NMIJ Newsletter
No.19, May 2024

Establishment of the Global Research and Development Center for Business by Quantum-AI Technology (G-QuAT)

Dr. MURAYAMA Norimitsu
Senior Vice-President of AIST & Director of G-QuAT

In recent years, quantum technology has been attracting worldwide attention as a global transformative force and the race for social implementation is intensifying. However, despite its potential, this technology has not yet achieved full practical application. To address this issue, the Global Research and Development Center for Business by Quantum-AI Technology (G-QuAT) was established in July 2023 under the direct leadership of the chief technology officer, serving as a comprehensive support center to facilitate industry growth. To promote the creation of use cases, G-QuAT is building advanced fusion computing technology by linking quantum devices with the National Institute of Advanced Industrial Science and Technology (AIST) 's supercomputer system, which has one of the largest AI computing capacities in Japan.

In addition, G-QuAT focuses on R&D of elemental technologies, and component and material technologies that are essential for practical use of quantum computers.

Rendering image

Furthermore, for large-scale integration of qubits, G-QuAT is strengthening the R&D of quantum device design and fabrication technologies that AIST has been conducting. As a special organization for R&D, G-QuAT will bring together the diverse research results and resources of AIST, such as National Metrology Institute of Japan (NMIJ), to create new industries utilizing quantum technology in a wide range of industrial fields.

Greetings from the Prime Senior Researcher

Dr. KANEKO Nobu-Hisa

Recent discussions surrounding the term "quantum computer" have become increasingly prevalent. Despite its current demonstration on a modest scale, a prevailing belief exists that quantum computers will eventually execute calculations far beyond the capability of modern supercomputers. Such advancements are anticipated to drive industrial applications and address complex societal challenges. Consequently, companies engaged in quantum technology and those possessing technologies potentially relevant to quantum computing are gaining significant attention.

A notable number of hardware components required for quantum computing can be derived from existing general-purpose technologies. This ability sets the stage for the entry of diverse "non-quantum" industries into the quantum field. In response, G-QuAT at AIST, established in 2023, is partnering with NMIJ to lower the barriers to entry into the quantum industry. This partnership aims to articulate clear evaluation criteria and establish a measurement testbed for "quantum" hardware components.

The establishment of the testbed for quantum hardware components represents a pivotal step forward. This initiative will focus on examining high-frequency, cryogenic, thermal, and optical characteristics of various hardware components. This platform will be developed to facilitate collaboration with companies and other research institutions, aiming to complete the construction of testbed facilities and evaluation capabilities by spring 2025. This endeavor will demonstrate the extensive expertise of NMIJ and is expected to attract participation from a broad spectrum of industries, heralding a new era of quantum computing development and application.

Research Topics

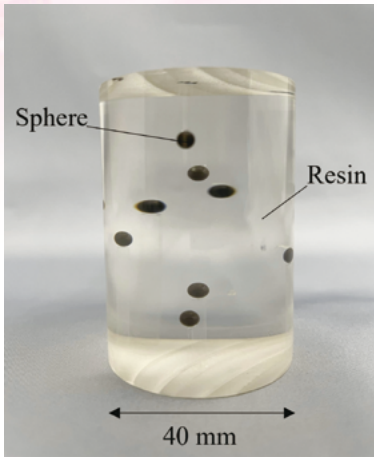
Development of a gauge for performance testing of XCT

WATANABE Mari

X-ray computed tomography (XCT) stands out as a crucial non-destructive technique for accurately capturing both the external and internal geometrical features of industrial components. To enhance XCT performance testing, we introduced an innovative gauge design, named the Marimo gauge, which incorporates spheres embedded within a cylindrical resin structure. This design is informed by several key considerations aimed at optimizing the gauge performance and compliance with established standards.

The design principles of the Marimo gauge are as follows:

1. Reduction of artifacts: The cylindrical form and the absence of supporting structures ensure uniform X-ray transmission across all rotational positions, significantly minimizing the noise or artifacts that can detract from image quality.
2. Standards compliance: By embedding spheres arbitrarily within the resin, the Marimo gauge aligns with the requirements of both VDI/VDE and ASME standards, making it a versatile tool in industrial metrology.
3. Cost-effectiveness: The gauge can be produced economically, offering a cost-effective solution for XCT calibration needs.
4. Suitability for high-magnification XCT: The ability to manufacture the Marimo gauge with dimensions smaller than 40 mm renders it particularly useful for high-magnification XCT measurements, where precision is paramount.



Performance testing gauge for X-ray computed tomography: the Marimo gauge

The Marimo gauge has been rigorously tested to ensure its utility as a reference standard, focusing on aspects such as the coefficient of thermal expansion and the long-term stability of the resin. Its design enables versatile placement and orientation without the risk of deformation, facilitating calibration through multiple orientation measurements via XCT. The calibration process has demonstrated that the Marimo gauge can achieve measurement uncertainties as low as 3 μm when the center-to-center distance between the spheres is 30 mm.

The development of the Marimo gauge represents a significant advancement in the field of XCT metrology, offering a reliable, standard-compliant, and cost-effective option for the calibration and performance testing of XCT systems.

Reference: M. Watanabe et al., *Precision Engineering* **84**, 15-20, 2023,
DOI: 10.1016/j.precisioneng.2023.06.009

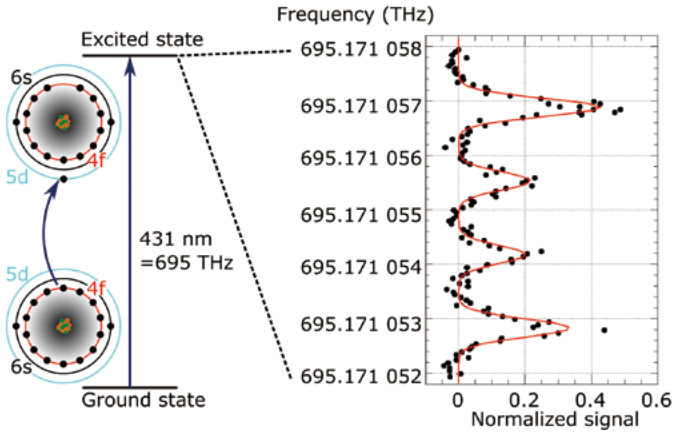
Observation and absolute frequency measurement of a new narrow-linewidth transition in ytterbium

KAWASAKI Akio

Optical lattice clocks have attained remarkable levels of accuracy in time measurements. However, ongoing enhancements in stability and accuracy remain crucial for refining metrological applications and fundamental physics searches. Ytterbium (Yb) is a commonly selected atoms in optical lattice clocks. Theoretical predictions suggested the existence of an additional narrow-linewidth transition involving the excitation of an electron from an inner-shell 4*f* orbital, a phenomenon not directly observed until recently. We successfully observed this novel narrow-linewidth transition in ^{171}Yb and conducted the first absolute frequency measurement, utilizing the depletion of atoms resonating with the narrow-linewidth transition from a magneto-optical trap. The obtained absolute frequency has 12-digit accuracy: 695 171 054 858.1 (8.2) kHz for the F = 3/2 hyperfine state. Our investigation further extended to the measurement of magnetic properties, including the g factor and hyperfine structure.

The observation of this transition paves the way for several pioneering research avenues. It offers a novel method of investigating the time variation of the fine structure constant and exploring potential new forces between an electron and a neutron, as well as testing the violation of Lorentz invariance. Moreover, the introduction of a secondary clock transition highly sensitive to external fields can potentially improve the stability of an optical lattice clock by simultaneously monitoring external perturbations affecting the resonant frequency of the primary clock transition.

Reference: A. Kawasaki et al., *Phys. Rev. A* **107**, L060801, 2023,
DOI: 10.1103/PhysRevA.107. L060801



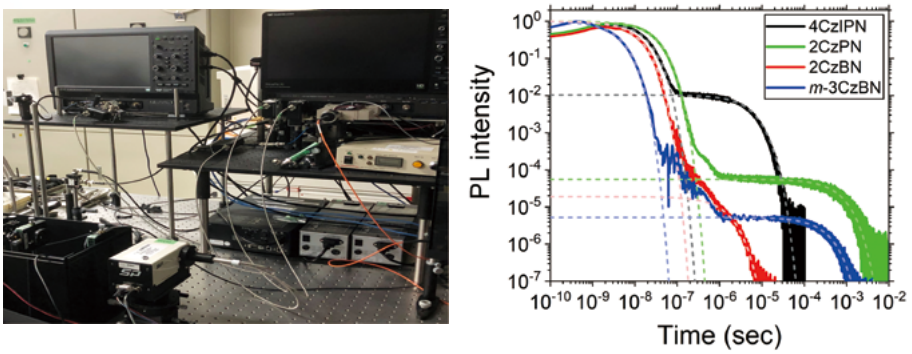
Change in the electronic structure of the observed transition and spectrum of the transition for the F = 3/2 hyperfine transition level

Development of rapid measurement techniques for Materials Informatics in photofunctional materials

HOSOKAI Takuya

Materials Informatics (MI) presents an innovative approach to forecasting the functionality of novel materials using machine learning. MI can be utilized to develop photofunctional materials such as solar cells, photocatalysts, and light-emitting materials, which are crucial for modern societal progress. To date, MI of photofunctional materials has primarily leveraged only easily obtainable data such as steady-state luminescence/absorption. In contrast, transient photoluminescence/absorption data, which capture the dynamic material properties, remain underutilized owing to insufficient data accumulation as prolonged times and efforts are required for measurements.

NMIJ is dedicated to developing high-throughput measurement techniques for transient photoluminescence by integrating a high-bandwidth real-time sampling method. This method involves a high-speed 12-bit digital storage oscilloscope and a variety of photodetectors. Consequently, we can successfully detect photoluminescence signals in a time range of 0.4 nanoseconds to over a millisecond with a signal dynamic range of over 7 digits within a few minutes. This technology is advantageous over the traditional single photon counting method in terms of the cost of measurement time. It holds great promise as a rapid, high-precision tool for capturing transient response data for photofunctional materials, which can expedite the development of MI-based photofunctional materials.

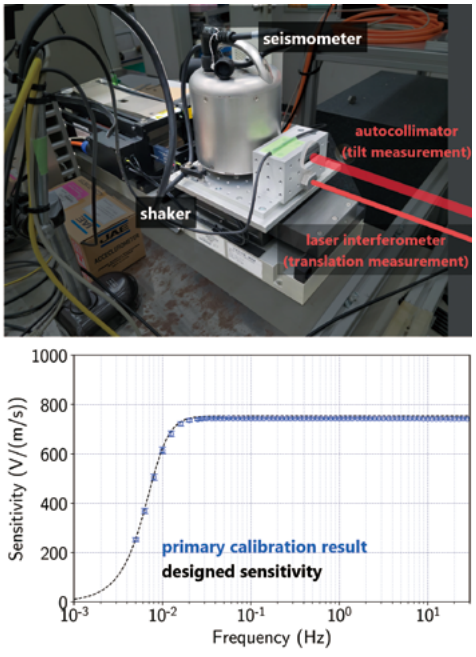


Photograph of transient photoluminescence apparatus (left) and an example of transient photoluminescence time profile (right)

Reference: M. Furukori et al., *J. Mater. Chem. C* **11**,4357,2023.
DOI: 10.1039/D3TC00482A

Primary vibration calibration at ultra-low frequency for broadband seismometers

SHIMODA Tomofumi, KOKUYAMA Wataru, NOZATO Hideaki



Developed primary calibration system (top) and example of calibration results for a broadband seismometer (bottom)

Broadband seismometers are essential instruments for monitoring ultra-low-frequency vibrations ranging from a few millihertz to several tens of hertz and are deployed globally for earthquake observation and nuclear test detection. The calibration of these instruments across their observational frequency spectra has become increasingly important to ensure the accuracy and reliability of measurements. Traditional primary vibration calibration involves vibrating a calibration target with a shaker and comparing its output signal to that of a reference laser interferometer. However, this method encounters limitations at frequencies below 0.1 Hz, where the gravitational influence of the earth exacerbates measurement errors due to even minimal tilting of the shaker, particularly as the applied acceleration diminishes.

Addressing this challenge, NMIJ has developed an accurate correction technique that simultaneously measures both the translation and tilt of the shaker. This approach utilizes a combination of a laser interferometer and an autocollimator, effectively minimizing the error source associated with the tilt of the shaker and coupling with the gravity of the earth. Consequently, this advancement extends the measurable frequency range down to 5 mHz, setting a new global standard for the lowest frequency attainable in primary calibration.

The development of this calibration method marks a significant milestone, enabling the direct confirmation of the low-frequency cutoff in broadband seismometer sensitivity through real vibrations. When integrated with in situ comparison calibration, this enhanced primary calibration technique promises to improve the observational precision of the worldwide seismometer network significantly.

Reference: T. Shimoda et al., *Meas. Sci. Technol.* **33**, 125021, 2022,
DOI: 10.1088/1361-6501/ac9077

Featured Topics

Dr. OTA Akihiro appointed as the CIML Member for Japan

Dr. OTA Akihiro
Director of RIEM, NMIJ

In February 2024, Dr. OTA Akihiro, Director of the Research Institute for Engineering Measurement (RIEM) at NMIJ, was appointed as the Committee International de Métrologie Légale (CIML) Member for Japan. The International Organization of Legal Metrology (OIML) stipulates that each member state is represented by a designated government official who serves as its CIML Member. This member is responsible for casting votes on behalf of their nation on pivotal matters pertaining to legal metrology. Dr. OTA succeeded Dr. TAKATSUJI Toshiyuki, the Councilor of NMIJ at that time, who had fulfilled this significant role since October 2020. The tenure of Dr. OTA as Director of RIEM since 2020 has been marked by his dedication to the field of legal metrology within NMIJ, where he has significantly contributed to advancing measurement standards and practices.

His extensive involvement in metrology extends to serving on the Sub-Committee on Sound and Vibration Measuring Instruments of the Japan National Committee for International Legal Metrology and the Subcommittee on Sound, Ultrasonic, and Vibration of the Japan National Committee for International Metrology. Additionally, Dr. OTA has held the position of Vice-Chair of technical committee (TC) 22 of the International Measurement Confederation (IMEKO), as well as chairmanship of the National Committees for Working Groups 33 and 34 of ISO/TC 108. Beyond these roles, Dr. OTA is the Chairperson of the Technical Committee for the Japan Calibration Service System (JCSS), established under the Measurement Act. His appointment as a CIML Member for Japan is a testament to his profound expertise and leadership in the field of metrology.

Greetings from Dr. HOSAKA, the Newly Appointed Chair of APMP TCTF

HOSAKA Kazumoto

Dr. HOSAKA Kazumoto
Director of the Research Institute for Physical Measurement, NMIJ

It is with great honor that I address you as the newly appointed chair of the Asia-Pacific Metrology Programme's Technical Committee on Time and Frequency (APMP TCTF). This moment is significant, as it has been 17 years since NMIJ last assumed the leadership role of the TCTF chair. We are at the cusp of an exciting era for the Time and Frequency community, faced with numerous pivotal issues that demand our expert attention and deliberation. I think that the redefinition of the SI second will be the most important topic over the next 10 years for us. The new definition must be acceptable by all NMIs, whether they have the ability to develop their own primary or secondary frequency standards, or not. The argument regarding leap seconds will also be an important subject as the insertion of new leap seconds would cause significant impacts on the social infrastructure developed to a higher level. In light of these challenges, fostering stronger collaborations among colleagues engaged in frequency standards, both within the APMP and globally, is more crucial than ever. I humbly ask for your support and cooperation as we navigate these interesting times together in the TCTF. Your collaboration will be invaluable as we strive to work towards harmonious and universally beneficial outcomes.

Dr. KISHIKAWA Ryoko received the APMP Young Metrologist Prize

Dr. KISHIKAWA Ryoko
Senior Researcher

Dr. KISHIKAWA Ryoko, a Senior Researcher within the Electromagnetic Measurement Group, has been honored with the APMP Young Metrologist Prize in recognition of her outstanding contribution to APMP's activities among young metrologists. The work of Dr. KISHIKAWA has been instrumental in the development of metrology standards for RF impedance, a critical parameter for the deployment of 5th generation mobile communication systems (5G), spanning the frequency range of 9 kHz to 40 GHz. Her expertise and dedication have led to the issuance of more than 190 calibration certifications in her capacity as a calibration authority. Beyond her contributions to RF impedance metrology, Dr. KISHIKAWA has also pioneered a novel calibration method for electromagnetic compatibility test instruments and investigated wireless power transfer technologies for space satellites. These innovations have not only advanced the field of metrology, but also have showed the potential for significant technological advancements in telecommunications and aerospace. The achievements of Dr. KISHIKAWA in RF impedance metrology and her broader contributions to the field have been rightfully acknowledged through the awarding of the APMP Young Metrologist Prize.

Conclusion of a Comprehensive Memorandum of Understanding between AIST and KRISS, Korea

– Strengthening collaboration in the field of quantum technology –

On 3rd January 2024, AIST of Japan and the Korea Research Institute of Standards and Science (KRISS) formalized a comprehensive memorandum of understanding (MOU), signifying a pivotal expansion of their collaborative efforts to now include the domain of quantum technology. This agreement builds upon the initial MOU established in 2001 by NMIJ and KRISS, which focused on cooperation in metrology and measurement standards. Historically, this MOU has been renewed every five years, reflecting the evolving partnership and shared objectives between these institutions.

Mr. ISHIMURA Kazuhiko, President and CEO of AIST (Left)
Dr. Ho Seong Lee, President of KRISS (Right)

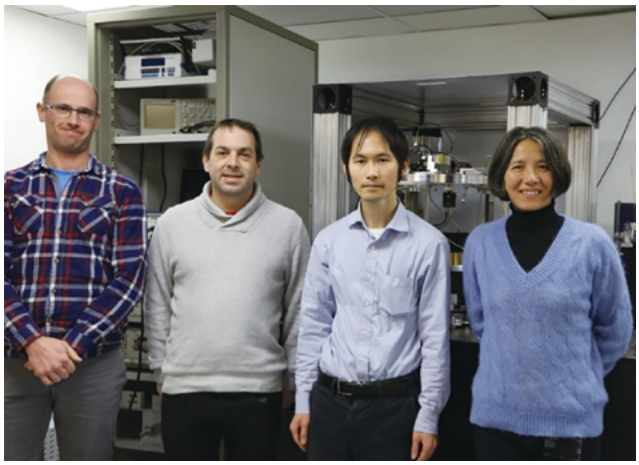
The incorporation of quantum technology into the collaborative framework was catalyzed by the establishment of the Global Research and Development Center for Business by Quantum-AI Technology (G-QuAT) in July 2023. This strategic expansion signifies the transition of the specific MOU into a comprehensive understanding, broadening its scope to cover all research areas pursued by AIST. This enhancement of the collaborative spectrum is timely, as the demand within the quantum technology sector is anticipated to escalate significantly. The reinforced relationship between AIST and KRISS is expected to drive forward new technological innovations, marking a significant milestone in the advancement of quantum technology research and development.

Research report conducted at the BIPM

- Contributing to the development of a Kibble balance apparatus for realizing the kilogram at the BIPM -

FUJITA Kazuaki

A one-year secondment at the Bureau International des Poids et Mesures (BIPM) from February 2023 to January 2024 was spent contributing to developing a Kibble balance apparatus. The Kibble balance method is used to realize the unit of mass (kilogram) based on the Planck constant using the electromagnetic force generated by current and magnetic field. It has been reported that the largest sources of uncertainty in Kibble balance measurements at the BIPM are nonideal movements of the current-carrying coil due to unwanted forces and torques.



From left, Dr. Franck Bielsa, Mr. Adrien Kiss, Mr. Kazuaki Fujita, Dr. Hao Fang at the BIPM

Therefore, a novel balance beam mechanism using flexure strips was developed, where the secondment was dedicated to characterizing the balance mechanism. The measurements confirm the key features of the design of the new mechanism. Further investigations and optimizations of the mechanical and electrical systems are underway. These improvements have contributed to developing of an accurate Kibble balance to realize the new definition of the kilogram and to contribute to international comparisons of kilogram realizations.

The visiting secondment program was a valuable experience, exposing me to energetic discussions on key issues in metrology. I sincerely thank everyone for their enormous support and encouragement while carrying out the work.

Reference: F. Bielsa, K. Fujita, A. Kiss, and H. Fang to be published in *CPEM 2024 Digest*

Director and Vice-Director of METAS visit NMIJ

Dr. Philippe Richard, Director of the Federal Institute of Metrology METAS (Switzerland) and CIPM Vice-President, and Dr. Bobjoseph Mathew, Vice-Director of METAS and CIML President since October 2023, visited Japan from 27th January to 3rd February 2024. The primary objective of their visit was to foster mutual understanding and friendship between Switzerland and Japan within the realm of legal metrology and metrology standards via a series of engagements. Their packed itinerary included a courtesy visit to METI, a technical tour of NMIJ, attending a lecture organized by the Japan Measuring Instruments Federation, and a trip to the Kansai region to visit the Ishida Corporation and Advanced Telecommunications Research Institute International (ATR).

During their visit to NMIJ, they attended a lecture on DX activities at NMIJ and Legal Metrology in Japan, inspected the Metrology Training Center, and toured the laboratories. The laboratory tours included examination of the Kibble balance, Particle metrology, Supreme-black sheet enabled by microcavity surface texture for light and thermal radiation management, and evaluation of energy storage batteries based on precision electrical measurements and quantum electrical standards.

Dr. Mathew is in the center, and Dr. Richard is on his right.

Additionally, they engaged in fruitful discussions with Dr. Usuda, Director General, and 14 other learned experts and strengthened their friendship with them.

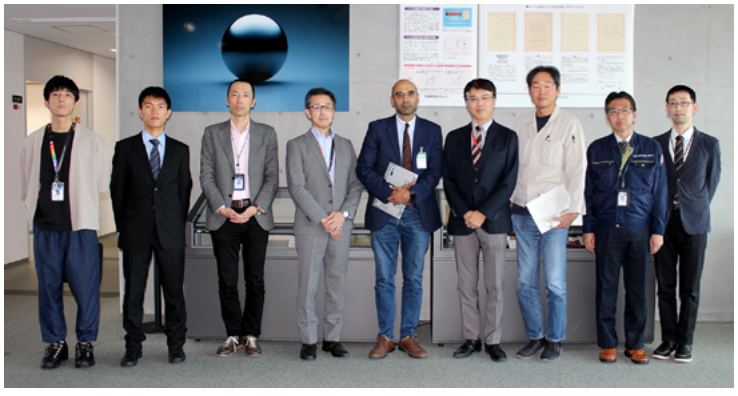
Visit by the President of the National Institute for Metrological Research

On 28th July 2023, Professor Diederik Sybolt Wiersma, the President of the National Institute for Metrological Research (INRiM, Italy), visited NMIJ. This event was attended by Dr. USUDA Takashi, Director General of NMIJ, along with 16 other members of the institute. The gathering served as a platform for showcasing the latest research endeavors of NMIJ. Highlights included the digitalization of testing data, innovative evaluation methods for energy storage batteries, and the development of airborne particle number concentration standards. This visit underscored the collaborative spirit and the exchange of cutting-edge scientific advancements between the institutions.

Dr. USUDA (left) and Professor Wiersma (right)

Visit by the Head of Digital Innovation from National Physical Laboratory (NPL, UK)

On 13th October 2023, Dr. Sundeep Bhandari, Head of Digital Innovation at the National Physical Laboratory (NPL, UK) visited NMIJ. This occasion facilitated a fruitful exchange of ideas on digital technologies between Dr. Bhandari and six researchers from NMIJ, including Dr. HOSAKA Kazumoto, Director of the Research Institute for Physical Measurement at NMIJ. The meeting commenced with an overview of the digital initiatives undertaken by NMIJ, followed by a presentation by Dr. Bhandari on the journey of NPL towards becoming a digital National Metrology Institute. The discussions delved into the future prospects and the inherent challenges of integrating digital technology into the realm of measurement science, highlighting the shared commitment to advancing the field through technological innovation.



Group photograph at NMIJ with Dr. Bhandari at the center.

Dr. USUDA Takashi delivered a lecture at the APMP Symposium

The APMP Symposium, themed “Grand Vision for 2030+: Advancing Metrology in Addressing Global Challenges,” was organized by the National Institute of Metrology (NIM) in Shenzhen, China, on 1st December 2023. Dr. USUDA Takashi, Director General of NMIJ, delivered an online lecture titled “120 Years of Metrology in Japan, the Key Role of NMIJ, and the Vision for the Decade to Come.”

To commemorate the symposium, NIM presented a souvenir to Dr. USUDA as a token of appreciation.

Dr. USUDA extended his gratitude to NIM for organizing the event and for their considerate arrangements.

Online lecture by Dr. USUDA (right) and Image of the souvenir (left)

43rd Korea-Japan Cooperation Committee for Legal Metrology in Daejeon, Korea

The 43rd Korea-Japan Cooperation Committee for Legal Metrology convened on the 21st and 22nd of November 2023, in Daejeon, Korea. 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 MOU between NMIJ and the Korean Technical Metrology Service (KATS).

The Japanese delegation was represented by Ms. WAKAHARA from the Ministry of Economy, Trade and Industry; Dr. OTA, Mr. MIKURA, and Dr. MORINAKA from NMIJ; and Mr. TETSUKA and Mr. NAMIKI from Japan Electric Meters Inspection Corporation (JEMIC).

The Korean contingent comprised 20 participants, with six representatives from KATS, including Mrs. Yonghyun Lee; two from the Korea Research Institute of Standards and Science (KRISS); and the rest from various organizations such as the Korea Association of Metrology and Measurement (KASTO), Korea Testing and Research Institute of Machinery and Electrical Electronics (KTC), Korea Testing Laboratory (KTL), and Korea Testing and Research Institute (KTR).

The primary agendas for 21st November included the approval of KTR to join the 43rd Korea-Japan Cooperation Committee, the introduction of each participating organization, an overview of the legal metrology systems in both countries, EV charger systems and related work in both countries, and collaboration with international legal metrology organizations including OIML and APLMF and discussion of bilateral cooperation plans. The following day, on 22nd November, the committee visited KRISS and toured the hydrogen charging facility and other key installations.

This further deepened the cooperation in legal metrology between the two countries. The next committee session is scheduled to be held in Japan in 2024.

NMIJ hosted the International Commission on Radiological Protection (ICRP) Seminar

NMIJ had the honor of hosting the International Commission on Radiological Protection (ICRP) Seminar on 13th November 2023 at the AIST Waterfront. Since its establishment in 1928, the ICRP has played a pivotal role in the development and dissemination of guidelines and recommendations for the protection against ionizing radiation, covering all its aspects.

Dr Maria Antonia Lopez Ponte
(CIEMAT, Secretary of ICRP Committee 2)

The seminar, titled "Radiation Protection and Dosimetry," featured presentations by ICRP members, Dr. Kimberly Applegate and Dr. Maria Antonia Lopez Ponte. The event also featured significant contributions from Dr. KOWATARI Munehiko of the National Institutes for Quantum Science and Technology, and Dr. KATO Masahiro from NMIJ. Dr. KATO presented the dosimetry standard activities conducted at NMIJ and introduced a collimated irradiation system designed for the calibration of environmental radiation monitoring devices within Japan. The symposium was conducted in a hybrid format, offering both in-person and online participation options. It successfully attracted 35 attendees on-site and 122 participants virtually, indicating a strong interest in the topics discussed related to radiation protection and dosimetry.

For those interested in accessing the seminar program, presentation materials, and related reports, please visit the following URL: https://unit.aist.go.jp/nmij/english/public/events/seminar/2023/ICRP_seminar/

Emerging Scientist Workshop (Japan-China-South Korea Young Researcher in Metrology Workshop, ESW) 2023 participation report

KURAMOTO Naoki

The Emerging Scientist Workshop (ESW) convened young researchers from the national metrology institutes of Japan, China, and South Korea over three days, from 5th to 7th September 2023, at KRISS in Daejeon, South Korea. This annual event, collaboratively organized by NMIJ, KRISS, and the National Metrology Institute of China (NIM), marked its first in-person assembly in four years due to the impact of COVID-19. The workshop featured the participation of 10 selected young researchers and 2 prime senior researchers from NMIJ. They engaged with their counterparts from China and South Korea through both oral and poster research presentations, as well as tours of laboratories. The agenda allowed ample time for the presentation of research, alongside personal introductions that included hobbies and backgrounds, fostering a vibrant exchange of ideas. Distinguished researchers from the participating institutes delivered invited lectures, enriching the academic discourse in the workshop. This assembly proved to be an invaluable platform for all participants, offering them a unique opportunity to reflect on their potential career trajectories within the field of metrology. The ESW also encouraged personal connections among the next generation of metrologists, laying the foundation for future collaborative endeavors.

Data on international activities

NMIJ contributes to a wide range of international activities. The following figures show the international activities carried out in one year from 1st April 2023 to 31st March 2024.

International comparisons piloted by NMIJ: 2

Peer reviewers dispatched: 14 (face-to-face: 13, online: 1)

Invited reviewers: 3

Selected Research Reports

1) N. Takegawa, T. Morioka, "Analytical methodology for calculating discharge coefficients of critical flow nozzles for high-pressure hydrogen," *International Journal of Hydrogen Energy* **58**, 737-744, 2024, https://doi.org/10.1016/j.ijhydene.2024.01.207

2) Y. Tanaka, K. Hattori, M. Yoshioka, "Determining the sensitivity coefficients of factors contributing to Rockwell hardness for uncertainty evaluation," *Measurement* **227**, 114310, 2024, https://doi.org/10.1016/j.measurement.2024.114310

3) S. Nakamura, D. Matsumaru, G. Yamahata, T. Oe, D.-H. Chae, Y. Okazaki, S. Takada, M. Maruyama, A. Fujiwara, N.-H. Kaneko, "Universality and multiplication of gigahertz-operated silicon pumps with parts per million-level uncertainty," *Nano Letters* **24**, 9–15, 2024, https://doi.org/10.1021/acs.nanolett.3c02858

4) A. Nishiyama, G. Kowzan, D. Charczun, R. Ciuryło, N. Coluccelli, P. Masłowski, "Line-shape study of CO perturbed by N_2 with mid-infrared frequency comb-based Fourier-transform spectroscopy," *Measurement* **227**, 114273, 2024, https://doi.org/10.1016/j.measurement.2024.114273

5) T. Shiga, Y. Terada, S. Chiashi, T. Kodama, "Effect of bundling on phonon transport in single-walled carbon nanotubes," *Carbon* **223**, 119048, 2024, https://doi.org/10.1016/j.carbon.2024.119048

6) E. Yamazaki, D. Lalwani, Y. Ruan, S. Taniyasu, N. Hanari, N. J.I. Kumar, P. K.S. Lam, N. Yamashita, "Nationwide distribution of *per*- and polyfluoroalkyl substances (PFAS) in road dust from India," *Science of The Total Environment* **892**, 164538, 2023, https://doi.org/10.1016/j.scitotenv.2023.164538

7) S. Ri, J. Ye, N. Toyama, N. Ogura, "Drone-based displacement measurement of infrastructures utilizing phase information," *Nature Communications* **15**, 395, 2024, https://doi.org/10.1038/s41467-023-44649-2

8) D. Asakawa, R. Yamamoto, N. Hanari, K. Saikusa, "Differences in the internal energies of ions in electrospray ionization mass spectrometers equipped with capillary–skimmer and capillary–RF lens interfaces," *Analytical Methods* **15**, 6150-6158, 2023, https://doi.org/10.1039/D3AY01450A

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