferences from proteins, salts, and other substances. Using this technique, the research team achieved direct detection of weakly polar substances such as polycyclic aromatic hydrocarbons in single cells, with a sensitivity reaching 10^{-18} mol. The findings were published in *Analytical Chemistry*.

The NIM team has further integrated this technique with an optofluidic optical tweezers system, enabling label-free capture and real-time in situ analysis of target cells, thus providing a novel technological pathway for live-cell metabolic research. This technique has promising applications in metabolic status monitoring and quality control of therapeutic products such as stem cells and CAR-T cells, thereby supporting the assessment of the safety and efficacy of cell-based therapies.

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Publication: *Analytical Chemistry*, 2025, 97 (32): 17795-17803.
https://doi.org/10.1021/acs.analchem.5c03362

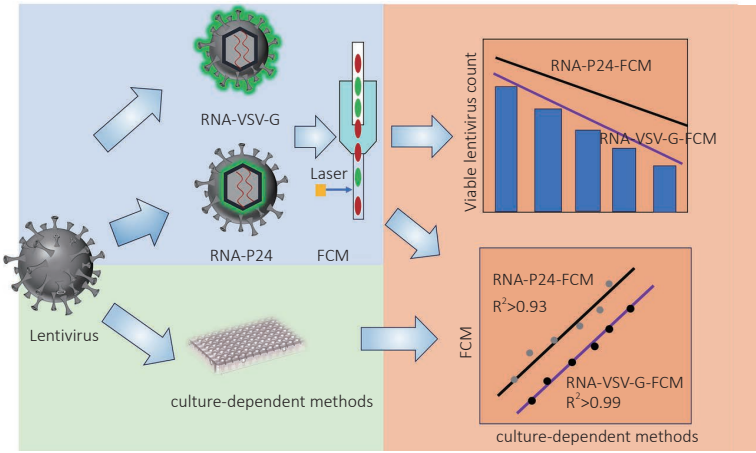
Unlocking Viral Viability: Accurate Quantification of Viable Lentiviral Vector in One Hour

Precise dose control of lentiviral vectors is essential for ensuring product safety and controlling costs in gene and cell therapy. Conventional culture-based viability assays typically require 3 to 4 days and exhibit limited repeatability. The rapid methods, meanwhile, are susceptible to interference from empty viral particles, proteins, and nucleic-acid fragments, making it difficult to specifically identify and accurately quantify viable viral particles.

To address those challenges, NIM developed an RNA–VSV-G dual-label flow cytometric method. The method simultaneously detects lentiviral RNA and the vesicular stomatitis virus G glycoprotein (VSV-G), rather than P24 protein, which mediates viral entry into target cells. Particles positive for both RNA and VSV-G are counted as viable lentiviral particles, while non-target impurities can be excluded.

The method enables accurate quantification of lentiviral particles with different viability states within one hour, with a detection limit of 1 particle/μL. It showed strong linear relationship with conventional culture-based assays (R^2> 0.99) and has been successfully applied to support the repeatable preparation of CAR-expressing Jurkat cells, achieving a robust cell positivity rate of 75%.

This work provides a rapid and accurate metrological approach for process quality control of viral vectors. It may also support the development of future international measurement standards and interlaboratory comparisons for lentiviral vector viability.



Rapid and Accurate Quantification of Viable Virus Particles with a Dual-label Detection Strategy Targeting Functional Proteins and Nucleic Acids

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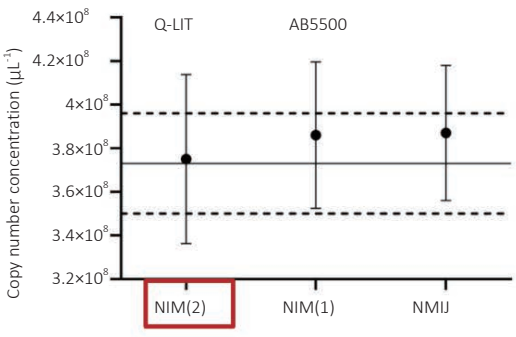
Publicaiotn: *Analytical Chemistry*, 2025 97 (27): 14512-14520.
https://doi.org/10.1021/acs.analchem.5c01862

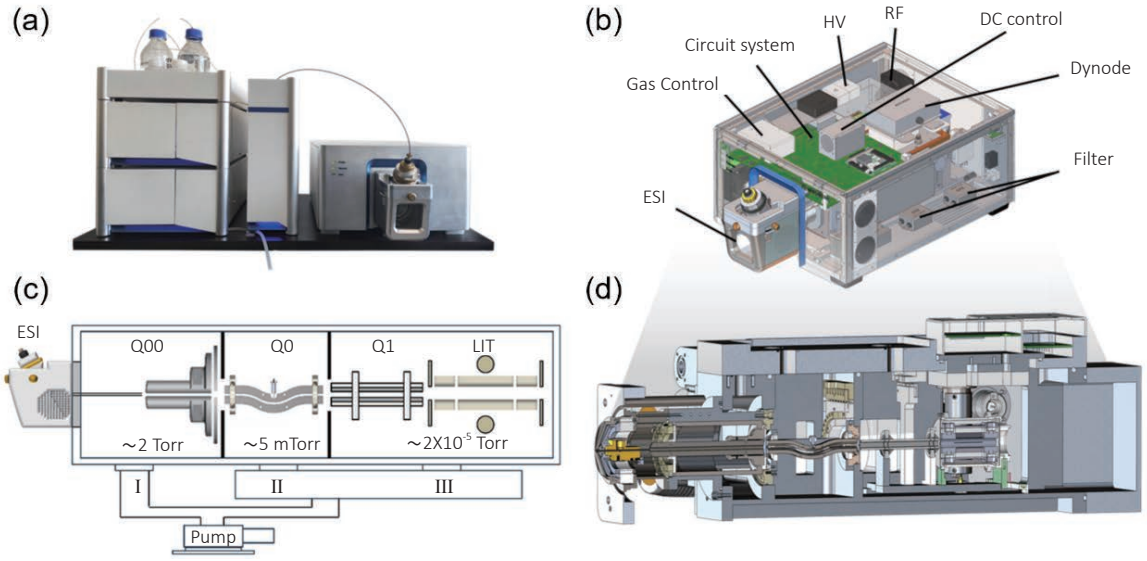
Quadrupole-Linear Ion Trap Tandem Quantitative Bio-Mass Spectrometer Supporting Precision Medicine

Early-stage disease biomarkers, present in extremely low concentrations in human blood and body fluids, are subject to complex background interference. Traditional detection techniques lack sufficient sensitivity and accuracy, making them difficult to meet the clinical needs for early disease screening and precision diagnosis.

NIM has developed a new mass spectrometry (MS) system based on a linear ion trap that enables simultaneous separation, enrichment, fragmentation, and precise measurement of gaseous ions, significantly enhancing the instrument's sensitivity, accuracy, and linear range. The limit of quantification for reserpine has been improved from 3 fg to 0.3 fg, with intra-day peak area repeatability better than 2.95%. Validation results showed excellent linearity within the range of 0.3 fg–300 pg (six orders of magnitude), with correlation coefficients≥ 0.9999. Long-term stability, assessed through 200 con-



Ultra-sensitive Quadrupole-linear Ion Trap Liquid Chromatography-mass Spectrometry System



Compact Liquid Chromatography-mass Spectrometry System (LC-MiniMS)

secutive injections of vancomycin in serum samples, was better than 2.13%, enabling the precise qualitative and quantitative detection of trace biomarkers in complex biological samples.

This achievement has received a Gold Award at the Beijing Conference & Exhibition on Instrumental Analysis (BCEIA) and two Chinese Clinical Medical Device Registration Certificates. This MS was used to complete the CCQM-K181 Key Comparison "SARS-CoV-2 RNA Copy Number Quantification," with the results achieving international equivalence. It is capable of accurately analyzing amino acids, vitamins, hormones, and therapeutic drugs in matrix samples such as whole blood, plasma, serum, and urine, supporting early disease screening and precision diagnosis.

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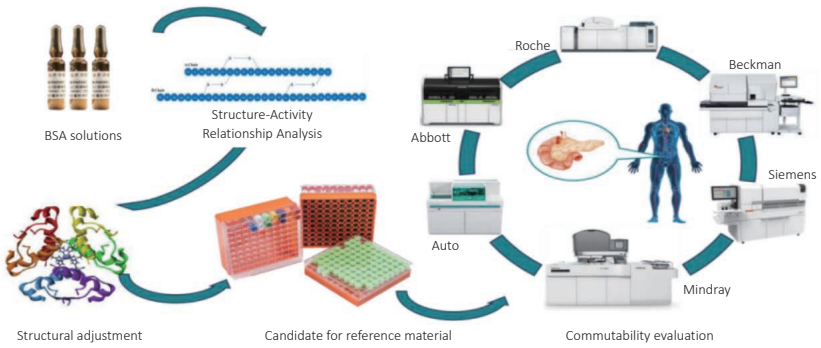
Publication: *Chinese Chemical Letters*, 2025, 37 (6): 112109.
https://doi.org/10.1016j.cclet.2025.112109

Protein Affinity Measurement: Innovations and Industrial Applications

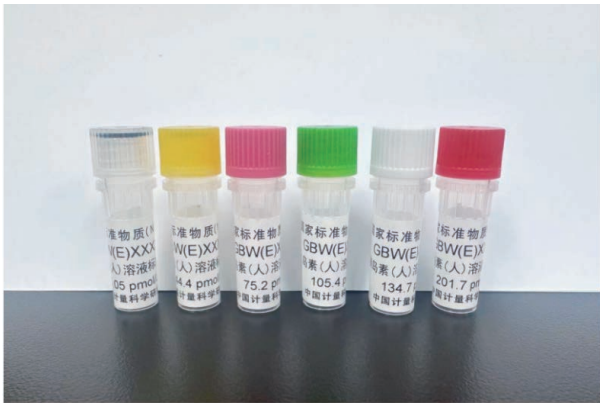
Protein affinity is a core parameter in drug screening and in vitro diagnostic (IVD) reagent development. However, the industry has long faced significant challenges, including the lack of accurate methods for measuring active concentration, a shortage of certified reference materials (CRMs), and the inability to precisely determine affinity constants.

NIM has achieved a series of innovations spanning active protein purification instrumentation, metrological methods, CRMs, and industrial applications:



Structure-activity-based Commutability Modulation Technology

- Developed an active protein purification system enabling real-time monitoring of affinity, for which a national invention patent was granted;
- Established a calibration technique for the core parameters of surface plasmon resonance (SPR) instruments and an SPR-based method for measuring protein active concentration, achieving an expanded uncertainty of 4.8% (k=2);
- Proposed a structure–activity relationship (SAR)-based commutability modulation technique for CRMs, for which a national invention patent was granted; and
- Developed a series of commutable human insulin solution CRMs that, compared with existing serum insulin CRMs, reduced production cost to less than 1% and lowered measurement uncertainty by 38%.



Commutable insulin solution reference materials

These achievements have been applied to the performance evaluation of domestically produced SPR spectrometers, the active concentration measurement of transgenic protein standards in agricultural breeding, and immunoaffinity-enrichment-based isotope dilution mass spectrometry quantification of serum myoglobin. This work has effectively corrected systematic errors introduced by differences in antibody affinity, ensuring consistency between mass spectrometry and immunoassay results.

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https://doi.org/10.1515/cclm-2025-032

Calibration of Bioaerosol Monitors: Quantitative Generation of Fluorescent Particles Based on Inkjet Technology

Bioaerosols can cause health hazards including inflammation, allergies, and respiratory diseases. Currently, commonly used bioaerosol monitors are based on ultraviolet (UV)-induced fluorescence methods. However, the fluorescence interference from non-biological particles such as vehicle exhaust, cigarette smoke, and polycyclic aromatic hydrocarbons (PAHs) significantly undermines the measurement reliability of these monitors.

To address the calibration and performance evaluation of such monitors, NIM has developed an Inkjet Aerosol Generator (IJAG). By adjusting parameters such as generation conditions and solution concentration, the IJAG can effectively produce monodisperse solid particles in the size range of 0.4 μm to 15 μm. Tryptophan (Trp) and 7-hydroxycoumarin-4-acetic acid (7-HCA) were selected as fluorescent tracers to simulate the fluorescence emission characteristics of ambient bioaerosols. The IJAG can serve as a standard aerosol generator, with the particle size and number concentration of the generated aerosol traceable to SI units. The expanded uncertainties are 0.84% and 2.8% (k=2), respectively.

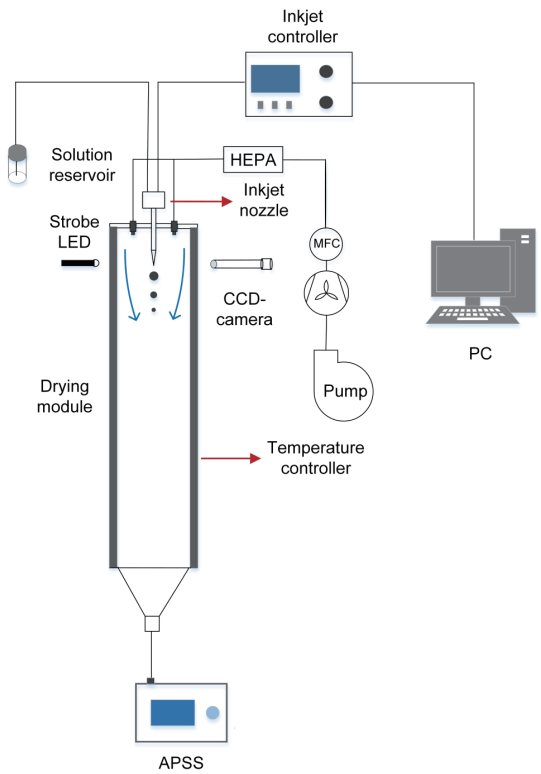

Diagram of the developed Inkjet Aerosol Generator (IJAG)

The IJAG has been used for on-site and factory calibration of online bioaerosol monitors, ensuring measurement reliability and delivering SI-traceable metrological support for environmental monitoring and public health early warning.

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Publication: *Science of the Total Environment*, 2024, 947, 174633.
https://doi.org/10.1016/j.scitotenv.2024.174633

03

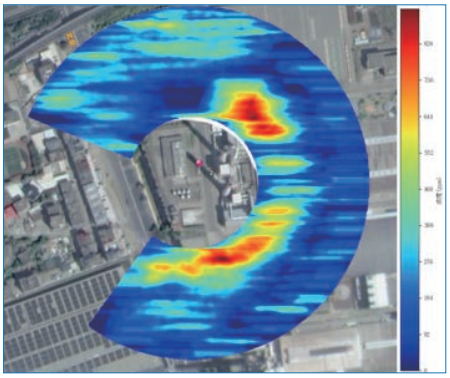
Services to Industry

High-Precision Energy and Industrial Carbon Emissions Monitoring System

The demand for high-precision monitoring of greenhouse gases (GHGs) is growing rapidly across the energy and industrial sectors. Traditional differential absorption lidar (DIAL) systems are primarily concentrated in the 1.5 μm wavelength band, but they suffer from insufficient spatio-temporal resolution and high detection limits, making them unable to meet the requirements for high-precision on-site emissions monitoring.

NIM has optimized the generation of mid-infrared lasers and the reception of weak-echo-signals, achieving a breakthrough in the key technique for fabricating narrow-linewidth, highly stable laser light sources in the 2 μm band. Building on this, the team has developed a DIAL monitoring system capable of quantitative remote sensing of CO_2 over long distances within industrial sites. Field test results from coal-fired power plants and glass manufacturing facilities showed that the average deviation between the DIAL system and continuous emissions monitoring systems (CEMS) ranged from 0.95% to 4.34%, comparable to the performance of similar international monitoring equipment.

Field testing of DIAL at an industrial site



Two-dimensional CO_2 concentration distribution map

This system has already been deployed across a wide range of industrial scenarios in China, such as thermal power generation, glass manufacturing, oil and gas extraction, landfills, and industrial park verification, having cumulatively served more than 10 industrial carbon emission measurement sites. In the future, it can be used to support routine carbon emission verification for various industrial enterprises, providing a reliable and integrated industrial carbon emission measurement solution for the precision monitoring of regional industrial GHG emissions and the empirical validation of carbon emission factors (CEFs) for energy and industrial products

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Smart Metrology Supervision Platform for Electric Vehicle Supply Equipment

By the end of Dec. 2025, the total number of Electric Vehicle Supply Equipment (EVSE) connectors in China had surpassed 20 million, and the average power per public EV charging connector had reached 46.53 kW. Conventional verification methods struggle to efficiently serve such a vast number of EVSE units and to meet the demand for evaluating the high-power and highly dynamic metrological performance of ultra-fast EVSE units.

NIM developed a phantom-load verification device for ultra-fast EVSE units. Using the phantom-power-based full-load-curve verification technique, the device enables automated verification of EVSE units without consuming actual electrical energy, thereby avoiding energy waste. The team also established three remote intelligent metrology cabins in Hangzhou City, Qingdao City, and Hefei City in China. These cabins integrate remote verification, video monitoring, temperature and humidity monitoring, and encrypted data transmission into mobile metrology laboratories, enabling remote acquisition, trusted transmission and dynamic supervision of verification data.

Remote Intelligent Metrology Cabin for EVSE

Verification Device for Ultra-fast DC EVSE Calibrators

The smart supervision platform, enabled by data collaboration with industry partners, has been demonstrated in 34 cities across five provinces in China, i.e. Provinces of Zhejiang, Shandong, Fujian, Hainan, and Anhui. Utilizing online monitoring data from over 13,000 EVSE units in more than 800 charging stations, it can improve regulatory efficiency, reduce overall costs and enhance trust in charging transactions.

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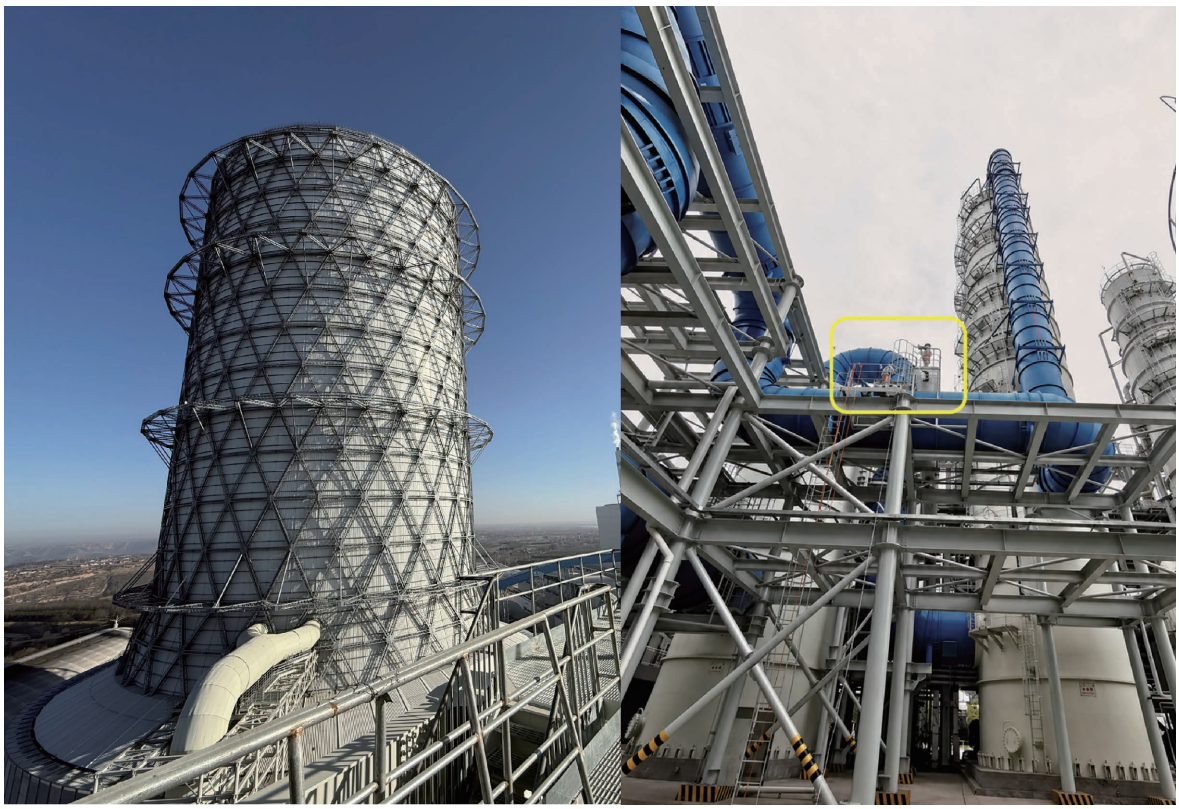
Online Energy Measurement System for Industrial-Scale Carbon Capture, Utilization and Storage

By the end of 2025, the annual CO_2 capture and storage capacity of operational carbon capture, utilization and storage (CCUS) facilities worldwide had exceeded 50 million tons. The demand for high-precision energy measurement and performance assessment of CCUS systems is growing rapidly. Conventional measurement methods are highly susceptible to variations in facility scale, fluctuations in operating conditions, and system heat losses, difficult to meet the requirements for dynamic energy consumption measurement and cross-project performance comparison.

NIM has systematically optimized the calibration of various sensors in the distributed control system (DCS) of CCUS, as well as the online monitoring performed through these sensors for complex operating conditions involving high temperature, high humidity, multi-component gas mixtures, and flow fluctuations. Breakthroughs have been achieved in



Field testing at a CCUS demonstration project

monitoring boundary determination, adaptive measurement under complex operating conditions, and full-process mass and energy measurement. Building on these achievements, the team has developed an online CCUS energy measurement system capable of performing in situ calibration and commissioning of field instruments and DCSs without interrupting facility operation. The system enables continuous, traceable and dynamic assessment of captured CO_2, specific heat consumption for CO_2 capture, and absorbent escape.

Online sampling unit for absorbent escape

The system has been deployed in multiple CCUS projects in China, covering kiloton pilot plants and demonstration projects with annual capacities of 300,000, 500,000 and 1.5 million tons. The system can provide reliable online measurement solutions for CCUS energy-efficiency verification, emission-reduction accounting, and cross-project performance comparison. It can also offer a data foundation and technical support for absorbent screening and evaluation, as well as process-parameter optimization.

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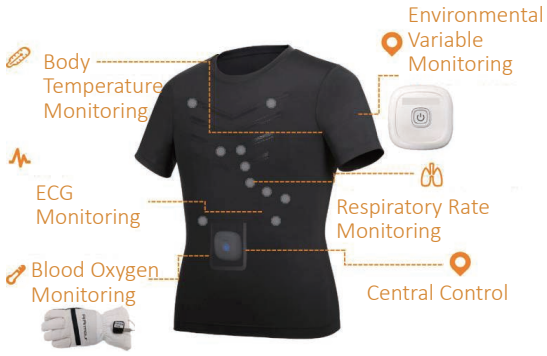
Flexible Wearable Vital Sign Monitoring Techniques for High-Altitude Extreme Environments

In disaster rescue scenarios such as earthquakes and mudslides, rescuers must work for extended periods in extreme environments characterized by high altitude, low temperature, low pressure, and hypoxia. To address the challenges that vital signs are susceptible to environmental interference and sudden cardiovascular risks are difficult to detect in time, NIM researchers developed a flexible wearable electrocardiogram (ECG) monitoring vest for high-altitude extreme environments.

NIM has overcome key technical challenges such as simultaneous multi-parameter acquisition, signal anti-interference, and self-adaptation to environmental under extreme conditions. Supported by key human physiological parameter standard devices traceable to national measurement standards, it enables integrated continuous acquisition and data calibration of ECG, respiration, blood oxygen saturation, body temperature, and other parameters, thereby realizing real-time vital sign monitoring and dynamic early warning in high-altitude extreme environments.



High-altitude Flexible Wearable Monitoring Equipment

At present, this technique has been applied in large-scale cardiac screening involving more than 10,500 person-times in locations such as Lhasa and the Lizi Port in Tibet. Its lightweight and highly integrated design makes it suitable for complex emergency rescue scenarios, including post-earthquake ruins and deep tunnels, providing metrological support for ensuring the operational safety of rescue personnel and for early screening and warning of cardiovascular diseases.

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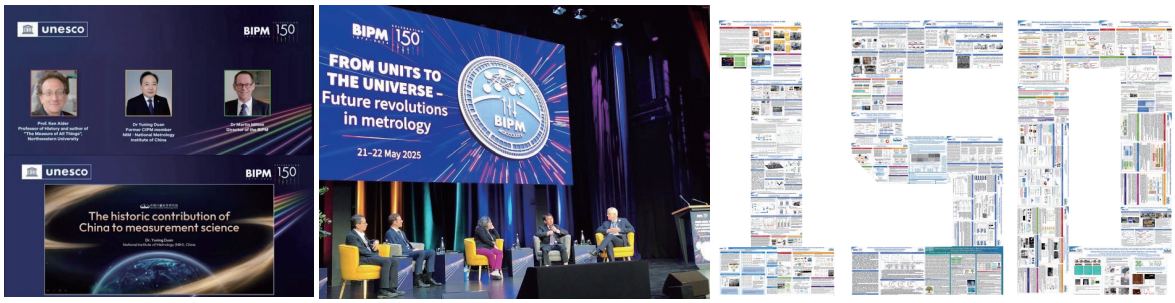
04

Collaboration and Cooperation

NIM Participates in Celebration of 150 Years of Metre Convention

To commemorate the 150th anniversary of the signing of the Metre Convention, the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the BIPM jointly organized a celebration in Paris, France during the period of the World Metrology Day in May 2025. A NIM delegation led by Dr. QU Jifeng, Vice Director General of NIM, attended the events.



At the high-level Symposium themed Science, Innovation and Global Impact held at the UNESCO Headquarters, Dr. DUAN Yuning, former Vice Director General of NIM and former CIPM member, delivered a speech online titled the Historic Contribution of China to Measurement Science.

Dr. Qu took part in the filming of a promotional video on the Metric System, elaborating on its most significant impact from the perspective of metrology-enabled globalization. He also served as a panelist in the panel discussion themed Metrology in the Quantum Era.

In addition, 27 scientific posters from NIM, covering 8 topics on metrology challenges, were all accepted for the 150th anniversary poster session. Particularly, one poster was selected as one of the two stand-out posters on the topic of Environment and Climate Change.

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The 5th Lancang–Mekong Cooperation Symposium in Metrology Held in Nanning City

From July 29 to 30, 2025, the 5th Lancang-Mekong Cooperation Symposium in Metrology was successfully held in Nanning City, Guangxi, China. Under the theme Advancing Clean Energy Cooperation for a Green and Sustainable Region, the Symposium brought together over 150 participants from 10 countries across ASEAN and Europe.

During the Symposium, the national metrology institutes of the six Lancang-Mekong countries, i.e. Cambodia, China, Laos, Myanmar, Thailand, and Vietnam, renewed the *Joint Statement for Lancang-Mekong Cooperation in Metrology (2025–2028)*, and jointly identified cooperation objectives and priority tasks for the next three years in key areas such as clean energy, including capacity building, development of metrological traceability systems, and mutual recognition of measurements. In addition, a series of professional reports and technical visits were organized in electric vehicle charging facilities and photovoltaics.

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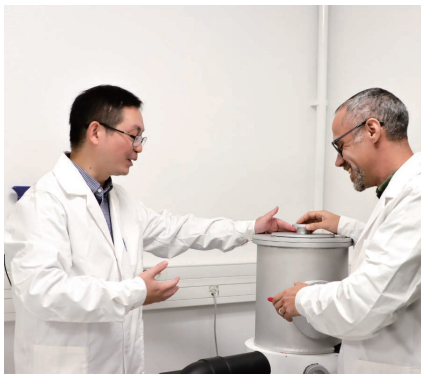
NIM and BIPM Collaborate to Bring Selective Sampling Method into Digital Era



In the field of radionuclide activity metrology, the traditional β-γ coincidence counting method relies on a "time window" to determine event simultaneity, which inevitably introduces accidental coincidence events that require complex correction procedures. Moreover, the conventional analog circuit systems are architecturally complex and operationally cumbersome, limiting their widespread adoption among national metrology institutes (NMIs) worldwide.

NIM and BIPM researchers collaborated to upgrade the Selective Sampling Method originally invented at BIPM. Using the BIPM's 4πβ (LS)-γ detection system as the platform, they replaced the conventional analogue electronics with highspeed digitizers and developed the corresponding digital algorithms, thereby migrating the core functions from hardware to software. They also proposed a novel digital cross-sampling background correction method, which, for the first time, extended the technique to medium- and low-activity measurements. In 2025, the digital selective sampling method was successfully deployed at BIPM. Validation tests with cobalt-60 standard solutions showed excellent agreement with the conventional method, with a relative deviation of only 0.3%.

Through this partnership, NIM and BIPM have brought a proven technique into the digital era. The new technique will ensure more reliable results in nuclear medicine, environmental monitoring, and radiation safety. It is also more accessible to other NMIs worldwide.

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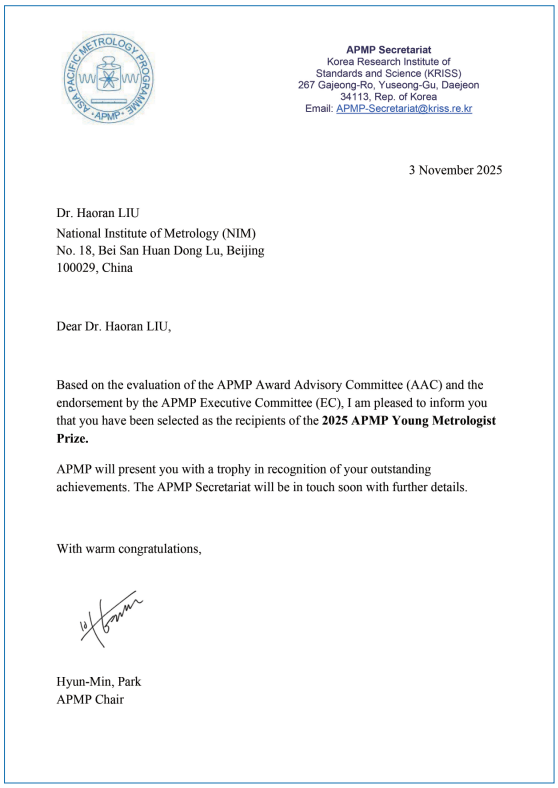
Dr. LIU Haoran Received 2025 APMP Young Metrologist Award

Dr. LIU Haoran, an associate researcher of Division of Ionizing Radiation, NIM, was awarded the 2025 APMP Young Metrologist Award at the 41st General Assembly and related events of the Asia-Pacific Metrology Programme (APMP) held in Incheon, Republic of Korea, in November 2025. He was the sole recipient of the award for the year.

Dr. Liu has been engaged in research on radionuclide metrology and the associated digital transformation, with notable achievements in primary standardization of radionuclides and digital analysis algorithms. He currently serves as Chair of Section 2 of the Consultative Committee for Ionizing Radiation (CCRI) and the representative of NIM in APMP TCRI. Previously, as the assistant to APMP TCRI Chair, he helped organize the APMP-BIPM Joint Workshop on Ionizing Radiation Metrology, led the compilation and publication of the annual TCRI Laboratory Progress reports, and served as a peer reviewer for on-site CMCs peer reviews.

The APMP Young Metrologist Award is intended to recognize individuals with outstanding achievements in metrology research and significant contributions to the Asia-Pacific metrology community.



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3 November 2025

Dr. Haoran LIU
National Institute of Metrology (NIM)
No. 18, Bei San Huan Dong Lu, Beijing
100029, China

Dear Dr. Haoran LIU,

Based on the evaluation of the APMP Award Advisory Committee (AAC) and the endorsement by the APMP Executive Committee (EC), I am pleased to inform you that you have been selected as the recipients of the **2025 APMP Young Metrologist Prize.**

APMP will present you with a trophy in recognition of your outstanding achievements. The APMP Secretariat will be in touch soon with further details.

With warm congratulations,

Hyun-Min, Park
APMP Chair

Contact: Dr. LIU Haoran
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