NMIJ Newsletter
No.9, May 2019

Interview with the Director: Redefinition of the SI Units

"The challenge of a more universal kilogram: The dream of metrologists for a century."

In May 2019, the definition of the unit of mass (the kilogram) is revised for the first time in 130 years. A number of countries contributed top-level technologies to the revision; NMIJ/AIST played a decisive role. In this interview, Dr. Takashi Usuda, Director General of NMIJ, explains why the new definition is needed and what has come out from the researches.

The start of the SI: two prototypes

Whenever you measure something such as a length, weight, temperature or time, you need a reference standard. If the standard varies, the reliability of measurements is undermined. Therefore, people down the ages have searched for standards that will not vary.

Modern science, industry and daily life are underpinned by a common global standard, the SI. The starting point of the SI was the "international prototype of the metre" and the "international prototype of the kilogram" which were specified in 1889. The prototypes have since been carefully maintained at the International Bureau of Weights and Measures (BIPM) in France. The French government does not interfere with the BIPM. Even the Nazis, when they occupied Paris in the Second World War, did not interfere.

Dr. Takashi Usuda, Director General of NMIJ, explains that European people saw the two international prototypes as a kind of Noah's Ark. Whatever catastrophe might occur, as long as measurement standards could be maintained, then it might be possible to rebuild civilization. There is a clear impression that measurement units are crystals of knowledge and must be very carefully protected.

Scientific progress needs accurate units

The definition of length was revised in 1960 and 1983; the prototype of the meter has already been retired. However, the kilogram prototype has continued in service for 130 years now. Usuda explains why the kilogram is being revised now.

"As science progresses, requirements for accurate measurement become increasingly severe; imprecision that was acceptable in the past can no longer be tolerated. From time to time, the SI reviews its standards in response to the needs of society and more advanced science, and changes to more universal standards. In the case of length, the definition was changed from the metre prototype to a definition based on a physical constant, the speed of light. This improved measurement precision by a factor of about 1000.

"In contrast, the definition of mass has not been revised in 130 years, because the required precision is very high and is technically difficult to achieve. The kilogram prototype is said to have changed by about 50 micrograms over that 130 years, about the mass of the grease in a single fingerprint. With the emergence of fields of science and technology dealing with tiny masses, such as nanotechnology, even tiny changes cannot be ignored.

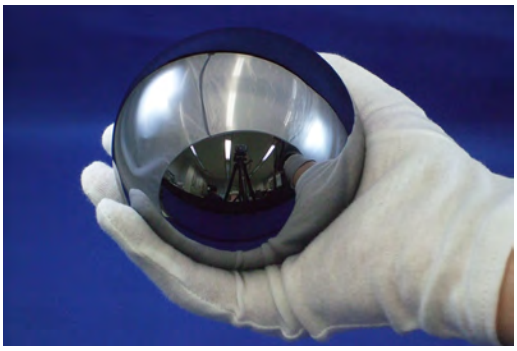
"Revising the definition of mass has been under discussion for a century and national metrology institutes in various countries have been conducting the R&D for about 50 years, but only in the last decade has a revision become feasible, leading to the upcoming redefinition."

The International Avogadro Coordination Project

The science journal Nature has listed the redefinition of the kilogram as one of the five hardest scientific challenges, on a par with detecting gravitational waves. How has AIST tackled this difficult question, known to be a dream of metrologists for a century?

Usuda explains that the definition of the kilogram has been worked on for half a century in Japan, since the days of the former National Research Laboratory of Metrology. About 40 years ago, work began on precisely measuring the Avogadro number using the X-ray crystal density (XRCD) method employing silicon, the material that produces the most perfect crystals available. The idea was to count numbers of silicon atoms to determine masses. However, in the real world, silicon is a mixture of three stable isotopes, with atomic weights of 28, 29 and 30. With this obstacle, a measurement accuracy that surpasses the existing kilogram prototype could not be achieved.

In 2004, a number of countries launched the International Avogadro Coordination Project, working together to overcome this obstacle. In Russia, a nuclear fuel facility used special centrifuges to separate out the silicon-28 isotope, providing silicon-28 with a purity of 99.99%.



The silicon sphere used to measure the Avogadro constant

Extreme measurement precision at AIST

When ideal silicon was obtained, the goal suddenly looked more achievable. The different countries each brought their best technologies to bear, forming a monocrystal, measuring the lattice spacing, and creating a one-kilogram sphere. This is the most perfect sphere ever created by humanity.

Then, at last, the mass and volume were measured. This is when AIST's advanced technologies came into effect.

Diameters of the sphere in about 2000 directions were measured using a superhigh-precision laser interferometer developed at AIST. Because silicon expands with temperature, technologies to precisely control temperature in a vacuum were employed, enabling a world-beating measurement accuracy of 0.6 nm. This incredible accuracy approximately matches the spacing between atoms (the lattice spacing). The volume was then calculated from the diameter measurements.

With a newly developed surface analysis system, a thin layer covering the surface of the silicon sphere (a film of oxides, etc.) was measured, and the mass and volume of the silicon object excluding this thin film were determined. In this way, the Avogadro constant was successfully measured to a world record accuracy of 2.4 parts in 100 million. From this, Planck's constant, another fundamental physical constant, was calculated.

Separately, Planck's constant was measured by a number of countries using a technique known as the Kibble balance. The Planck's constant values measured by the two methods matched.

Usuda adds, "Evaluation from multiple perspectives with different technologies and methods is important and allows us to verify that there are no omissions or errors. Combining cross-checking with discussions to bring everyone to a correct answer is the job of the metrologist."

Japan's prominent role in the SI redefinition

In 2017, eight datasets measured by national metrology institutes in different countries were submitted to the Committee on Data for Science and Technology (CODATA) and an updated value of Planck's constant was determined. The new definition of the kilogram is based on this value.

Of the eight datasets, four came from measurements AIST was involved with. Of these, three were contributed by the International Avogadro Coordination Project and one was data from new measurements at AIST.

After the Meiji Restoration, Japan was slow to adopt the metre prototype and kilogram prototype systems that had been devised in Europe. In the 150 years since, however, science and technology in Japan have progressed to reach a level where we can contribute to the framework originally created in Europe.

The cutting-edge measurement technologies that led to this redefinition are real science, providing new knowledge to humanity. In any age, the best scientific technologies of the time are employed when setting a unit; this result is an excellent demonstration to the world of Japan's capabilities in science.

There are seven base units in the SI system: the meter (length), the kilogram (mass), the second (time), the ampere (electric current), the kelvin (thermodynamic temperature), the mole (amount of substance) and the candela (light intensity).

In this revision, four units—the ampere, the kelvin and the mole along with the kilogram—are to be revised at the same time. Of these, the kilogram, the ampere and the mole are intimately related; when the definition of the kilogram is changed, the other two inherently must change too. The definition of the ampere is based on the elementary electric charge, and the definition of the mole is based on the Avogadro constant.

The situation with the kelvin is a little different. In simple terms, the old definition of temperature infers temperatures using states of water as reference points: when water freezes and boils. However, this is a reversal of cause and effect. The reference should be temperature, and water should freeze and boil at certain temperatures. Accordingly, the kelvin will be defined on the basis of the Boltzmann constant, which is a common feature of both liquids and gases.

As mass is liberated from the kilogram prototype, temperature can be liberated from the physical substance that is water. After this revision, all seven of the SI base units will be expressed as formulas of physical constants.

Adoption scheduled for World Metrology Day 2019

Provided the new definitions are approved at the 26th General Conference on Weights and Measures (CGPM) in November 2018, the plan is to adopt the new definitions on the next World Metrology Day, which is May 20, 2019.

Usuda is one of the 18 members of the International Committee for Weights and Measures. These 18 discuss scientific issues and decisions relating to measurement standards and seek agreement from the CGPM, which all member states attend. The decisions of the CGPM constitute the history of units and standard references.

Asked how it feels to submit a historical SI redefinition to the CGPM, Usuda emphasizes that the redefinition is the result of many years of work: "The revision of a definition is the conclusion of cumulative tireless work by metrologists from the past to the present. Because a definition has great effects in the world, it must be agreed on by many countries. Bearing that in mind, it just happens to be now that all the pieces have fallen into place and it just happens to be me that is here. If the previous efforts of many people had been lacking in some way, the hurdles could not have been overcome."

The prospects: supporting nanotechnology

The redefinition of the kilogram has two major direct benefits.

One is that measurements of the same precision may be performed more easily and at lower cost. The procedure of periodically transporting the National Prototype of the Kilogram of Japan that AIST cares for to France for checking will become unnecessary.

The other is that both tiny and huge masses can be accurately measured. Now, mass per atom can be accurately determined. Therefore, if a number of atoms can be counted, a quantity in grams can be calculated from the number of atoms and a mass can be measured directly. This is expected to be helpful in fields such as nanotechnology.

The National Prototype of the Kilogram of Japan

Usuda describes the prospects: "When instruments are developed using the new definitions, the scope of possibilities will be broader. For example, maybe a mass per inkjet drop in a printer can be measured and maybe individual microparticles of atmospheric pollutants can be evaluated. Measurement technology is fundamental for competitiveness; it affects every industry. It is also essential for building a sustainable society, through environmental analysis, drug discovery, food analysis and so forth."

Inconspicuous revisions helping society

However, none of the new definition changes will be obvious to ordinary consumers. Usuda says that the correct way to implement a revision is cautiously, in a way that does not produce direct effects and goes unnoticed by most people. The present inconspicuous revisions are now being publicized through lectures, symposiums and press releases. Usuda is keen to tell high school students and others about the revisions; he is publishing texts for the ordinary reader, giving guest lectures and so forth.

"This revision of the SI definitions is a chance to think about how to use scientific knowledge to maintain a stable civilization. It is also a chance to look again at common knowledge that is rarely questioned. The big picture is interesting to me. I hope to nurture the motivation to consider new frameworks for the natural sciences."

As science and technology progress, unit definitions are changed; when unit definitions are changed, science and technology can progress further. AIST will continue to work with the rest of the world to support a civilization that can keep this virtuous circle turning.

This article is a reprint from "AIST report 2018".
https://www.aist.go.jp/en_digbook/aist_report/2018/book.pdf

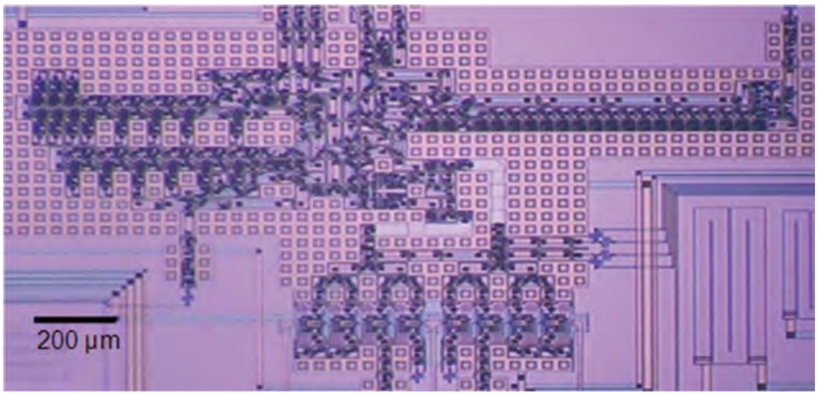
Researches Related to Redefinition of the SI

Johnson Noise Thermometry with superconducting integrated circuits for the new kelvin

Chiharu Urano, Takahiro Yamada, Kazuaki Yamazawa, Nobu-Hisa Kaneko and Yoshiro Yamada

Remarkable progress in primary thermometry has been made in the past decade with the objective of accurately determining the value of the Boltzmann constant for the redefinition of the kelvin. The NMIJ is actively involved in developing a primary thermometer called the Johnson Noise Thermometer (JNT). This thermometer measures the thermodynamic temperature directly through measurement of the thermal noise by detecting the power spectrum density of the voltage across the sensor element, in this case, an electrical resistor, and applying the Nyquist's formula relating the thermal noise with the resistance, the Boltzmann constant and the thermodynamic temperature.

To measure this extremely small voltage accurately and absolutely, a pseudo white-noise generator consisting of a Quantum Voltage Noise Source (QVNS) is applied to serve as a reference. NMIJ's JNT has a unique feature that it utilizes an Integrated QVNS (IQVNS). This in-house-made device integrates all functions required to generate the pseudo white noise on a 5 mm by 5 mm chip consisting of superconducting integrated circuits. Measurement conducted at the triple-point-of-water temperature has given the value of the Boltzmann constant which agrees within the 10 ppm uncertainty with the value adopted in the redefinition of the kelvin, supporting its reliability.



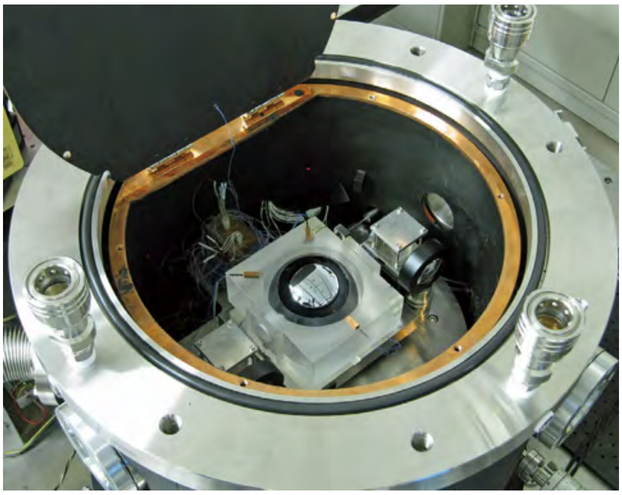
The NMIJ JNT's IQVNS, a pseudo white noise generator on a chip of superconducting circuits.

References:
T. Yamada et al., Appl. Phys. Lett., **108**, 042605 (2016).
C. Urano et al., Metrologia **54**, 847 (2017).

Redefinition of the kilogram for the first time in 130 years

Kenichi Fujii, Naoki Kuramoto, Shigeki Mizushima, Kazuaki Fujita, Atsushi Waseda, Hiroyuki Fujimoto (Research Institute for Engineering Measurement)
Lulu Zhang, Azuma Yasushi, Akira Kurokawa, Tomohiro Narukawa (Research Institute for Material and Chemical Measurement)

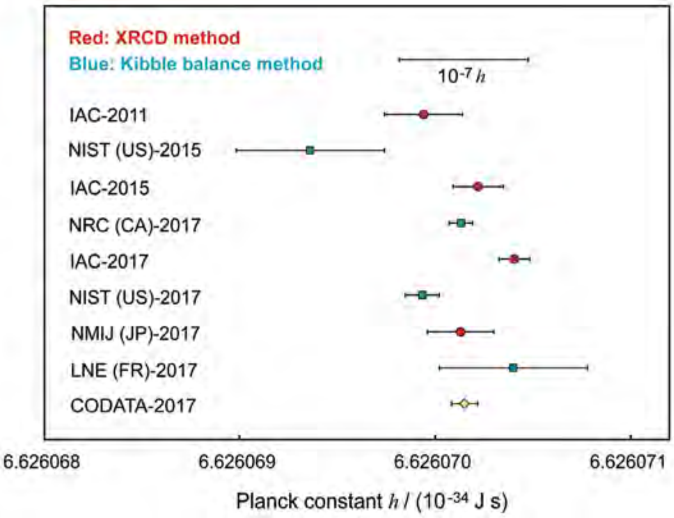
The unit of mass, the kilogram, has been the only SI base unit still defined by material artifact. Changing the definition using a universal constant has therefore been a long-desired dream in metrology. However, it was difficult to measure the universal constant, such as the Avogadro constant N_A or the Planck constant h, with an uncertainty better than the mass stability of the international prototype of the kilogram which has been reigning as the definition of the kilogram since 1889.



Optical interferometer for Si spheres to measure their diameters with an uncertainty of sub-nanometer region

In order to overcome the difficulty, NMIJ and some other NMIs launched the International Avogadro Coordination (IAC) project in 2004, where 5 kg of a ^{28}Si-enriched crystal was successfully grown with an isotope enrichment factor of better than 99.99 %. This made it possible to fundamentally reduce the uncertainty in measuring the isotopic abundance of the crystal. In this project, NMIJ measured N_A in cooperation with other partners by the X-ray crystal density (XRCD) method, where the density, molar mass and lattice constant of the crystals were measured with best uncertainties available in the world.

For this project, NMIJ developed an optical interferometer to measure the diameters of 1 kg Si spheres polished from the crystal with an uncertainty of sub-nanometer region. Accurate surface evaluation technologies for the Si spheres using the X-ray photoelectron spectrometry and the spectroscopic ellipsometry, and a precise vacuum mass comparison technique were also developed at NMIJ. We also measured the molar mass of the crystal by isotope dilution mass spectrometry and evaluated the lattice uniformity in the crystal by developing a self-referenced lattice comparator.



Experimental values of the Planck constant from the XRCD method (red) and from the Kibble balance method (blue) are shown here. Their bars express the experimental standard uncertainties. To reach statistical consistency, all the experimental uncertainties were expanded by a factor of 1.7 in deducing the weighted mean value of the Planck constant (yellow).

The measured values of N_A were converted to h using accurately known values of fundamental physical constants. Using the data from the IAC project and some other results from the Kibble balance method, the CODATA Task Group on Fundamental Constants (TGFC) deduced a fixed value of h in October 2017, which is to be used in the revised SI. In November 2018, the new definition of the kilogram, together with the new definitions of the ampere, the kelvin and the mole, was adopted by the 26th General Conference on Weights and Measures. NMIJ thus contributed to the new definition of the kilogram and succeeded in realizing the new definition of the kilogram using the ^{28}Si-enriched spheres. The revised SI comes into force on May 20th, 2019, the World Metrology Day.

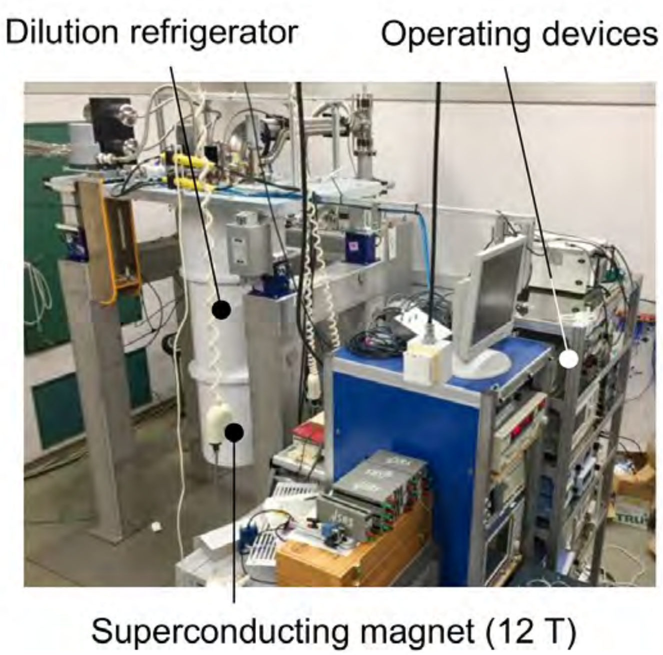
More detail: https://www.aist.go.jp/aist_e/list/highlights/2017/vol10/index.html

Development of quantum electrical metrology triangle experiment

Nobu-Hisa Kaneko, Shuji Nakamura, Takehiko Oe, Yuma Okazaki and Michitaka Maruyama

Once the International System of Units or SI is revised, the quantum current generated by a single electron pump device, based on the single electron tunneling effect, is purely SI traceable together with other well-established quantum electrical standards of voltage and resistance, namely, a Josephson voltage standard (JVS) and quantized Hall resistance standard (QHRS). In basic science in elementary school we have learned so-called the "Ohm's law" which combines the three electrical quantities (units): ampere (A), voltage (V) and resistance (Ω), i.e., $V = IR$. At schools we have been also taught that when any two of them are measured, the remaining one can be calculated. Then we are not expected to measure all three at the same time.

However what if we measure/generate all three? This is the quantum electrical metrology triangle (QMT) experiment, whereby we can confirm the consistency of the three quantum effects. The uncertainties of two quantum standards, a JVS and QHRS, are quite small as low as some parts per billion (ppb or 10^{-9}) or far smaller in the case of voltage. Contrary to them, single electron pumps are under development and the uncertainty is still larger than some hundreds parts per billion. As for the resistance arm, we fabricated 1MΩ and 10MΩ quantum Hall "array" devices that work as a quantum current-voltage (I-V) converter and convert the quantum current generated by a single electron pump to voltage. The voltage will then be measured by a JVS. For this voltage arm, NMIJ/AIST has fabricated 2 V JVS devices suitable for this purpose thanks to the CRAVITY, the superconducting micro-fabrication facility at AIST. There are several candidates for quantum electron pumps, e.g., superconductor based, GaAs semiconductor based, and Si semiconductor based devices, all of which have been fabricated in our project. Si based devices, which are thought to most accurately work at higher frequencies, will be installed in our system soon. Our project goal of QMT is to integrate all three quantum devices in one cryostat (see the figure), and do the experiments to confirm the consistency with the uncertainty of smaller than 100 parts per billion, collaborating with the NTT Basic Research Laboratories and the University of Electro-Communications. Let's see how our devices will bespeak the consistency.



Quantum electrical metrology triangle experiment setup

Congratulations on the Historic Redefinition of the SI Units!

Director General of NMIJ
Takashi Usuda

Activities on Redefinition of the SI

SI Promotion

In Autumn 2018, NMIJ/AIST published two public relations brochures, a Japanese translation of *Joint Statement of the SI* and a *Photo book*, introducing progress of the realization of the SI base units. Also, in the November issue of a public relations magazine of AIST, *AIST LINK,* metrology standards were featured and NMIJ's efforts on redefinition of the SI were introduced.

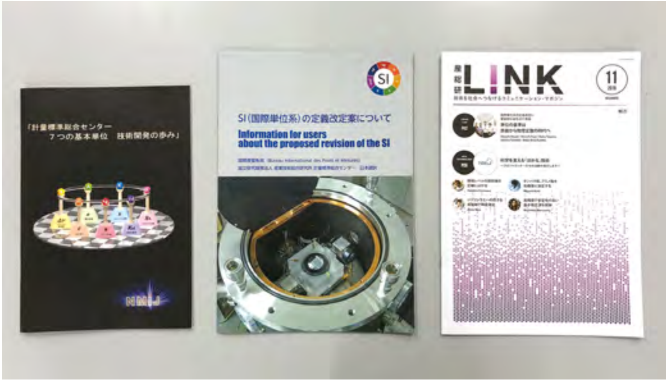


Photo book, Joint statement of the SI, and AIST LINK

Public viewing of the CGPM at NMIJ/AIST

To disseminate the redefinition through the media, NMIJ/AIST held a briefing session on the redefinition of the four base units and a photo session of the Japanese Prototype of the kilogram in August and November, respectively.

On 16th November 2018, the final day of the CGPM, researchers involved in the redefinition of the SI got together to share the historic moment through its live streaming. The scene was reported in many domestic newspapers, along with the resolution of the redefinition of the SI.

NMIJ/AIST cooperated with the special exhibition "1000 technologies that changed Japan" at the National Science Museum in Tokyo from 30th October 2018 to 3rd March 2019. As the exhibits, a replica of the National Prototype of the kilogram of Japan, a replica of the silicon sphere to determine the Avogadro constant, and the containers for transporting the prototypes of the kilogram and the meter were loaned from AIST.

Containers of the National Prototype of the kilogram and the meter; transported to Japan 140 years ago.

An open symposium "Measurement of New International System of Units (SI) -- Weight, Electricity, Temperature, Time and Our Life --" was held on 2nd December 2018, co-hosted by the Japan Science Council, the Japan Physical Society, the Japan Chemical Society, and NMIJ/AIST. A total of 300 participants, including general public and professional educators listened intently to the lectures, which were followed by lively question and answer sessions.

Dispatch of Delegates to the 26th CGPM

The 26th meeting of the General Conference on Weights and Measures (CGPM) was held from 13th to 16th November 2018 at Palais des Congrés Versailles, near the Palace of Versailles, France. A total of five delegates from Ministry of Economy, Trade and Industry (METI), Japanese Embassy in France and NMIJ participated, led by Dr. Takashi Usuda, Director General of NMIJ. As a member of the CIPM committee, Dr. Usuda presented a long-term strategy for the BIPM and Draft Resolution C (On the objectives of the BIPM) on the second day and the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) report on the third day. In the morning of the final day, after the deliberation on the redefinition of the International System of Unit (SI), it was approved unanimously as his expressing our position, saying “Oui”. In the afternoon, Dr. Usuda was re-elected to the CIPM committee and Dr. Yukinobu Miki, Senior Vice-President of AIST, to the Committee for the Election of the CIPM (CEC).

Delegates of Japan; (from left) Mr. Shigemitsu Toma (Japanese Embassy), Mr. Masahiro Fukui (METI), Dr. Norio Saito, Dr. Takashi Usuda and Dr. Tokihiko Kobata (NMIJ/AIST).

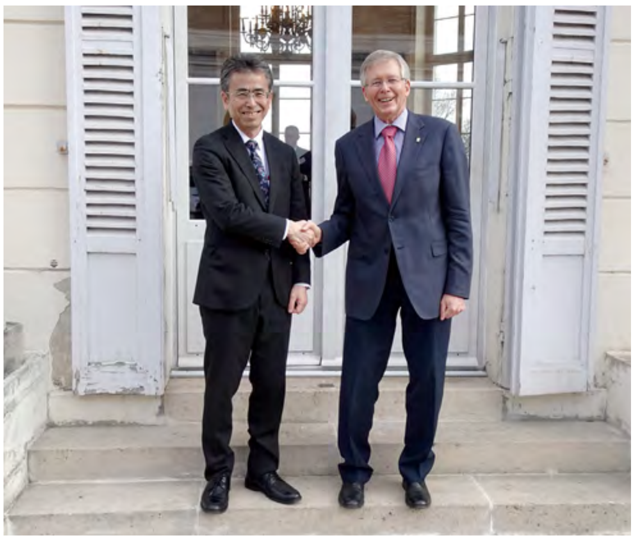
Scene from the last day of the CGPM. Delegation from Japan votes “Oui” on the resolution regarding the redefinition of the SI units.

Featured Events

Dr. Usuda, Director General of NMIJ, was Elected to the Secretary at the 108th CIPM

The first CIPM after the 26th CGPM in last November was held on 20th-21st March, at BIPM in France.

The CIPM, International Committee for Weights and Measures, is an administrative board of Metre Convention, consisting of 18 committee members from each different country that has been elected at the CGPM. Moreover, the CIPM elects its President and the Secretary by mutual vote. As the result of the election on the first day, Dr. W. Louw (South Africa) was chosen for the President, Dr. Usuda for the Secretary. Dr. Usuda is a first Asian Secretary ever since the establishment of the CIPM in 1875. In his four-year term, he will assist the president to supervise the BIPM and manage the CIPM meeting. He will also support the chair (the President of the Académie des sciences de Paris) at its 27th CGPM in 2022.



New and former Secretaries, Dr. Usuda (left) and Dr. J. McLaren from Canada (right)

UzNIM SE (Uzbekistan) Delegation Visits NMIJ

On 20th February 2019, Mr. Lazizbek Saidoripov, Deputy Director of the Uzbek National Institute of Metrology (UzNIM SE), Uzbekistan and three other delegates visited NMIJ in Tsukuba, aimed at exploring the possibility of technical assistance on quality system and calibration service training.

A warm welcome to the delegates began with the greetings and remarks by Dr. T. Usuda, Director General of NMIJ, followed by introduction of each institution. Detailed presentation on "Calibration Services and Quality System of NMIJ" accompanied with a lab tour on four quantity standards, i.e., mass, thermometry, vacuum and pressure, and electromagnetic fields was provided to clearly describe the NMIJ's functions and activities in developing and disseminating of standards.

On this occasion, the delegates also visited the APMP Chair, Dr. T. Takatsuji, Director of Research Institute for Engineering Measurement (RIEM), to get deeper understanding on APMP activities and confirm their rights and responsibilities as an associate member.

It was a rather tight schedule, however, the delegates seemed very satisfied with this visit.

APMP General Assembly and Related Meeting 2018

The National Metrology Centre (NMC), Agency for Science, Technology and Research (A*STAR) and the Health Science Authority (HSA) co-hosted the APMP 2018 from 20th-30th November 2018 at Resorts World Sentosa in Singapore.

The meeting was held in conjunction with some workshops and technical tutorials. In this transition period of the SI redefinition, it was a great opportunity for all participants to discuss and learn on the redefinition of the SI during this meeting. About 300 participants from 31 economies across the Asia Pacific, as well as from other regional metrology organizations and international organizations for standards and conformance infrastructure congregated in Singapore for this big event. Dr. Toshiyuki Takatsuji, APMP Chair managed excellently this big meeting the same as the last General Assembly.

In the symposium titled "Future of Metrology, Future of Industry", Dr. Takashi Usuda, Director General of NMIJ gave a talk about "Redefinition of the SI-Strategy for National Metrology Institutes and Industry" as one of the keynote speakers.

This annual meeting helps APMP members to develop further improvement not only for the science and technology but foster relationships with other related international organizations and among APMP members. 36 NMIJ delegates which is the highest number of delegates participated in the meeting. The next GA will be held in Sydney, Australia in November 2019.

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**

25th APLMF Meeting

An annual APLMF meeting was held in Christchurch, New Zealand from 7th to 9th November 2018. A total of 50 participants attended from 14 member economies including four participants from NMIJ and METI. It was a meeting for celebrating the 25th anniversary of APLMF. At this meeting, the seven Working Groups (WGs) were restructured as new five WGs on agricultural measurement, metrological control, prepackaged products, utility meters and OIML-CS (Certificate System). In addition, Malaysia agreed to take over the Presidency from New Zealand in late 2019.

53rd CIML Meeting

An annual meeting of OIML (International Organization of Legal Metrology), was held in Hamburg, Germany, from 8th to 12th October 2018. Participants are from 52 members and 17 corresponding observers, 183 in total. Japan sent six participants from NMIJ and METI (Ministry of Economy, Trade and Industry). At this meeting, Dr. Charles Ehrlich of USA was assigned to the First Vice President and Mr. Anthony Donnellan of Australia, the Director of BIML (International Bureau of Legal Metrology). A new version of R139 (compressed gaseous fuel measuring systems for vehicles) was approved to which NMIJ contributed as the project co-convener.

AOTS Training Course

A training course "Implementation for Social and Industrial Infrastructure in Metrology" of AOTS (Association for Overseas Technical Cooperation and Sustainable Partnerships) was held in the Tokyo area from 3rd to 14th December 2018. 14 participants attended from Bangladesh, Bhutan, Cambodia, India, Indonesia, Malaysia, Mongolia, Myanmar, Nepal, Papua New Guinea, Philippines, Sri Lanka, Turkey and Viet Nam. They leaned earnestly the Japanese social infrastructure in metrology through visits to the related public organizations and private companies.

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
Prof. Joseph C. Klewicki	Melbourne School of Engineering, Australia	04 October 2018	Discussion on wall turbulence and visit to high Reynolds number facility
Dr. Michael Reader-Harris	NEL, UK	16 - 22 October 2018	Discussion on ISO5167-3 revision and visit to flow rate facility in NMIJ
Dr. Agata Cygan	Nicolaus Copernicus University, Poland	03 - 20 December 2018	Research collaboration
Dr. Cristian-Gabriel Arsene	PTB, Germany	21 October 2018 - 03 November 2019	Development of high precision analysis for serum protein using high resolution mass spectrometry
Dr. Jonghan Jin and Mr. Sunghun Eom	KRISS, Republic of Korea	21 - 22 November 2018	Discussion about thickness measurement of silicon wafer
Dr. Shelly Ko	CMS/ITRI, Taiwan	13 February - 11 March 2019	Training on radiation temperature measurements

Peer Reviewer Dispatch

The NMIJ dispatches peer reviewers to other NMIs on their requests (if available).

Name	Institute Reviewed	Visiting Date	Peer Review Field
Dr. N. Furuichi	NIMT, Thailand	18 - 22 November 2018	Liquid flow rate
Dr. H. Abe	SCL, Hong Kong	26 - 29 December 2018	Humidity, -60 °C to +65 °C

International Comparisons

The NMIJ has participated in the following international comparisons.

NMIJ Participants	KCDB Code	Field	Title	Pilot Lab
Dr. T. Asakai	CCQM-P93	Amount of Substance, Electrochemistry	Preparative pilot study for phosphate pH CRMs	SMU
Dr. T. Asakai	CCQM-K152/ P192	Amount of Substance, Electrochemistry	Assay of potassium iodate	UNIIM
Dr. Y. Kitamaki	CCQM-K148.a	Amount of Substance, Organics	Characterization of organic substances for chemical purity: Bisphenol A	BIPM
Dr. T. Shimosaka, Dr. N. Matsumoto, Dr. T. Watanabe	CCQM-K118	Amount of Substance, Gas Analysis	Comparison of natural gas	BAM / VSL
Dr. T. Oe	BIPM.EM-K12	DC Resistance, 100 Ω/ QHR, 10 kΩ/100 Ω	On-site key comparison of quantum Hall effect resistance standards of NMIJ and the BIPM	BIPM
Dr. T. Kinumi	CCQM-P164	Amount of substance, Mol	Growth hormone determination in serum using isotope dilution mass spectrometry	PTB
Dr. T. Kinumi	(ACRM)	Amount of substance, Mol	Co-validation of hexapeptide and glycated hexapeptide	NIM, China
Dr. K. Sugawara	(VAMAS TWA2 Project)	Nano Particles	International round robin test for guidelines for shape and size analysis of nano-particles by atomic force microscopy	NIMS
Dr. H. Harano	CCRI(III)-K9. Cf.2016	Neutron	Key comparison of measurements of neutron source emission rate	NPL
Dr. A. Masuda	CCRI(III).S1-H*(10)	Neutron	Supplementary comparison for the calibration of ambient dose equivalent (rate) meters in ISO neutron reference fields	PTB

Selected Research Reports

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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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