NMIJ Newsletter
No.20, November 2024

Hosting the G-QuAT–KRISS Quantum Workshop

Dr. URANO Chiharu
Director, Research Planning Office
Global Research and Development Center for Business by Quantum-AI Technology (G-QuAT), AIST

Dr. Ho Seong Lee, President, KRISS, right: Dr. MURAYAMA Norimitsu, Senior Vice-President, AIST

In January 2024, a comprehensive memorandum of understanding (MOU) was signed between the National Institute of Advanced Industrial Science and Technology (AIST) and Korea Research Institute of Standards and Science (KRISS), adding quantum projects to the existing MOU that had already been concluded. As a first step in finding partners for personnel exchanges, information sharing through joint symposiums and collaborative research based on this MOU, the "G-QuAT–KRISS Quantum Workshop" was held at the AIST Tsukuba Center on August 1, 2024.

At the workshop, following an overview of quantum technology research from both the G-QuAT and KRISS, individual initiatives related to quantum technology, such as quantum computers, quantum sensing technology, implementation technology for quantum computers, and testbeds, were introduced by both parties. After a networking session at lunch, the participants took a two-hour lab tour and visited five laboratories.

The workshop comprised lively discussions about future prospects and challenges, and we seem to have made a fruitful start towards collaboration.

Group photo of the participants

Greetings from the Principal Researcher

Dr. FUKUDA Daiji
Principal Researcher, Research Institute for Physical Measurement (RIPM), NMIJ

Physics and quantum mechanics, which began in the 19th century, have rapidly evolved, leading us into a new era of applications in the 21st century. Quantum computers and quantum sensors, leveraging the principles of quantum mechanics, are now poised to perform large-scale calculations and achieve detection capabilities far beyond what was previously possible. These advancements are deeply connected to the fundamental quantum properties of atoms, electrons, and photons, establishing a strong link with metrology. For example, in quantum key distribution, an optical communication method offering absolute security, the quantized nature of photons in the transmission path is a critical physical parameter that ensures the confidentiality of communication. In the future, the emergence of numerous new quantum applications is anticipated, and they are expected to expand into commercial ventures, driving the need for enhanced metrology to support them. Given these developments, I believe that National Metrology Institutes will be increasingly required to advance measurement technologies in line with quantum technology progress, maintain their technical capabilities, and foster an environment where Japanese companies can easily enter the new quantum industry and develop innovative applications.

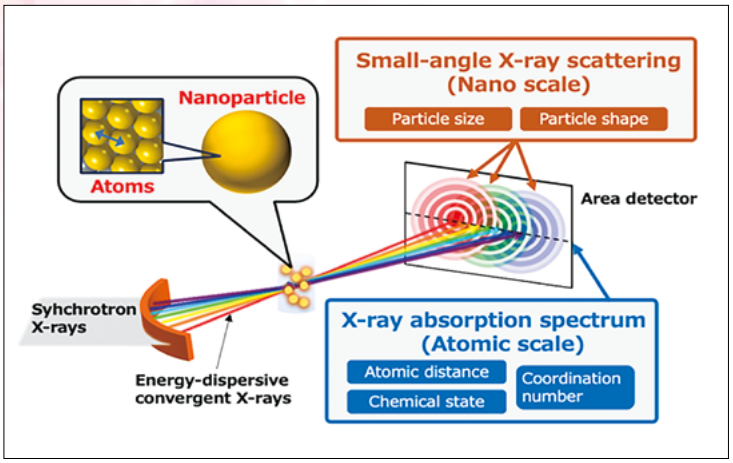
Research Topics

Development of a fast simultaneous XAS/SAXS measurement technique for multimodal analysis of nanomaterials

SHIRASAWA Tetsuro

The functions of nanomaterials, widely utilized in various industrial products such as fuel cells, generally originate from their nano-scale and atomic-scale structures. Small-angle X-ray scattering (SAXS) is used to analyze nano-scale structures such as the size and shape of nanostructures, while X-ray absorption spectroscopy (XAS) examines atomic-scale properties, including atomic distance, coordination number, and chemical state. These techniques are often used together to perform multiscale analyses of nanomaterials.

NMIJ has developed an innovative technique that simultaneously measures XAS spectra and SAXS distributions using an energy-dispersive convergent X-ray beam generated from white synchrotron radiation, along with an area X-ray detector. This breakthrough method has successfully observed the atomic- and nano-scale structures of precious metal nanoparticles, which form a fuel cell electrode, in just 0.1 s. Beyond the rapid characterization of nanoparticles, this technique is also suitable for operando observation—real-time monitoring in an operational environment that reveals correlations between nano-scale structures, atomic-scale properties, and material functions. Analyzing the resulting multimodal data can significantly improve the prediction of nanomaterial structures and properties, leading to optimized functionality.



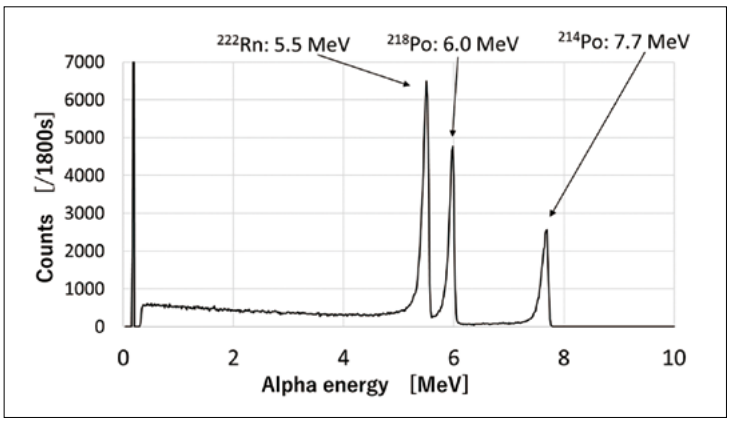
Schematic illustration of simultaneous XAS/SAXS measurements

Reference: T. Shirasawa et al., *Phys. Chem. Chem. Phys.* **26**, 18493, 2024, https://doi.org/10.1039/D4CP01399A

Development of ^{222}Rn primary standard using the proportional counter

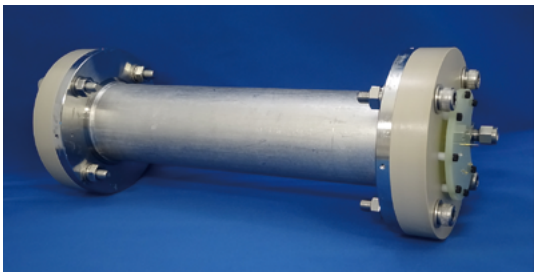
FURUKAWA Rio, HARANO Hideki

Radon (^{222}Rn) is a naturally occurring radioactive gas and the largest contributor to public exposure to natural radiation. It is established that internal exposure to ^{222}Rn increases the risk of lung cancer, leading to the availability of various radon monitors in the market designed to measure ^{222}Rn activity concentration [Bq m^{-3}]. At NMIJ, the standardization of gaseous ^{222}Rn concentration is currently under development, using a Multi-Electrode Proportional Counter (MEPC) as the primary ^{222}Rn standard. The measurement efficiency of the MEPC is influenced by the geometry of the radiation from ^{222}Rn and its progenies. NMIJ has successfully used the MEPC to determine ^{222}Rn concentrations provisionally. Moving forward, the focus will be on optimizing the measurement conditions of the MEPC to achieve higher accuracy through comparisons with other standards. Additionally, efforts will be made to establish a calibration system for radon monitors.



Typical alpha spectrum obtained by the MEPC

Reference: R. Furukawa et al., *Appl. Radiat. Isot.* **202**, 111076, 2023, https://doi.org/10.1016/j.apradiso.2023.111076



Multi-electrode proportional counter

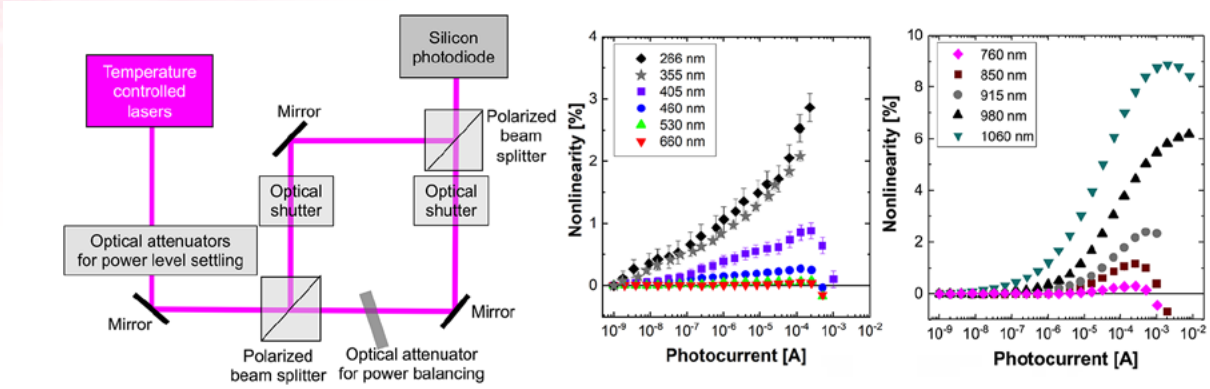
Accurate and wide-dynamic-range optical power evaluation with a silicon photodiode

TANABE Minoru

Silicon (Si) photodiodes (PDs) are widely used as optical sensors because of their ability to cover the ultraviolet-to-near-infrared wavelength range and their dynamic optical power range of more than six orders of magnitude. A Si PD ideally shows a linear response at any optical power, i.e., its photoelectric response is proportional to the incident power. However, actual PDs exhibit characteristic nonlinear responses that depend on the incident wavelength. This nonlinearity may affect the accuracy of optical measurements using Si PDs in areas such as photometry, radiometry, and colorimetry.

NMIJ developed an accurate nonlinearity evaluation system for Si PDs in the ultraviolet to near-infrared range. We evaluated the spectral nonlinearity of different types of Si PDs and found that the nonlinear behavior depends strongly on the incident wavelength and varied greatly depending on the PD type. These experimental results were well explained by theoretical models considering carrier dynamics, making it possible to predict the nonlinear behavior from some device parameters and obtain a correction factor for the measured power responsivity at different power levels.

Reference: M. Tanabe, *Meas. Sci. Technol*. **35**, 022001, 2024, https://doi.org/10.1088/1361-6501/ad080c



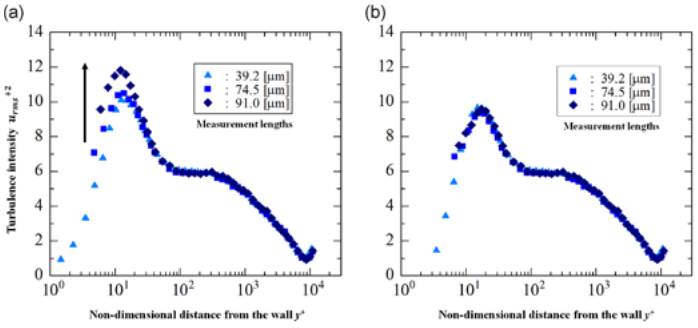
Nonlinearity evaluation system for Si PDs (left), and experimentally measured nonlinearities in the ultraviolet and visible ranges (middle) and in the near-infrared range (right).

Development of a spatial resolution correction method for achieving high precision in laser Doppler velocimetry

ONO Marie, FURUICHI Noriyuki

Various fluids are transported through pipelines, from residential to industrial scales. Understanding flow conditions in pipelines is important for enhancing safety and reducing energy consumption. However, for the large flow rates (or high Reynolds numbers) observed in large-scale manufacturing and power plants, the basic flow characteristics remain unclear because of insufficient experimental facilities and measurement difficulties. In such flow fields, accurate measurement of the velocity profile in a pipe is important for understanding the flow characteristics. Laser Doppler velocimetry (LDV), which is a noninvasive velocity measurement method, is useful for liquid flow. However, in large-flow-rate fields, the spatial resolution issue from the measurement volume of the LDV system significantly affects the measurements of the mean velocity and turbulence intensity, which represents the root-mean-squared (RMS) value of the velocity.

We measured the velocities in pipe flow using an LDV system at a national standard facility for large water-flow rates and evaluated the spatial resolution effect. The length of the measurement volume that directly affects the measurement values is defined as the “measurement length,” and the flow velocities were measured at different measurement lengths. The results show that the turbulence intensity near the wall increased with the measurement length, as shown in Figure (a). An accurate measurement length, crucial for correction, was determined using a wire rotary calibration device for the LDV system as a new approach. By applying the correction method to the measured measurement length and velocity gradient, the corrected turbulence intensity profiles with three different measurement lengths were consistent, as shown in Figure (b). In future work, we plan to validate the developed correction method through collaborative research with Physikalisch-Technische Bundesanstalt (PTB), Germany.



Velocity RMS values at each position in pipe flow: (a) Measured RMS, (b) corrected RMS

Reference: M. Ono et al., *Phys. Fluids* **34**, 045103, 2022, https://doi.org/10.1063/5.0084863

Featured Topics

19th NMIJ–KRISS Summit

NMIJ and Korea Research Institute of Standards and Science (KRISS) participated in the 19th NMIJ–KRISS Summit held on July 30, 2024, at NMIJ, Tsukuba, Japan.

This summit was the first face-to-face meeting between the two institutes in five years, as all meetings during this period were held online due to the COVID-19 pandemic. Seven delegates from KRISS engaged with their NMIJ counterparts in discussions on various topics, including reviews of the last cooperation package (2019) and the new cooperation package proposed by KRISS. Both institutes also presented developments in digital transformation and quantum technologies.

On July 31, 2024, NMIJ hosted lab tours, where KRISS delegates visited six laboratories and an exhibited hydrogen cell electric vehicle, facilitating an exchange of technical and scientific expertise between experts from both institutes.

During the summit, both parties agreed to move forward in specific areas of collaboration such as hydrogen metering and real-time optical clock comparisons, whereas other topics were considered for further discussion. Collaborations are expected to strengthen technical exchanges between the two institutes.

The 44th Japan–Korea Cooperation Committee for Legal Metrology in Yokohama

The 44th Japan–Korea Cooperation Committee for Legal Metrology convened on July 11–12, 2024, in Yokohama, Japan. The Committee aims to facilitate the exchange of information and encourage collaboration on legal metrology between Japan and Korea. It establishes a cooperative framework in the international community based on the Memorandum of Understanding (MOU) between NMIJ and the Korean Agency for Technology and Standards (KATS). The Japanese delegation, consisting of 13 representatives, participated with Mr. HIRABAYASHI, Ms. KIJIMOTO, and Mr. KIKUCHI from the Ministry of Economy, Trade and Industry; Mr. TETSUKA, Mr. WATANABE, and Mr. YAMASOTO from the Japan Electric Meters Inspection Corporation (JEMIC); and Dr. OTA, Mr. MIKURA, Dr. MORINAKA, Mr. ITO, Mr. KAMINAGA, Mr. SHIMADA and Mr. HORIKOSHI from NMIJ.

The Korean delegation comprised of 7 participants, with 2 representatives from KATS, including Ms. Yonghyun Lee; 2 representatives from the Korea Association of Standards & Testing Organizations (KASTO), and 1 representative each from the Korea Testing Certification Institute (KTC), the Korea Testing Laboratory (KTL), and the Korea Testing and Research Institute (KTR). There were 20 participants from Japan and Korea who attended.

The primary contents for July 11 included Measurement Act in Japan, Q&A on the Legal Metrology System in Japan, annual reports from each participating organization, EV charger systems, related work in both countries, and collaboration with international legal metrology organizations. The following day, on July 12, the committee visited the Tatsuno Corporation, toured the hydrogen charging facility and other key installations at the request of Korea.

The convening of this committee further strengthened the cooperation in the field of legal metrology between Japan and Korea. The next committee session is scheduled to be held in Korea in 2025.

The 44th Japan-Korea Cooperation Committee for Legal Metrology

Showroom at TATSUNO Corporation

Renewal of MOU between BIPM and NMIJ


Dr. USUDA Takashi, Director General, NMIJ (Left)
Dr. Martin J.T. Milton, Director, the BIPM (Right)

On June 9, 2024, the Memorandum of Understanding (MOU) between the Bureau International des Poids et Mesures (BIPM) and NMIJ was renewed. For the past decade, NMIJ has been working with the BIPM under the terms of an MOU that was first signed in 2014. This partnership has focused on the development of quantitative nuclear magnetic resonance (NMR) techniques, leading to significant advances in related research fields. In this MOU renewal, the objects of collaboration have been expanded by focusing on highly interesting fields, such as quantum sciences and radiation measurements. This renewal is expected to accelerate research in the relevant fields and improve the reliability of the international system of units.

Conclusion of MOU between Department of Science Service, Thailand, and NMIJ

On July 11, 2024, NMIJ and the Department of Science Service (DSS), Thailand, signed an MOU for research collaboration.

The previous Letter of Intent (LOI) between the two organizations, which was in effect for approximately seven years from 2015, was primarily focused on length- and mass-related calibrations as the main subject of technical exchanges.

On this occasion, in response to the trend of expanding calibration scope and diverse needs, both organizations have recognized the necessity of strengthening their omnidirectional collaboration. Therefore, they have reached the decision to conclude a specific MOU in order to comprehensively address technologies that span the relevant research areas within NMIJ.


Dr. USUDA Takashi, Director General, NMIJ (Left)
MD, FETP, Rungrueng Kitphati, Director General, DSS (Right)

Renewal of LOI between Physikalisch-Technische Bundesanstalt, Germany, and NMIJ

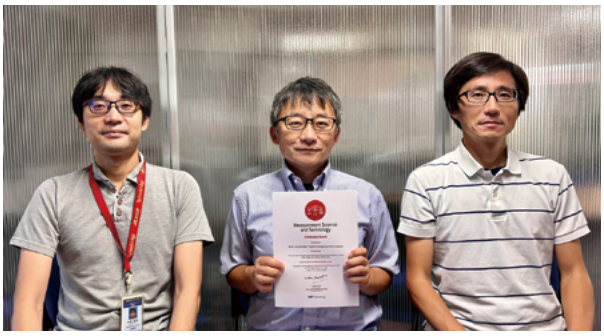

Dr. USUDA Takashi, Director General, NMIJ (Left)
Prof. Dr. Cornelia Denz, President, PTB (Right)

On August 23, 2024, NMIJ and Physikalisch-Technische Bundesanstalt (PTB), Germany, signed an LOI for research collaboration.

This LOI, which has been in progress since it was first signed in 2015, focuses on research collaboration to improve the accuracy of kilogram realization. During this period, NMIJ and PTB have collaborated on research and have succeeded in realizing kilograms with the highest accuracy in the world. Currently, national mass standards worldwide are determined based on the results of kilogram realization by several research institutes, including NMIJ and PTB. The ongoing collaboration between these two leading institutes is expected to be the key to improving the accuracy of international mass standards.

Measurement Science and Technology Centenary Award

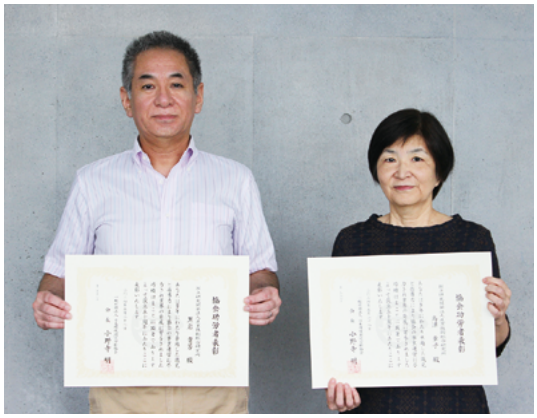
Dr. KANEKO Nobu-Hisa, Principal Researcher, along with his colleagues Dr. OKAZAKI Yuma and Dr. TANAKA Takahiro, has been honored with the Measurement Science and Technology Centenary Award for their research paper, “Perspectives of the generation and measurement of small electric currents." This paper provides a comprehensive overview of the generation and measurement of small electric currents down to the femtoampere range, covering the historical background, current status, and future perspectives. In the revised SI of 2019, a quantum approach based on the control of single electrons is essential for realizing small electrical current standards—a field in which NMIJ has made significant contributions. Applications of small current measurement include radiation dosimetry and airborne particle monitoring. NMIJ remains committed to advancing this research, aiming to implement the findings in industry as well as science.



From left, Dr. OKAZAKI, Dr. KANEKO, Dr. TANAKA

Reference:
N.-H. Kaneko et al., *Meas. Sci. Technol.* **35**, 011001, 2024,
https://doi.org/10.1088/1361-6501/ad03a2

Celebrating the 50th anniversary of the Japan Environmental Measurement and Chemical Analysis Association



Dr. KUROIWA (left) and Dr. TAKATSU (right)

The Japan Environmental Measurement and Chemical Analysis Association (JEMCA) celebrated its 50th anniversary with a memorial ceremony and celebration on May 28, 2024. JEMCA has been instrumental in contributing to environmental preservation by promoting proper management within the environmental measurement and analysis industry through various programs, including quality control initiatives.

NMIJ has actively supported the activities of JEMCA by dispatching committee members. In recognition of their "longstanding contribution to the promotion of the association's programs and the development of the industry," Dr. KUROIWA Takayoshi, Chief Officer for Quality Management of Metrology, and Dr. TAKATSU Akiko, Invited Senior Researcher at the Center for Quality Management of Metrology, were honored with the Association's Distinguished Service Award during this 50th-anniversary event.

Greetings from Dr. OGUSHI, the Newly Appointed Chair of APMP TCM

I have been working on research in force and torque metrology standards and measurement techniques for 26 years. Currently, I am part of the Research Institute for Engineering Measurement (RIEM) at NMIJ. I am profoundly grateful and honored to have been elected as the new Chair of the Technical Committee for Mass and Related Quantities (TCM) in the Asia Pacific Metrology Programme (APMP). My term as Chair will be for three years, from December 2023 to November 2026. We aim to promote international research cooperation, international comparison, obtaining CMC approval, and registration on the KCDB. TCM is responsible for a wide variety of quantities, such as mass, density, force, torque, pressure, vacuum, hardness, and gravity. To achieve these goals, the cooperation of many experts is essential. I will do my utmost to ensure that all TCM members can work together towards these objectives.

Dr. OGUSHI Koji
Chief Senior Researcher, RIEM

Publication of the roadmap of metrology standards and calibration technologies supporting Beyond 5G/6G in collaboration with NICT

KINOSHITA, Moto

Roadmap of metrology standards and calibration technologies supporting Beyond 5G/6G

To realize Beyond 5G/6G next-generation mobile communication systems, it is essential to ensure the performance of radio equipment through measurements based on national standards. The National Institute of Information and Communications Technology (NICT), which offers the highest level of calibration services for measuring instruments required for radio station licenses in Japan, and NMIJ, the national metrology institute in the field of radio-frequency, have outlined their R&D schedule to enable the industry to develop technology plans for Beyond 5G/6G.

In May 2024, NICT and NMIJ jointly published a roadmap of measurement standards and calibration technologies that support Beyond 5G/6G. This roadmap provides crucial guidelines for the measurement standards and calibration technologies necessary for the Beyond 5G/6G era. Specifically, it is expected to serve as a key resource for the development and practical application of wireless devices, detailing R&D plans for measurement standards and calibration technologies in the terahertz band from 330 GHz to 1.1 THz, a currently undeveloped area. The roadmap is available as a leaflet and can be downloaded from the NICT and NMIJ websites. It will serve as an important document for future technological development.

https://unit.aist.go.jp/nmij/news/2024/pdf/20240520.pdf (in Japanese)

Quantum Workshop at the BIPM

With the recent emphasis on the importance of standards and standardization in quantum computing and sensing technologies, the “Workshop on Accelerating the Adoption of Quantum Technologies through Measurements and Standards” was held at the BIPM on March 21–22, 2024. Representing AIST, Dr. USUDA Takashi, Director General, NMIJ, delivered a lecture, while Dr. FUKUDA Daiji, Principal Researcher, and Dr. NAKAMURA Shuji, Chief Senior Researcher, attended the workshop in person. Additionally, Dr. KANEKO Nobu-Hisa, Principal Researcher, served as an organizing committee member, alongside representatives from nine other organizations, and was responsible for preparing, managing, and moderating the event. The workshop saw an impressive turnout, with 149 participants from 43 national metrology institutes and designated institutes across 39 economies engaging in lively discussions, on the current landscape and the critical need for international collaboration moving forward.

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For more information, please visit https://www.bipm.org/en/bipm-workshops/quantum-tech

The Emerging Scientist Workshop (ESW) 2024 participation report

The annual Emerging Scientist Workshop (ESW), which rotates among three national metrology institutes—Japan's NMIJ, Korea's KRISS, and China's NIM (National Institute of Metrology of China)—was held from August 26–28, 2024 in Beijing. A total of 49 researchers, including eight selected young researchers from NMIJ, participated in this year’s workshop. The participants actively engaged through oral and poster presentations, which deepened their exchanges and encouraged collaborative discussions. The workshop provided ample time for researchers to introduce their work, background, and related technologies, leading to a lively and insightful exchange of ideas. Additionally, invited lectures by internationally recognized senior researchers from each participating institution enriched the event. Overall, the workshop was highly productive and offered valuable inspiration for participants’ future career development.

Overview of online participation at NMIJ

2024 NCSLI/CPEM Workshop & Symposium

Presentation during the CPEM session

The 2024 NCSLI/CPEM Workshop & Symposium took place in July 2024 at the Gaylord Rockies Resort & Convention Center in Denver, Colorado, USA. The event was hosted by the National Conference of Standards Laboratories International (NCSLI) in collaboration with the Conference on Precision Electromagnetic Measurements (CPEM). The biennial CPEM was scheduled to be held in conjunction with the annual NCSLI Workshop & Symposium as an in-person event in 2020. However, due to the COVID-19 pandemic, it was conducted online that year. This year, more than 500 participants engaged in lively discussions and technical exchanges. Researchers from NMIJ presented the latest advancements in electrical, electromagnetic, and high-frequency measurements during the CPEM sessions and also hosted a booth at the NCSLI exhibition.

https://ncsli.org/mpage/WS_2024

NMIJ exhibition booth

Selected Research Reports

1) T. Yoshida, S. Wada, N. Furuichi, "Image-processing-based ultrasonic velocimetry development with high applicability to flows in microparticle dispersion," *Physics of Fluids* **36**, 053329, 2024, https://doi.org/10.1063/5.0206765

2) T. Uchida, Y. Tanaka, A. Suzuki, "Automatic detection of pleural line and lung sliding in lung ultrasonography using convolutional neural networks," *Heliyon* **10,** e34700, 2024, https://doi.org/10.1016/j.heliyon.2024.e34700

3) Y. Amagai, A. Ichinose, R. Ikawa, M. Sakamoto, T. Ogiya, M. Konishi, K. Okawa, N. Sakamoto, N.-H. Kaneko, "Harvesting thermal energy from spring water using a flexible thermoelectric generator," *Energy Conversion and Management* **313**, 118605, 2024, https://doi.org/10.1016/j.enconman.2024.118605

4) K. Godo, K. Kinoshita, Y. Nakazawa, K. Ishida, A. Fujiki, M. Nikai, Y. Niimi, H. Teranishi, T. Nishioka, "LED-based standard source providing CIE standard illuminant A for replacing incandescent standard lamps," *Measurement* **239**, 115479, 2025, https://doi.org/10.1016/j.measurement.2024.115479

5) Y. Zhu, "On-line generated ozone as a reactive cell gas for tandem quadrupole inductively coupled plasma mass spectrometry," *Chemical Communications* **60**, 3974, 2024, https://doi.org/10.1039/d4cc00636d

6) T. Shiga, Y. Terada, T. Kodama, S. Chiashi, "Influence of perturbative intertube interactions on ballistic and quasi-ballistic phonon transports in double-walled carbon nanotubes," *International Journal of Heat and Mass Transfer* **233**, 126030, 2024, https://doi.org/10.1016/j.ijheatmasstransfer.2024.126030

7) K. Shu, Y. Tajima, R. Uozumi, N. Miyamoto, S. Shiraishi, T. Kobayashi, A. Ishida, K. Yamada, R. W. Gladen, T. Namba, S. Asai, K. Wada, I. Mochizuki, T. Hyodo, K. Ito, K. Michishio, B. E. O'Rourke, N. Oshima, K. Yoshioka, "Cooling positronium to ultralow velocities with a chirped laser pulse train," *Nature* **633**, 793, 2024, https://doi.org/10.1038/s41586-024-07912-0

8) K. Michishio, L. Chiari, F. Tanaka, Y. Nagashima, "Anisotropic Photodetachment of Positronium Negative Ions with Linearly Polarized Light," *Phys. Rev. Lett.* **132**, 203001, 2024, https://doi.org/10.1103/PhysRevLett.132.203001

Edited and issued by NMIJ International Cooperation Office (NMIJ ICO),
National Metrology Institute of Japan (NMIJ),
National Institute of Advanced Industrial Science and Technology (AIST)
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