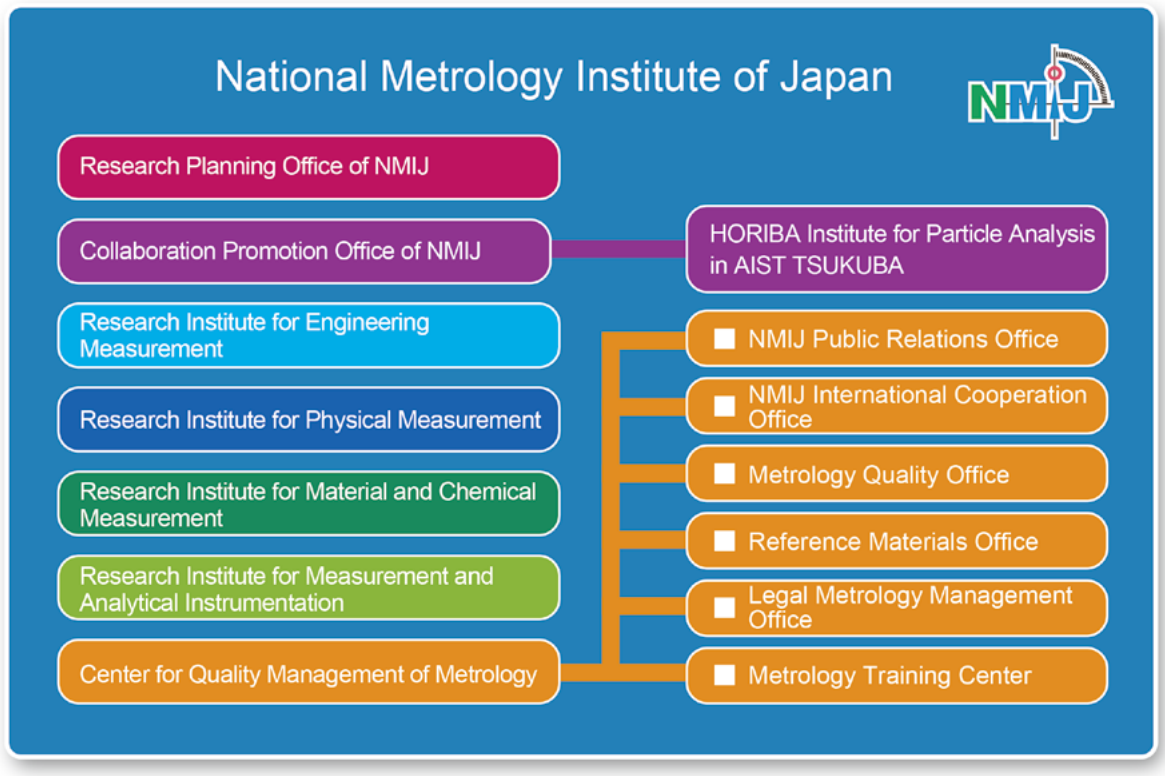
NMIJ Newsletter
No.17, June 2023

Greetings from the Director of RIPM

Dr. HOSAKA Kazumoto
Director of RIPM

In 2015, the Research Institute for Physical Measurement (RIPM) was established as a branch of the National Metrology Institute of Japan (NMIJ). We have been conducting research for advanced measurement technologies in the fields of electricity and magnetism, photometry and radiometry, thermometry, time and frequency, and related quantities. We primarily focus on developing and maintaining national primary measurement standards for these quantities and disseminating the standards to the Japanese industry and other stakeholders through activities such as calibration services. We place great emphasis on studies on state-of-the-art technology in research and development that contribute to the creation of new industries. For example, new technologies based on the fundamental theory of quantum mechanics have recently drawn significant attention from industries, and expectations for innovation have increased. Furthermore, the marketplace for next-generation mobile communication systems—5G and 6G—is expected to grow exponentially. From a metrological point of view, the redefinition of the SI second poses a considerable challenge. Toward the new SI second based on the optical frequency, we have been developing an optical time scale using optical lattice clocks. We expect that the development of these innovative technologies will create new value as infrastructure to maintain future industry and society. In particular, we will dynamically extend our research in these fields and contribute to industrial competitiveness.

Organization Chart of NMIJ



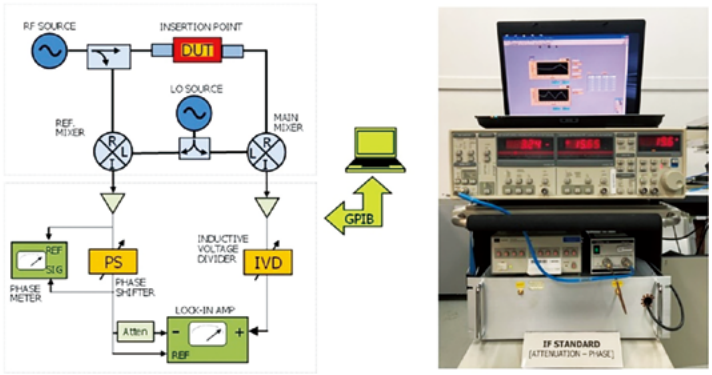
Research Topics

Radio frequency/microwave attenuation and phase-shift standards

WIDARTA Anton

In radio-frequency (RF) and microwave (MW) S-parameter (transmission and reflection coefficients) measurements, the phase information can often be ignored because of its small impact on specification measurements. However, with the increasing complexity of antenna devices, such as various smart antennas used in 5G/6G wireless technology, and with applications related to safety and security, such as current radars used in advanced emergency braking systems, phase information can no longer be ignored. Therefore, accurate information on both amplitude and phase is essential for the S-parameter measurements used in such applications.

Recently, NMIJ developed a precision attenuation and phase-shift measurement system in the frequency range of 10 MHz to 18 GHz, which is used as a primary national standard. The system works based on the intermediate frequency (IF=1 kHz) substitution technique built into a dual-channel null system configuration using a lock-in amplifier as a precision-null detector. An inductive voltage divider and a particular IF phase-shifter are used for the amplitude or attenuation and phase adjustments, respectively, in the null-balancing process. The IF attenuation and phase-shift values represent the RF attenuation and the phase shift of the calibrated device. The dual-channel null balancing system is employed because it is advantageous for signal stability of the source, gain stability of the detector and the highest sensitivity. This system has measurement capabilities of up to 60 dB of attenuation with uncertainties ranging from 0.002dB for attenuation and 0.029° for phase shift. Standards in the frequency range of 10 MHz to1GHz are distributed according to the Japan Calibration Service System (JCSS). A simple working standard system for routine calibration services has also been developed using a general-purpose receiver traceable to the primary standard mentioned above.



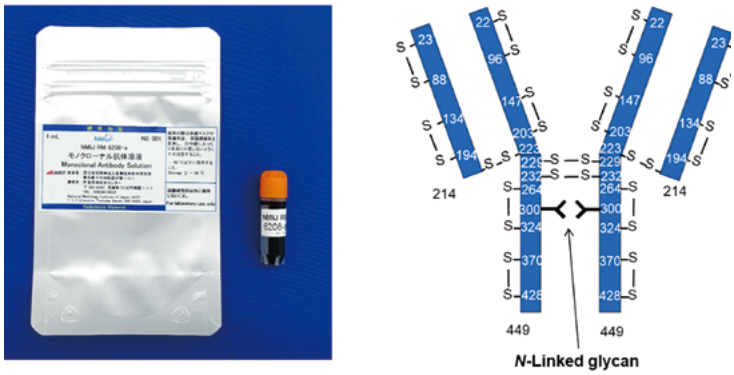
Block diagram of the primary standard system for RF/MW attenuation and phase-shift (left) and a photograph of its working standard system (right).

References:
1. A. Widarta, *IEEE Trans. Instrum. Meas.*, 68, 6, 1840–1843, 2019, DOI: 10.1109/TIM.2018.2888920
2. A. Widarta, *Proc. CPEM Dig.*, Wellington, New Zealand, 2022

Development of monoclonal antibody reference material to support the development and quality control of antibody drug

KINUMI Tomoya

Biopharmaceuticals, especially antibody drugs, have a molecular weight exceeding tens of thousands and are produced using biological processes that lead to structural heterogeneity, including post-translational modifications and the formation of aggregates. In this regard, the International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH) has published guidelines requiring detailed characterization of the structure and the aggregate, including antibody concentration, for the development and quality control of antibody drugs. To address this, we developed a monoclonal antibody reference material (NMIJ RM 6208-a). The 22 physicochemical properties covering most of those required by the ICH guidelines for this reference material and their measurement conditions are available as a case study, thereby, enabling the use of the material and associated case study as a package. This allows the validation of analytical procedures and instruments for determining the important properties of antibody drugs. Hereafter, regarding properties such as glycosylation, whose results depend on the measurement method, we aim to meet the needs of a wide range of characterization by accumulating case studies through inter-laboratory comparisons with external institutions.



Monoclonal antibody reference material, AIST-MAB (NMIJ RM 6208-a), and its structure.

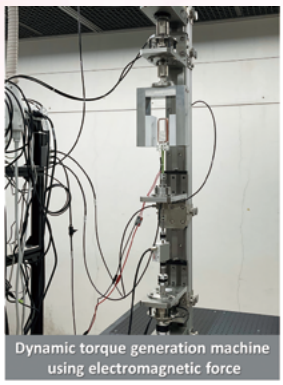
References:
T. Kinumi et al., *Front. Mol. Biosci.*, 9, 842041, 2022
DOI: 10.3389/fmolb.2022.842041

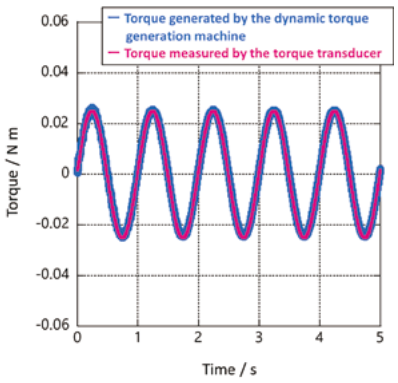
Development of a dynamic torque generation machine for the establishment of dynamic torque calibration technology

HAMAJI Misaki

In recent years, the demand for the precision measurement of torque with time variation (dynamic torque) has increased for the performance evaluation of engines and motors. However, dead-weight-type torque standard machines that have supplied torque standards as national standards are not suitable for precisely measuring dynamic torque, because these machines use gravity to generate torque. Therefore, in this pioneering research, we developed a new machine that can generate dynamic torque traceable to the International System of Units (SI) by using the principle of torque generation through electromagnetic force, instead of gravity (the left figure).

This system generates torque by applying an electric current to a coil installed in a uniform magnetic field. The generated torque can be changed dynamically by altering the applied electric current. By connecting a torque transducer for measuring generated dynamic torque to the coil and synchronously measuring the applied electric current and output of the torque transducer, the dynamic characteristics of the torque transducer can be evaluated.





Measurement of dynamic torque generated by dynamic torque generation machine.

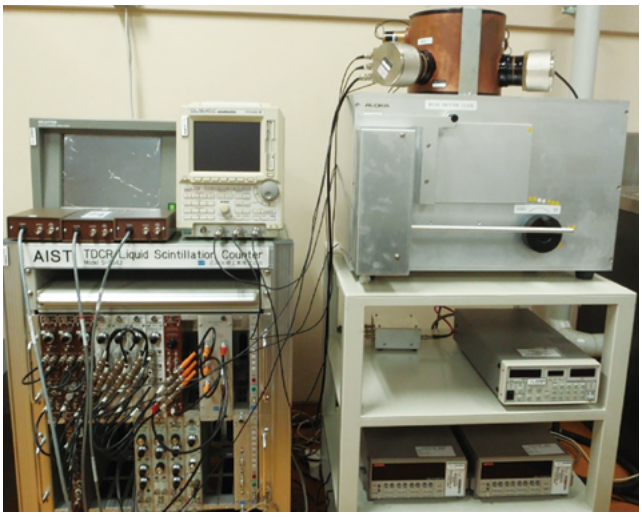
For the first time, a sinusoidal dynamic torque of approximately 1 Hz traceable to the SI was successfully generated using an electromagnetic force (the right figure). The relative expanded uncertainty of the dynamic torque generated by this machine was evaluated to be 0.29 %. In the future, we will contribute to developing precise measurement technology and establishing calibration technology for dynamic torque by further expanding the torque and frequency ranges.

References:
Hamaji et. al., *Meas. Sci. Technol.*, 33, 115901, 2022
DOI: 10.1088/1361-6501/ac8441

Radioactivity standard for nuclear medicine

SATO Yasushi

Recently, novel radiopharmaceuticals have been actively developed for scanning and therapy in the field of nuclear medicine. Clearer images and better therapeutic effects are obtained by administering nuclear pharmaceuticals that specifically accumulate in tumors. Thus, accurate measurement of radioactivity is necessary for the safe and effective use of radiopharmaceuticals. However, nuclides that are not currently in use are utilized as novel radiopharmaceuticals. We researched and developed measurement and calculation methods for each radionuclide because these nuclides decay in various ways, such as through the emission of beta, alpha, and annihilation radiation, or coexistence with many radioactive progenies. Moreover, an international comparison was conducted to ensure the equivalence of radioactivity measurements. The transfer instrument is used for international comparison of short-half-life radiopharmaceuticals, and currently, only one transfer instrument is available in the world. Thus, research institutes in several countries have developed new transfer instruments to conduct international comparisons more frequently and accurately. In this direction, we have also initiated research and development of this transfer instrument. Thus, the NMIJ has made progress in the research and development of nuclear medicine.



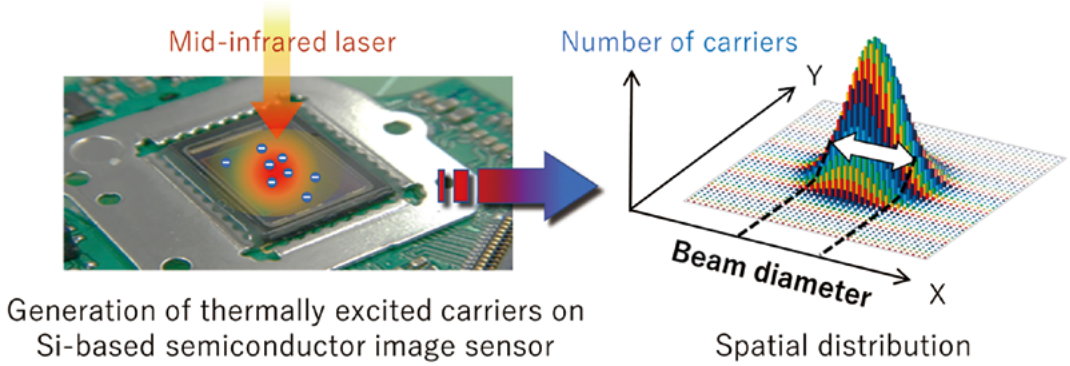
The equipment for standardization of radionuclides.

Beam diameter measurement of mid-infrared lasers using semiconductor image sensor

NUMATA Takayuki

Mid-infrared lasers are widely used in material processing and advanced medicine. In these fields, measurement and control of the laser beam diameter are necessary because the power density of the irradiated laser beam onto the target object is crucial for the quality of processing and the safety of medical treatment. Conventionally, techniques using thermal array detectors, scanning spatial filters, and the observation of burn patterns on acrylic blocks are used for these measurements. However, these methods have drawbacks such as high cost, limited performance for real-time measurement, and toxic fumes during measurement. To address these issues, the NMIJ developed a new principle for measuring the beam diameter of mid-infrared lasers. In this method, the light-receiving surface of the silicon-based semiconductor image sensor is irradiated and spot heated using the mid-infrared laser beam to be measured. The carriers are subsequently excited via the heated spot and compose an image according to the temperature distribution. The ratio between the diameters of the thermally excited carrier distribution and the incident laser beam with a Gaussian distribution becomes constant and independent of the incident beam diameter. Therefore, the arbitrary beam diameter of the incident laser can be calculated by applying a ratio that is preliminarily evaluated for the distribution of thermally excited carriers. On the basis of this principle, we demonstrated a new method of beam diameter measurement for mid-infrared lasers that can solve the problems encountered in conventional methods.

References: T. Numata, *Appl. Phys. Express*, 15, 096502, 2022
DOI: 10.35848/1882-0786/ac8145

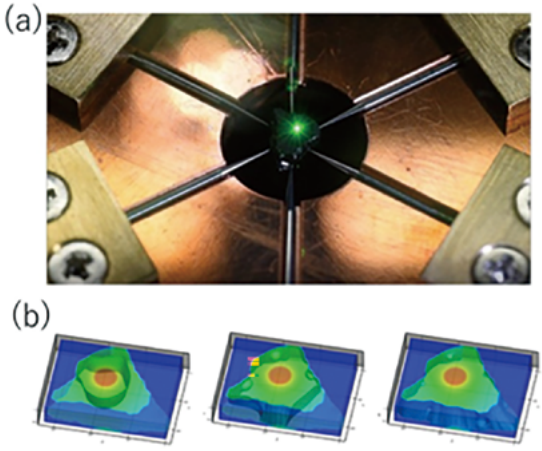


Measurement principle for beam diameter of mid-infrared lasers developed at NMIJ.

Thermal diffusivity measurement on a particle from the asteroid Ryugu using a non-contact measurement technique

YAGI Takashi, YAMASHITA Yuichiro

The asteroid explorer Hayabusa2 has brought a total of approximately 5.4 g of particles from the asteroid Ryugu to Earth. The thermophysical properties of the asteroid are valuable information that can reveal the details of chemical reactions and material formations inside an early parent asteroid. The particle tested was a few millimeters square in area, and additional processing and installation of sensors were not allowed to avoid contamination. Therefore, we adopted a non-contact thermal diffusivity measurement technique known as laser spot periodic heating radiation thermometry.



(a) photograph of the measured Ryugu particle set in the chamber and (b) typical simulation results to derive thermal diffusivity.

The sample was held by six needles in a high-vacuum chamber and the surface was periodically heated with a laser spot. The temperature change at the rear surface was detected by infrared radiation measurement using a high-spatial-resolution Ge lens and a liquid nitrogen-cooled InSb infrared sensor. Furthermore, we conducted temperature simulations of the particle using a computer cluster to determine the thermal diffusivity. The obtained thermal diffusivity is $(3.2 \pm 0.3) \times 10^{-7}$ m^2 s^{-1}, indicating that the thermophysical properties of the particle are similar to those of resin.

The obtained thermophysical property has been used in various numerical simulations to explore the early formation and thermal evolution of Ryugu, contributing to research on the formation of the solar system.

Featured Topics

The 27th Meeting of the CGPM and Dr. Usuda's Re-election as Secretary of the CIPM

The 27th meeting of the General Conference on Weights and Measures (CGPM) was convened at the Palais des Congrès, Versailles, France, for four days, from 15th to 18th November 2022. The meeting was held in a hybrid mode, in person and online, and adopted seven resolutions, including a resolution on the extension of the range of SI prefixes and another resolution on the future redefinition of the second.

The four new prefixes for SI adopted by the CGPM are "ronna (symbol R)" for 10^{27}, "quetta (symbol Q)" for 10^{30}, "ronto (symbol r)" for 10^{-27}, and "quecto (symbol q) for 10^{-30}. The range of SI prefixes was extended for the first time in the 31 years since 1991 to cope with the increasing amount of digital information, reflecting the rapid and worldwide advancement of science and technology. The meeting also adopted the abolition of leap seconds, which will have an enormous impact on the field, mainly on information technology.

During the four-day meeting, Dr. YASUNAGA Yuko, Deputy to the Director General of the United Nations Industrial Development Organization (UNIDO), presented and delivered a valuable message on the relationship between UN Sustainable Development Goals and standardization toward the metrology community.

The results of the International Committee for Weights and Measures (CIPM) and the Committee for CIPM Election (CEC) were announced on the last day of the conference. Dr. USUDA Takashi, Director General of NMIJ, was re-elected as a member of CIPM, and Dr. KOBATA Tokihiko, Deputy Director General of NMIJ, was elected as a member of CEC. They both won the most votes in their respective elections, indicating the NMIJ's presence in the world. Later, from 21st to 23rd March 2023, the 112th CIPM was held at BIPM in France, and Dr. USUDA was re-elected as Secretary for another four-year term starting from 21st March 2023. Dr. USUDA continues to supervise the BIPM, manage the CIPM, and will serve as a moderator assisting the President in the next CGPM to be held in 2026.

The 27th meeting of the CGPM

https://www.bipm.org/en/-/2023-03-21-cipm-louw-usuda

From left to right: Dr. Usuda (Secretary), Dr. Richard (Vice-President), Dr. Louw (President), Dr. Milton (BIPM Director and *ex officio* member of the CIPM) and Dr. Olthoff (Vice-President).

The 38th APMP General Assembly and Related Meetings (APMP 2022)

The 38th General Assembly and Related Meetings of the Asia Pacific Metrology Programme (APMP 2022) were held in a hybrid mode at the AIST Tokyo Waterfront Annex in Odaiba, Tokyo, for five days from 28th November to 2nd December 2022. The NMIJ served as a host and cooperated in its operations.

The APMP is a grouping of national metrology institutes (NMIs) from the Asia-Pacific region, and its full members and associate members have been taking turns hosting annual meetings. However, because of the outbreak of the Coronavirus Disease (COVID-19), APMP 2022 was the first in-person meeting held in three years.

While onsite meetings were conducted with limited participants taking thorough measures against COVID-19, the APMP symposium was held online with simultaneous interpretation in English and Japanese. By introducing new styles of distribution, APMP 2022 was able to target a wide range of audiences, regardless of their area of expertise or nationality.

In addition to regular meetings in which annual activities were reported by Executive Committee (EC) members and Technical Committee (TC) chairs, a workshop was held to discuss digital transformation (DX), which has been drawing attention worldwide. In the symposium titled "Metrology Underpinning a Sustainable Society" held on 30th November, six presentations were performed: three from NMIJ and three from APMP focus groups. The symposium ended in great success with 216 participants, including 59 onsite participants.

During the five-day meetings, the APMP Chairperson and Secretariat were transferred. The National Institute of Metrology (NIM) of China finished its three-year term, and the Korea Research Institute of Standards and Science (KRISS) of Korea took over the task for the next three years. Thus far, the NMIJ has assumed the chair country twice. At present, Dr. MORIOKA Kenji, Group Leader of Electromagnetic Fields Standards Group, is serving as an EC member, and Dr. Abe Hisashi, Chief Senior Researcher, is serving as Chair of the Technical Committee for Thermometry (TCT). At APMP 2022, Dr. HOSAKA Kazumoto, Director of the Research Institute for Physical Measurement, was elected and approved as Chair of the Technical Committee of Time and Frequency (TCTF). The NMIJ will continue to contribute to the APMP activities in various ways.

Mr. FANG Xiang, Director of NIM, APMP Chairperson, served until the 38th APMP (left), and Dr. USUDA Takashi, Director General of NMIJ (right).

The 38th APMP General Assembly and Related Meetings.

Initiative by NMIJ for issuing Digital Calibration Certificates (DCCs) from 1st November 2022

YAMAZAWA Kazuaki, TAKETOSHI Naoyuki

The NMIJ officially initiated issuing services of digital calibration certificates (DCCs) for customers from 1st November 2022. Although the number of service items compatible to DCCs is still small, we plan to gradually expand our service items.

The NMIJ selected the PDF as a format for DCCs. The PDF file looks very similar to existing calibration certificates issued on paper. The difference is that digital data such as calibration metadata and calibration results (in CSV format) are embedded in DCCs in response to clients' needs. To be consistent with paper certificates, the calibration results displayed on the face of the PDF are the authorized data and the identical data is embedded in the PDF as reference information.

The PDF format with machine-readable information for clients' reference is expected to be a significant benefit over paper certificates as a large amount of calibration data (RF impedance, antenna factor, etc.) is available. We will continue improving the DCC format to meet the demands of our clients.

This topic was introduced during the APMP DXFG webinar held on 28th November 2022 [1] and was also presented at the third DCC Conference (organized by PTB) held from 28th February to 2nd March 2023 [2].

A sample digital calibration certificate issued by NMIJ.

References:

[1] APMP-DXFG Webinar: 28th November 2022, https://apmp-dxfg.org/dxfg-eoy-webinar-2022.html (accessed 28th February 2023)

[2] 3rd International Digital Calibration Certificate (DCC) Conference, https://www.dcc-conference-2023.ptb.de/home (accessed 28th February 2023)

Online open seminar on Sustainable Infrastructure Research Laboratory

On 9th December 2022, the Sustainable Infrastructure Research Laboratory held the second open seminar online with around 120 participants. Prof. Shiotani from Kyoto University was invited to present the latest research on applying digital technology to infrastructure maintenance and management. The laboratory members introduced ongoing research related to infrastructure inspection methods that integrate information technology and the development of materials that can extend the life of structures through oral or poster presentations.

Data on international activities

The NMIJ contributes to a wide range of international activities. The following figures show the international activities carried out in one year from 1st April 2022 to 31st March 2023. We appreciate the kind support from the NMI community.

International comparisons (piloted by NMIJ): 27

Peer reviewers dispatched: 19 (face-to-face: 4, online: 15)

Invited reviewers: 8

Selected Research Reports

1) N. Takegawa, N. Furuichi, "Traceability management system using blockchain technology and cost estimation in the metrology field," Sensors, **23**, 3, 1673, 2023, DOI: 10.3390/s23031673
2) T. Yoshida, N. Furuichi, "Development of controllable volumetric prover for evaluating responsiveness of flowmeter under controlled-transient flows," Measurement, **208**, 112456, 2023, DOI: 10.1016/j.measurement.2023.112456
3) Y. Hori, "Quantitative evaluation and removal of periodic error caused by ghost reflections in a double-path homodyne interferometer," Measurement Science and Technology, **34**, 025011, 2023, DOI: 10.1088/1361-6501/ac929e
4) Y. Tanaka, K. Hattori, Y. Harada, "A study of the high-temperature strength of titanium alloys using nanoindentation and micro-cantilever bending tests," Metallurgical and Materials Transactions A, **53**, 3827–3832, 2022, DOI: 10.1007/s11661-022-06813-z
5) K. Niwa, H. Kubota, T. Enomoto, Y. Ichino, Y. Ohmiya, "Quantitative analysis of bioluminescence optical signal," Biosensors, **13**, 2, 223, 2023, DOI: 10.3390/bios13020223
6) K. Amemiya, Y. Shimizu, H. Koshikawa, H. Shitomi, T. Yamaki, "Supreme-black levels enabled by touchproof microcavity surface texture on anti-backscatter matrix," Science Advances, **9**, 2, 2023, DOI: 10.1126/sciadv.ade4853
7) T. Kobayashi, A. Takamizawa, D. Akamatsu, A. Kawasaki, A. Nishiyama, K. Hosaka, Y. Hisai, M. Wada, H. Inaba, T. Tanabe, M. Yasuda, "Search for ultralight dark matter from long-term frequency comparisons of optical and microwave atomic clocks," Physical Review Letters, **129**, 241301, 2022, DOI: 10.1103/PhysRevLett.129.241301
8) Y. Amagai, T. Shimazaki, K. Okawa, T. Kawae, H. Fujiki, N. Kaneko, "A straightforward DC-reversal method for the Thomson coefficient measurement," Measurement, **205**, 112205, 2022, DOI: 10.1016/j. measurement.2022.112205
9) S. Takeya, H. Fujihisa, S. Alavi, R. Ohmura, "Thermally induced phase transition of cubic structure II hydrate: Crystal structures of tetrahydropyran–CO_2 binary hydrate," Journal of Physical Chemistry Letters, **14**, 7, 1885–1891, 2023, DOI: 10.1021/acs.jpclett.2c03392
10) H. Abe, M. Amano, K. Hashiguchi, D. Lisak, S. Honda, T. Miyake, "Improvement of spectral resolution in a miniaturized trace-moisture sensor using cavity ring-down spectroscopy: Performance evaluation using a trace-moisture standard in He," Sensors and Actuators A: Physical, **351**, 114146, 2023, DOI: 10.1016/j.sna.2022.114146
11) H. Kato, A. Nakamura, "Novel colloidal dispersing concept in aqueous media for preparation by wet-jet milling dispersing method," Nanomaterials, **13**, 1, 80, 2023, DOI: 10.3390/nano13010080
12) T. Narukawa, T. Suzuki, S. Okabayashi, K.Chiba, "An online internal standard technique for high-performance liquid chromatography-inductively coupled plasma mass spectrometry (HPLC-ICP-MS)," Analytical Methods, **15**, 240, 2023, DOI: 10.1039/D2AY01696F
13) D. Asakawa, "Phenyl sulfate derivatives: New thermometer ions for characterization of internal energy of negative ions produced by electrospray ionization," Journal of the American Society for Mass Spectrometry, **34**, 3, 435–440, 2023, DOI: 10.1021/jasms.2c00321
14) N. Sei, H. Zen, H. Ohgaki, "Deformation of an electron bunch caused by free-electron lasers," Physica Scripta, **98**, 025510, 2023, DOI: 10.1088/1402-4896/acb253
15) Y. Unno, T. Fujiwara, Y. Kishimoto, T. Sanami, "Gas gain measurement for charged particle spectroscopy using glass GEM in low-pressure P-10 gas," Journal of Instrumentation, **18**, P01001, 2023, DOI: 10.1088/1748-0221/18/01/P01001
16) H. Kimura, T. Fujiwara, M. Tanaka, T. Kato, D. Nakauchi, N. Kawaguchi, T. Yanagida, "Radiation-induced luminescence properties of Ce-doped $ZnBr_2$-based glasses," Sensors and Materials, **35**, 513–519, 2023, DOI: 10.18494/SAM4146

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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