

Greetings from the CIML member

NMIJ/AIST is Japan's National Metrology Institute and responsible for Japanese measurement standards. The institute is also responsible for some part of legal metrology, like PTB in Germany and NIM in PR China. The main mission of NMIJ in legal metrology is type approval and dissemination of measurement standards for verification. The staff in charge of legal metrology at NMIJ are around thirty in number, and they are all active domestically and internationally.

Having scientific and legal metrology in a single institute is often very beneficial especially from the legal metrology point of view.

One good example is the case of liquid hydrogen dispensers. Hydrogen is thought as one of the best fuels for the next generation vehicles. That led to the situation where NMIJ should quickly develop the testing technique and documentary standard for those devices. NMIJ conducted a project with a combined team of scientific and legal metrology staff to accomplish the target. As a result, OIML R 139 was revised last year to incorporate the hydrogen dispenser with crucial contribution from the project.

In addition to the above topic, the following article covers the recent reformation in Japanese legal metrology system, participation in the new OIML-CS, and others, in which, some types of automatic weighing instruments were placed under the legal control. In the OIML-CS, Japan is an issuing authority in the categories of R 60 and R 76.

I also hope this article will help readers to know another important mission of NMIJ in more detail.



Dr. Yukinobu Miki

Senior Vice President of AIST
CIML Second Vice President

Contribution by NMIJ for the international legal metrology framework including OIML

Introduction

The national framework of legal metrology, scientific metrology and traceability system is specified in Measurement Act (1992). This act stipulates that the specified measuring instruments in the 18 categories should be under control of legal metrology for ensuring the reliability in transactions and certifications, and they are subject to type approval and verification. The act is also supplemented with cabinet orders, ministerial orders and Japanese Industrial Standards (JIS).

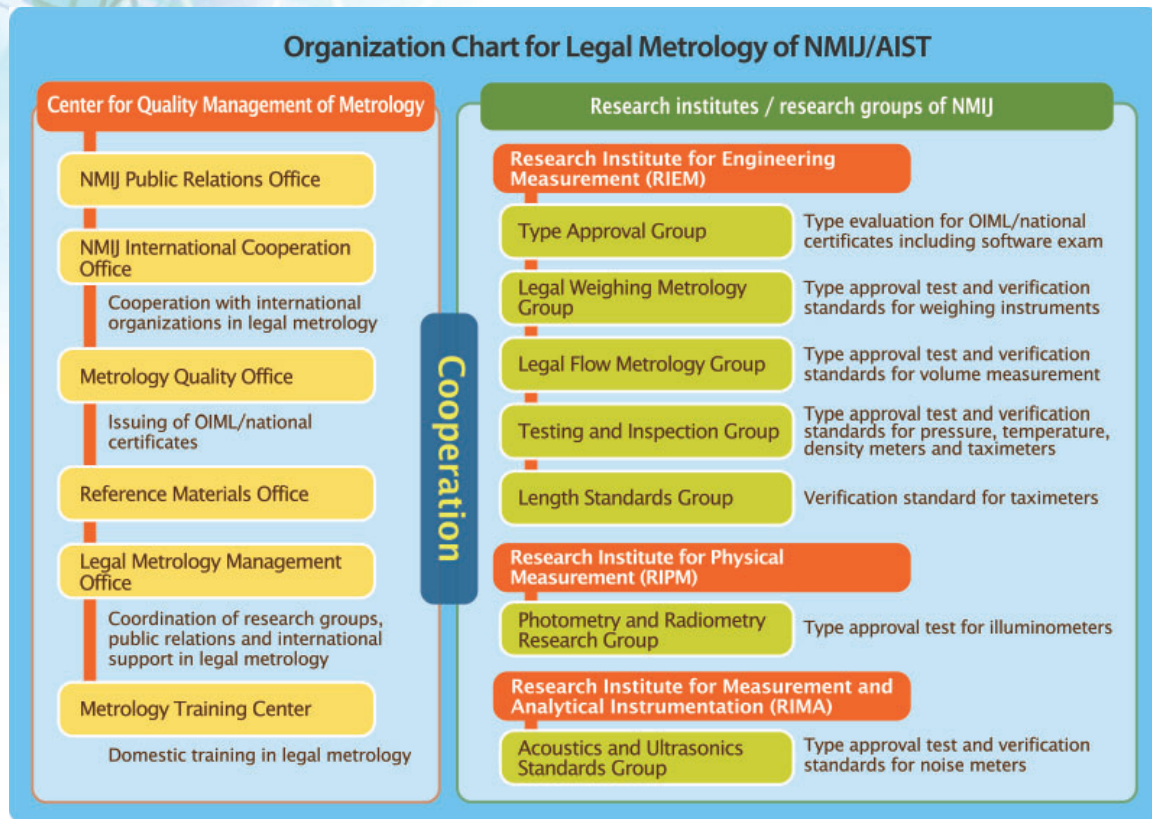
Ministry of Economy, Trade and Industry (METI) is responsible for both scientific and legal aspects of the Measurement Act. National Metrology Institute of Japan (NMIJ) is a part of National Institute of Advanced Industrial Science and Technology (AIST) and supports METI as a group of technical experts. In addition, Japan Electric Meters Inspection Corporation (JEMIC), Japan Quality Assurance Organization (JQA) and local

verification institutes in the 47 prefectures support the national infrastructure for legal metrology.

Japan participated in Metre Convention in 1885 and OIML Convention in 1961. METI is responsible for both treaties and NMIJ supports liaisons between these international organizations. The CIML member, as the representative to OIML, has been provided by NRLM (National Research Laboratory of Metrology) before 2001 and by AIST afterwards. As of 2019, Dr. Yukinobu Miki (Senior Vice President of AIST) is the CIML Second Vice President as well as the CIML member. Regarding the OIML technical activities, Japan joins to many TCs (technical committees) and SCs (sub committees) as a P (participating) member. With support of the domestic mirror committee to OIML, Japan is submitting many comments in response to approximately 30 inquiries annually regarding the OIML publications.

NMIJ, which consists of four research institutes and Center for Quality Management of Metrology (CQMM), maintains the national primary standards. In legal metrology, NMIJ provides services for type approval, inspection of verification standards (working standards used for legal metrology) and training of domestic experts in metrology. Research Institute for Engineering Measurement (RIEM) of NMIJ provides most of

the testing services for legal metrology. CQMM supports legal metrology through international cooperation and maintenance of the quality systems for testing. Research Institute for Physical Measurement (RIPM) and Research Institute for Measurement and Analytical Instrumentation (RIMA) also support part of the testing services in legal metrology (see figure below).



Review and reformation of administration system in legal metrology

In 2016, Measurement Administration Council provided a proposal regarding practical implementation of Measurement Act in the future. Following this proposal, METI has been revising the cabinet orders and ministerial ordinances that support Measurement Act since 2017, and NMIJ supports this activity.

As the primary reformation, the requirements to verification bodies was mitigated. Designated verification institutes, which are mostly private non-profit bodies, are then allowed to conduct verifications for the instrument categories of NAWI (non-automatic weighing instrument), AWI (automatic weighing instrument) and fuel dispensers.

In addition, AWIs are newly subjected to the legal metrological control as one of the specified measuring instruments in order to respond to the increasing social needs for consumer protection as well as conformance to the OIML's technical

requirements. In April 2019, type approval and verification started for the category corresponds to OIML R 51 (automatic catch-weighing instruments/photo 1).

Other categories correspond to R 50 (continuous totalizing automatic weighing instruments), R 61 (automatic gravimetric filling instruments) and R 107 (discontinuous totalizing automatic weighing instruments) will gradually be subject to the legal metrological control by 2020. In this control scheme, NMIJ is responsible for type approval and the designated verification institutes are responsible for verification of AWIs. To respond these reformations of the legislation system, NMIJ is conducting the following activities.

- New services for testing and issuing domestic certificates for type approval on automatic catch-weighing instruments since April 2019.
- Setting up of new test facilities for AWIs to be available in two AIST sites in Tsukuba-city and the Renewable Energy Institute, AIST (FREAI) in Fukushima Prefecture.

- Leading the drafting procedures of new JIS (Japanese Industrial Standard) as the technical requirement applied for the legal metrological control on AWIs. The domestic stakeholders (central/local governments, manufactures and users) also participate in this procedure. Four JIS documents correspond to OIML R 50, R 51, R 61 and R 107 are being drafted.

As another reformation to correspond to the recent redefinition of the four SI units in CGPM, a ministerial ordinance specifying the units to be used in legal metrology was revised in May 2019, and necessary amendments were added to the definitions in the ordinance.

Type approval and participation to OIML-CS

In Japan, type approval is required for the specified measuring instruments before mass production. When a type is approved, a type-approval number is issued, and it is printed on each instrument. AIST, supported by NMIJ, is responsible for the type-approval regarding most of the specified measuring instruments.

In OIML Certificate System (OIML-CS), AIST plays a role of an issuing authority as well as a testing laboratory in the instrument categories on R 60 (load cells) and R 76 (non-automatic weighing instrument) in the scheme A. OIML certificates issued in other countries may be accepted based on the mutual recognition arrangements under OIML-CS. Apart from OIML-CS, type-approval certificates issued in Netherlands and Germany may be accepted based on the bilateral MoUs (memorandum of understandings).

NMIJ maintains the testing facilities for type approval; dead-weight machines for load cell (Photo 2), an anechoic chamber for testing EMS (Photo 3), temperature-controlled chambers for environmental tests, test equipment for non-automatic weighing instrument, temperature baths for thermometer, pressure balances for aneroid pressure-gauge, test equipment for water meter and test equipment for fuel dispensers. In addition, the facilities for AWIs are being prepared for the new type approval service in this category.

Regarding the NMIJ's quality system for type approval, a conformity to ISO/IEC 17025 is required

to the testing laboratory of OIML-CS, and NMIJ is accredited by IAJapan, NITE (National Institute of Technology and Evaluation) which is the national accreditation body. Regarding a conformity to ISO/IEC 17065 for OIML-CS, NMIJ is preparing for an accreditation by NITE.

Regarding a statistical fact on OIML-CS, NMIJ has issued a total of 109 certificates including those for the previous certificate schemes (Basic system and MAA system). This is the 7th highest number in all issuing authorities of OIML-CS.

Revision of R 139

To ensure energy supply and prevent global warming due to CO₂, the government promotes development of FCVs (Fuel Cell Vehicles) as well as setting up of HRSs (Hydrogen Refueling Stations). Reliable measurement of the mass of hydrogen at HRSs is indispensable to protect the consumers in transactions. For this reason, a new JIS B8576 (measurement system of hydrogen-fuel) was published in 2016.

To assure international coordination in technical requirements for hydrogen metering systems, Japan proposed a project (TC 8/SC 7/p7) for revising R 139 (compressed gaseous fuels measuring systems for vehicles) at the 51st CIML meeting in 2016 as a co-convenor supporting Netherlands. In this project, the experts of NMIJ submitted many valuable proposals based on the experimental results. Its final draft was approved and was published in 2018. Because the efficient achievement of this project was highly evaluated in OIML, Dr. Toshiyuki Takatsuji of NMIJ received an OIML letter of appreciation at the 53rd CIML meeting in 2018 as the co-convenor of the project.

Secretariat of OIML TC 8

Since 2011, NMIJ is the secretariat of OIML TC 8 (measurement of quantities of fluids) and is responsible for the OIML publications; R 40, R 41, R 43, R 63, R 119, R 120, R 138, D 25 and D 26. At present, TC 8 is responsible for two projects for revising R 63:1994 (petroleum tables) and R 119:1996 (pipe provers for testing of measuring systems for liquids). The secretariat proposed two 1st Committee Drafts of these documents in June 2019.



Photo 1: A typical automatic catch-weighing instrument

Photo 2: Dead-weight machines for testing load cells with a maximum capacity of 20 t

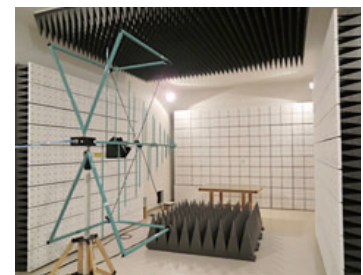
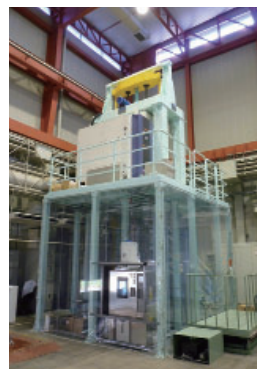


Photo 3: Anechoic chamber of electromagnetic wave for testing EMS (electromagnetic susceptibility)

Research Topics

Hydrogen gas flow measurement

Toshihiro Morioka, Yoshiya Terao, and Toshiyuki Takatsuji (RIEM)

Efforts are being made to promote and expand the hydrogen utilization as one of the next generation energy sources, in order to realize the decarbonizing society that is the key to the prevention of global warming. Fuel cell vehicle (FCV) is a representative example. In Japan, a total of more than 3,000 FCVs have already been in use, and the hydrogen refueling stations (HRSs) to provide hydrogen fuel have been installed at more than 100 places. A hydrogen dispenser at HRS can dispense five kilograms of hydrogen in about three minutes. This is a major advantage of FCVs against electric vehicles which take more than 20 minutes to charge the battery. The hydrogen dispenser has a built-in flowmeter as a metering instrument, and hydrogen transactions are conducted in the same way as that of the conventional gasoline.

The Gas Flow Standards Group in the Research Institute for Engineering Measurement has been developing the hydrogen gas flow rate measurement technology so that the hydrogen transactions will be performed appropriately at HRSs. Critical nozzles were calibrated with hydrogen by means of the gas

flow rate calibration facility with the gravimetric method, and its calibration range in mass flow rate was 1.1 mg/min to 110 g/min. The build-up method, which increases flow by combining several calibrated critical nozzles (Figure 1) and further increasing the calibrating pressure, enabled flowmeter calibration at a maximum pressure of 82 MPa and a maximum flow rate of 3.0 kg/min. Demonstration tests of measurement precision of the hydrogen dispenser are currently implemented by means of a master meter method that was jointly developed with Iwatani Corporation by using this technology (Figure 2). As a result, the master meter method performed a shorter testing time than the weighing method that had been used before.

As described in the previous article, although the international recommendation OIML R 139 has been revised under initiative of Japan and Netherlands, it will be further revised by using the results of this research. We aim for realizing the measurement precision test of the hydrogen dispenser with higher reliability at lower cost, and for further spread of HRS in the future.

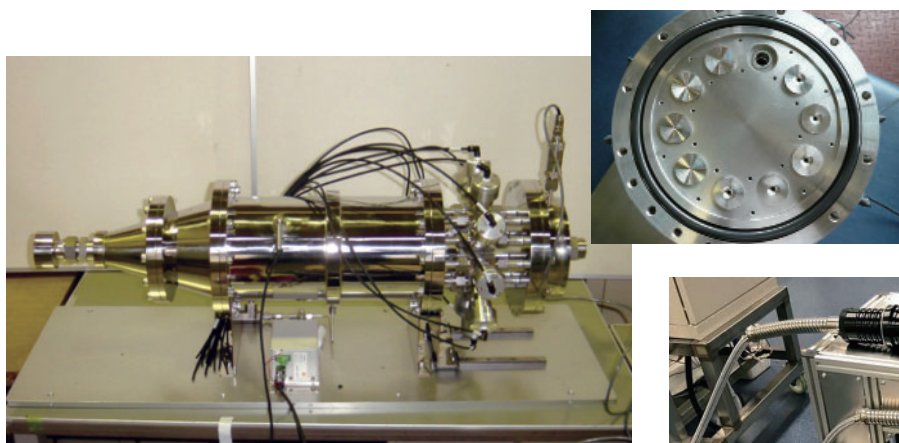


Figure 1: Multi-nozzle-type calibrator.

Figure 2: Test equipment of measurement precision of hydrogen dispenser with a master meter method.



Upcoming Event

Welcome to IMEKO 2021

The XXIII IMEKO World Congress will be held
from August 30 to September 3, 2021 in Yokohama, Japan.
For more information : www.imeko2021.org

APMP Mid-Year Meeting 2019

The National Metrology Laboratory - Industrial Technology Development Institute (NML-ITDI) hosted the APMP Mid-Year Meeting 2019 from 17th to 21st June 2019 in Mactan Island, Cebu, Philippines. Dr. Toshiyuki Takatsuji, APMP Chairperson, Dr. Chu-Shik Kang, Lead TC Chair and Dr. Angela Samuel, DEC Chair managed respective meetings and all meetings were completed successfully. Dr. Ryuzo Horiuchi, TCAUV Chair, Dr. Kazuaki Yamazawa, TCQS Chair, Dr. Takashi Shimada, TCFF Chair and Dr. Kazumi Inagaki, TCQM Chair participated in relevant meetings from NMIJ.

Dr. Anton Widarta, Associate Manager of International Cooperation Office attended DEC meeting and workshop as a delegate of NMIJ and delivered a presentation at the meeting, introducing the activities of NMIJ for Developing Economies. In DEC and MEDEA Focus Group Awareness Raising Workshop, participants had a deeper discussion in a variety of ways under the management of a facilitator.



Dr. Kazumi Inagaki



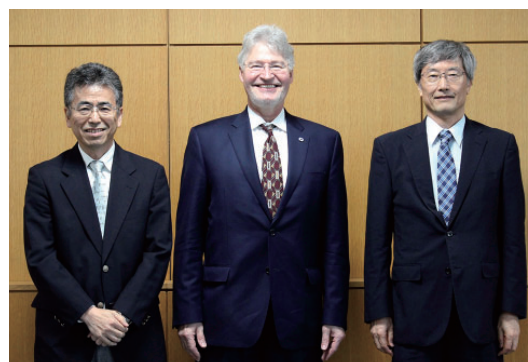
Dr. Anton Widarta

In the International Symposium on Metrology Awareness in Clean Water and NMI-Stakeholder Engagement Workshop and Focus Group Meeting held in JPark Island Resort and Waterpark held on 20 June, a total of 84 attendees participated in the symposium and workshop. Dr. Kazumi Inagaki, Group Leader of Environmental Standards Group of NMIJ delivered a presentation on Role of Metrology in Ensuring Clean Water as an invited speaker of the symposium.

The next APMP meeting, APMP 2019 General Assembly and related meetings will be held from 28th November to 6th December 2019 in Sydney, Australia.

NIST delegation visits NMIJ/AIST

On 1st July 2019, delegation of National Institute of Standards and Technology (NIST) visited NMIJ/AIST. The delegates were Dr. Walter G. Copan, Under Secretary of Commerce for Standards Technology and Director of NIST, Dr. James Olthoff, Principal Deputy Director and Associate Director for Laboratory Programs, and Dr. Claire M. Saundry, Director of International and Academic Affairs. Dr. Yukinobu Miki, Senior Vice-President of AIST, Dr. Takashi Usuda, Director General of NMIJ, and Directors of Research Institutes in NMIJ, welcomed them and discussed present activities and farther collaborations between NIST and NMIJ. The NIST delegation joined the lab tour in Tsukuba site about Realization of the New Kilogram using ^{28}Si Spheres, Optical Lattice Clock, and Quantum Electrical Standards, which was followed by visiting AIST Tokyo headquarter office for attending the signing ceremony of the Memorandum of Understanding (MoU) between NIST and AIST.

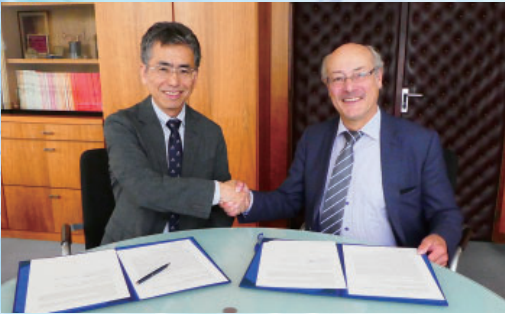


Renewal of MoU between BIPM and NMIJ



The Memorandum of Understanding (MoU) between NMIJ and BIPM was renewed on 17th June 2019. The purpose of this MoU is to set the general framework to promote BIPM and NMIJ to cooperate in development and application of (a) Quantitative NMR for supporting the international equivalence of organic primary calibrators and (b) next generation CO_2 in air standards. BIPM and NMIJ pursue the common goal to improve analytical methods and procedures available for all Member States and reinforce coordination activity of BIPM in key comparisons for the benefit of all Member States.

Renewal of LoI between PTB and NMIJ



The NMIJ signed the Letter of Intent (LoI) for scientific and technological research cooperation with Physikalisch-Technische Bundesanstalt (PTB). NMIJ and PTB mutually decided to extend the previous LoI for the cooperation in the field of the kilogram realization, which has been effective from 2015 to 2019. This renewed LoI come into force on 26th August 2019, valid for five years and will be extended by mutual written consent.

Dr. Peters gives lectures at NMIJ's measuring instrument software club

The NMIJ measuring instrument software club organized an event for exchanging knowledge with software testers/developers and invited Dr. Daniel Peters, the group leader of WG 8.54 (Embedded Metrological Systems) at PTB, as the lecturer for the general assembly of the group held on the 16th April 2019 at the AIST Tokyo Waterfront site. Two lectures titled "European Metrology Cloud project" and "Gentle introduction to blockchain technology in legal metrology" were given.

In response to NMIJ's invitation, Dr. Daniel Peters has stayed intermittently for 3 months in Japan from December 2018 to April 2019 to develop collaborative activities for IT security projects.



Dissemination of the new definition of SI base units through media

On 20th May 2019, NMIJ/AIST celebrated the epoch-making World Metrology Day when the new definition of the SI came into force. AIST set up a special website in order to introduce international efforts for the redefinition including valuable contribution of Japan. The Cabinet Order that prescribes the measurement units used in the Measurement Act in Japan has also been revised on the same day, and NMIJ announced through the website how the corresponding domestic standards are changed. It drew various mass media attention, about 40 news on the topic of the redefinition of the SI units were reported during the period from 17th May to 19th June.

In addition, AIST's official Twitter invited ideas for Japanese wordplay ("goro-awase"), how to memorize all the digits of the Planck constant easily. And many interesting ideas were gathered in response. NMIJ will keep effort to disseminate the new definition of the SI and the importance of metrological traceability to the SI.

Date	Media (N: newspaper / W: website)
17-20 May 2019	JPubb (W), Asahi Shimbun Digital (W), NTT Docomo dMenu News (W), Yukan Fuji (N), goo News (W), Livedoor News (W), mixi News (W), msn (W), MY J: COM (W), Yahoo! News (W), Gunosy (W), NAVER Matome (W), Yomiuri Shimbun Online (W)
21 May 2019	BIGLOBE News (W), NTT Docomo dMenu News (W), goo News (W), Hokkoku Shimbun (N), Kumamoto Nichinichi Shimbun (N), Livedoor News (W), Merumo (W), Oita Godo Shimbun (N), Srad (W), Yahoo! News (W), Yamagata Shimbun (N), Yomiuri Shimbun (N), Yomiuri Shimbun Online (W)
22 May - 6 June 2019	Gunosy (W), Kodansha (W), Asahi Shimbun (N), Ronza-Asahi Shimbun speech site (W), Shizuoka Shimbun (N), Ibaraki Shimbun (N), Too Nippo (N)
7-19 June 2019	Bluebacks Kodansha (W), Fukui Shimbun Online (W), Denki Shimbun (N), Fukui Shimbun (N), Too Nippo (N)

Neck strap commemorating the historic redefinition of the SI base units

The Measurement Act is a historic law that originated from the metrology law established in 1891, after Japan's participation in the Metre Convention in 1885. The day of 1st November, when the Measurement Act of Japan was revised and implemented in 1993, is enacted as the Measurement Anniversary in Japan.

This year, NMIJ has produced a neck strap for the anniversary of the Measurement Act, with the aim of promoting the SI in response to the recent redefinition of the SI base units. This neck strap is designed with print of the SI logo by BIPM, the seven SI base units, the seven physical constants defining the units, and the words that express the philosophy of the metric system. "À tous les temps, à tous les peuples" (For all times, for all peoples)



International Visitors / Guests

Many foreign guests visited NMIJ for technical discussions and a series of training. Ongoing and future collaborations were discussed with the guests listed below.

Name	Affiliation	Visiting Date	Visiting Topic
Dr. D. Peters	PTB, Germany	24 March - 26 April 2019	Investigative study on information-security applications in Japanese metrological practices
Mr. T.-H. Hsieh	CMS/ITRI, Taiwan	20 June - 13 September 2019	Technical training for Angle Standard
Dr. F. Yeh	CMS/ITRI, Taiwan	11 July - 9 October 2019	Research collaboration on high-temperature measurements using thermocouples
Ms. M. I. Salazar, Mr. R. F. Manalo, Mr. A. C. C. Gernale	NML-ITDI, Philippines	29 July - 8 August 2019	Technical training on hardness and torque standards.
Mr. R. A. Rahman	Osaka Univ., Japan	12 - 24 August 2019	Technical training at NMIJ by JICA internship program
Dr. S. Pasakawee	NIMT, Thailand	9 - 13 September 2019	Technical visit to Radio-Frequency Standards Group
Dr. P. Masłowski	Nicolaus Copernicus Univ., Poland	25 September 2019	Seminar on "Broadband cavity-enhanced spectroscopy using optical frequency comb"

Peer Review and International Comparisons

The NMIJ dispatches peer reviewers to other NMIs on their requests (if available). In the period from April to September 2019 five researchers from NMIJ visited five NMIs as on-site peer reviewers. Also, NMIJ has participated in the following international comparisons.

NMIJ Participants	KCDB Code	Field	Title	Pilot Lab	Start Date
Dr. Y. Kondo and Dr. Y. Bitou	-	Optical free form	EMPIR 15SIB01: Comparison of Optical free form	PTB	7 May 2019
Dr. H. Takahashi	CCAUV. A-K6	Acoustics	Pressure calibration of laboratory standard microphones type LS2P	LNE	24 June 2019

Selected Research Reports

- 1) T. Shirasawa, S. Yoshizawa, T. Takahashi, T. Uchihashi, "Structure determination of the Si (111) – $\sqrt{7} \times \sqrt{3}$ – In atomic-layer superconductor", *Physical Review B*, **99**, 10502(R), 2019, DOI: 10.1103/PhysRevB.99.100502
- 2) T. Narukawa, O. Shikino, K. Chiba, "Isotope dilution analysis of yttrium with labelled oxygen gas by dynamic reaction cell - ICP-MS: universal isotope dilution analysis", *Journal of Analytical Atomic Spectrometry*, **34**, 517-525, 2019, DOI: 10.1039/C8JA00420J
- 3) Y. Hisai, D. Akamatsu, T. Kobayashi, S. Okubo, et al., "Development of 8-branch Er: fiber frequency comb for Sr and Yb optical lattice clocks", *Optics Express*, **27**, 6404-6414, 2019, DOI: 10.1364/OE.27.006404
- 4) Q. Wang, S. Ri, A. Maenosono, Y. Tanaka, M. Koyama, "1-second-resolved strain mapping in Ti-6Al-4V alloys during dwell fatigue in SEM by video sampling moiré", *Mechanics of Materials*, **133**, 63-70, 2019, DOI: 10.1016/j.mechmat.2019.03.002
- 5) K. Amemiya, H. Koshikawa, M. Imbe, T. Yamaki, H. Shitomi, "Perfect blackbody sheets from nano-precision microtextured elastomers for light and thermal radiation management," *Journal of Materials Chemistry C*, **7**, 5418–5425, 2019, DOI: 10.1039/C8TC06593D
- 6) D. H. K. Murthy, H. Matsuzaki, Z. Wang, Y. Suzuki, et al., "Origin of the overall water splitting activity of Ta₃N₅ revealed by ultrafast transient absorption spectroscopy", *Chemical Science*, **10**, 5353-5362, 2019, DOI: 10.1039/C9SC00217K
- 7) Y. Bitou, O. Sato, S. Telada, "Three-spherical-mirror test for radius of curvature measurement using a Fabry-Pérot cavity", *Optics Express*, **27**, 13664-13674, 2019, DOI: 10.1364/OE.27.013664
- 8) Y. Eto, H. Shibayama, K. Shibata, A. Torii, et al., "Dissipation-assisted coherence formation in a spinor quantum gas", *Physical Review Letters*, **122**, 245301, 2019, DOI: 10.1103/PhysRevLett.122.245301
- 9) H. Fujiki, Y. Amagai, K. Okawa, "Establishment of high-voltage AC-DC voltage transfer standards in 1-100-kHz range at NMIJ", *IEEE Transactions on Instrumentation and Measurement*, **68**, 1921-1926, 2019, DOI: 10.1109/TIM.2018.2877858
- 10) N. Kuramoto, L. Zhang, K. Fujita, S. Okubo, H. Inaba, K. Fujii, "Volume measurement of a ²⁸Si-enriched sphere for a determination of the Avogadro constant at NMIJ", *IEEE Transactions on Instrumentation and Measurement*, **68**, 1913-1920, 2019, DOI: 10.1109/TIM.2018.2878072
- 11) S. Mizushima, N. Kuramoto, K. Fujii, T. Umeda, "Electron paramagnetic resonance study on a ²⁸Si single crystal for the future realization of the kilogram", *IEEE Transactions on Instrumentation and Measurement*, **68**, 1879-1886, 2019, DOI: 10.1109/TIM.2018.2884044
- 12) S. Shibayama, S. Fujii, K. Inagaki, T. Yamazaki, et al., "Development of certified reference material NMIJ CRM 6205-a for the validation of DNA quantification methods: accurate mass concentrations of 600-bp DNA solutions having artificial sequences", *Analytical and Bioanalytical Chemistry*, **411**, 6091-6100, 2019, DOI: 10.1007/s00216-019-01992-y
- 13) T. Takatsuji, H. Watanabe, Y. Yamashita, "Blockchain technology to visualize the metrological traceability", *Precision Engineering*, **58**, 1-6, 2019, DOI: 10.1016/j.precisioneng.2019.04.016
- 14) D. Asakawa, H. Takahashi, S. Sekiya, S. Iwamoto, K. Tanaka, "Sequencing of sulfopeptides using negative-ion tandem mass spectrometry with hydrogen attachment/abstraction dissociation", *Analytical Chemistry*, **91**, 10549-10556, 2019, DOI: 10.1021/acs.analchem.9b01568
- 15) T. Ariga, Y. Zhu, K. Inagaki, "Study on carbon-induced signal enhancement in inductively coupled plasma mass spectrometry: an approach from the spatial distribution of analyte signal intensities", *Journal of Analytical Atomic Spectrometry*, **34**, 1865-1874, 2019, DOI: 10.1039/C9JA00152B
- 16) Y. Kato, A. Sanada, "Extraordinary transmission by double-sided hyperbolic metasurfaces with Γ -point degeneration at millimeter-wave bands", *IEEE Transactions on Microwave Theory and Techniques*, **67**, 3297-3305, 2019, DOI: 10.1109/TMTT.2019.2919578
- 17) T. Hosokai, H. Nakanotani, S. Santou, H. Noda, Y. Nakayama, C. Adachi, "TADF activation by solvent freezing: The role of nonradiative triplet decay and spin-orbit coupling in carbazole benzonitrile derivatives", *Synthetic Metals*, **252**, 62-68, 2019, DOI: 10.1016/j.synthmet.2019.04.005
- 18) H. Kato, A. Nakamura, H. Banno, "Determination of number-based size distribution of silica particles using centrifugal field-flow fractionation", *Journal of Chromatography A*, **1602**, 409-418, 2019, DOI: 10.1016/j.chroma.2019.05.055
- 19) S. Ri, Q. Wang, P. Xia, H. Tsuda, "Spatiotemporal phase-shifting method for accurate phase analysis of fringe pattern", *Journal of Optics*, **21**, 095702, 2019, DOI: 10.1088/2040-8986/ab3842
- 20) P. Xia, Q. Wang, S. Ri, H. Tsuda, "Calibrated phase-shifting digital holography based on space-division multiplexing", *Optics and Lasers in Engineering*, **123**, 8-13, 2019, DOI: 10.1016/j.optlaseng.2019.06.022