NMIJ Newsletter
No.4, November 2016
National Metrology Institute of Japan

Greetings from Director of RIEM

Dr. Toshiyuki Takatsuji
Director of RIEM

The Research Institute for Engineering Measurement (RIEM) is one of four research institutes in NMIJ. The mission of RIEM is to contribute to manufacturing industries by establishing, maintaining and disseminating measurement standards in the areas of dimensional, mass related, mechanical and flow measurements.

Load Kelvin, who is famous for his name being used as a unit of thermodynamic temperature left a proverb, “If you cannot measure it, you cannot improve it”. It has been interpreted and expressed in various ways. One of the terms, “If you can not measure it, you can not make it.” expresses exactly the mission of RIEM. High quality products cannot be made without high precision metrology.

The strategy of RIEM to attain this mission is to form a technical base in these areas. There are many specialists of measurement in universities; however there is no place other than RIEM where specialists in specific metrology areas are gathered. In addition to this, RIEM has state-of-the-art measuring instruments and expertise in every metrology area. Thus, given this situation, I can say that RIEM can be a technical base in these areas.

In order to form such a technical home base, a wide spectrum of researches ranging from fundamental to applied researches must be conducted. In particular, RIEM has made significant contributions to the revision of the International System of Units (SI) especially for “kg". Concerning applied researches, a numerous number of collaboration researches and technical consultations have been produced and completed in response to a wide range of requests from industries. Members of RIEM have been performing extensive researches so that RIEM can be the right place as a “technical base” to provide solutions for the industrial users.

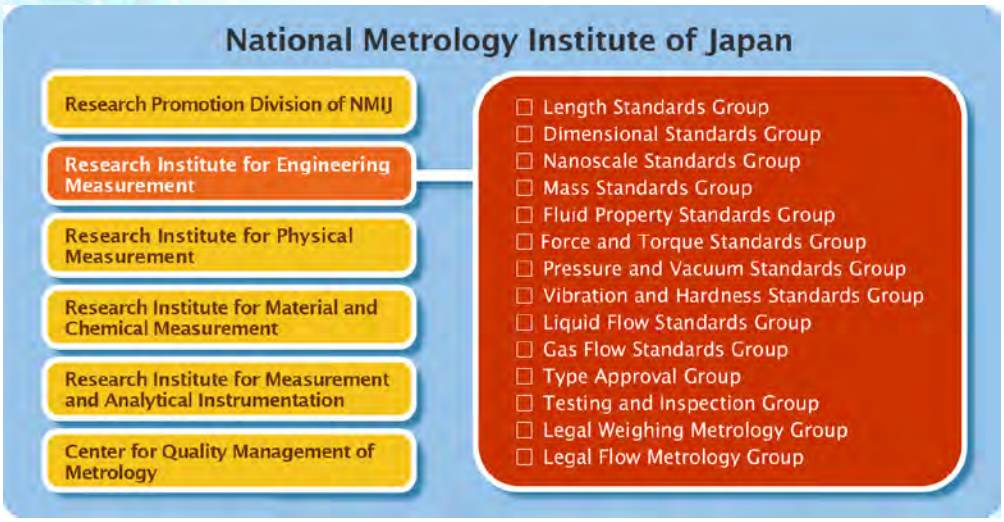
In addition to develop, maintain and supply metrological standards, RIEM is responsible for legal metrology. Technical activities of legal metrology include type approval tests of specified measuring instruments and inspections of verification standards used in local verification offices. The RIEM also performs various important tasks in legal metrology by cooperating with Ministry of Economy, Trade and Industry and providing trainings for local verification offices and manufacturers of measuring instruments. As for legal metrology, our mission is also to form a technical base where the technology and information are collected and provided.

One of the most important functions of a technical base is to be a network hub of information and human resources both for international and domestic. The RIEM is actively contributing to CIPM-MRA in the aim of supporting trade facilitation. The last but not the least important task of RIEM is to collaborate with foreign national metrology institutes (NMIs) and support for developing NMIs through regional metrology and legal metrology organizations, the Asia Pacific Metrology Programme (APMP) and the Asia Pacific Legal Metrology Forum (APLMF). I will take over the Chair of the APMP after the General Assembly which will be held in Da-nang, Vietnam in November. I am looking forward to playing this important role and feel a great responsibility as well. The RIEM has been promoting international collaboration extensively and will continue this policy. I would appreciate your kind support and cooperation in the metrology community.

Introduction of RIEM

Each of four institutes in NMIJ has their own role and mission in the field of measurement standards and legal metrology. The Research Institute for Engineering Measurement (RIEM) takes a responsibility for the measurement standards, especially we are deeply involved with manufacturing industries. The RIEM is also deeply engaged in legal metrology and plays a great role in that field.

There are fourteen groups in RIEM; ten of them are research groups responsible for measurement standards and four are technical groups working for legal metrology. The names of the groups can be seen in the figure, which simply describes the tasks assigned to the groups.



In research groups, advanced researches are conducted and the measurement standards are provided. These activities have brought the research groups the highest level of international researchers and facilities in respective research fields. The policy of RIEM is to provide metrological solutions in response to requests from industries by making use of these accomplishments. The RIEM contributes to the industries through the following activities:

◆ Technical transfer:

We can transfer our patents, knowledge and expertise to companies. Collaborative researches together with companies are also performed in the aim of developing new technologies.

◆ Technical consultation in the area of calibration services:

The NMIJ cooperates in the management of Japan Calibration Service System (JCSS) based on the Measurement Act. The RIEM can provide technical consultations to the accredited calibration laboratories of JCSS or those laboratories wishing to be accredited ones.

◆ Evaluation of new products:

We can provide third party evaluation of performance of the measuring instruments developed by companies. The results may serve for further improvement of the products. For small and medium enterprises, attachment of measurement reports issued by NMIJ will strengthen the competitiveness of the products in the market.

◆ Validity check of measuring instruments:

We check the validity of measuring instruments which are being used for the quality control purpose in production lines then issue certificates. Calibration in accordance with ISO/IEC 17025 requirements can also be performed. In case the instruments cannot be transported to NMIJ, on site testing is also possible.

◆ Collection of metrological information:

A lot of information is collected through various activities in many organizations related to the Metre convention. Several members of RIEM are playing important positions in these organizations. Many members are taking active parts in developing industrial standards such as ISO and JIS. We forward demands from industries to these activities and disseminate collected information.

◆ Legal metrology:

We provide technical information to manufacturers of measuring instruments and trainings to the staffs of verification offices. Impartiality and neutrality should be specially observed in this activity because NMIJ is the organization granting approval for type approval tests based on the Measurement Act.

Even if appropriate solutions cannot be given by ourselves, we can introduce external organizations such as universities by using our accumulated information and human networks. We will keep our policy “we never decline requests we have received from outside” in order to contribute to industries.

NMIJ activities (Apr. 2016 – Sep. 2016)

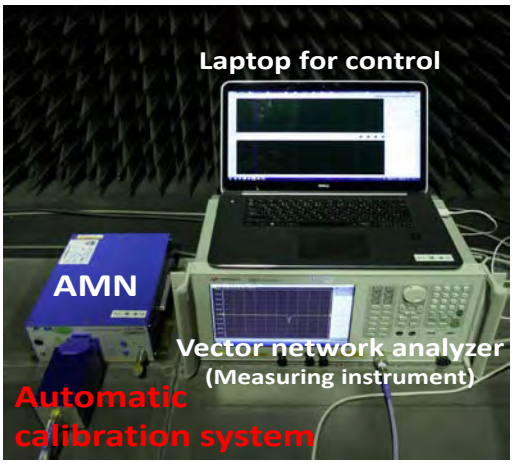
Research topics

New algorism and automatic system for calibration of artificial mains network

Ryoko Kishikawa and Masahiro Horibe

The NMIJ has established a new calibration algorism for impedance of artificial mains network (AMN) and developed an automatic calibration system for AMNs based on the algorism in collaboration with REPIC Corporation.

AMN is a test instrument for electromagnetic compatibility (EMC). In testing noise generated at an equipment under test (EUT), AMN fulfills a role as an impedance matching device between line impedance of EUT and input impedance of a noise measuring receiver. The required characteristics of AMNs are specified in the international standard of CISPR 16-1-2 in order to assure the EMC test accuracy. The developed automatic calibration system provides quick and accurate impedance calibration of AMN. In the established algorism, three standard terminations are used instead of open, short and load terminations in conventional calibration. The impedance values of the terminations are the standard, the upper limit value and the lower limit one specified in the CISPR 16-1-2. By using the method, the measurement uncertainty for both magnitude and phase of impedance are simply analyzed. In order to spread the method to the industry, automatic calibration systems based on it has been developed. This new system can reduces calibration and measurement time approximately 80 % compared with a conventional scheme.



Photograph of the new automatic calibration system.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160419/pr20160419.html

Portable high-precision DC current meter with clamp type DC current sensors

Atsushi Domae and Nobu-Hisa Kaneko

The NMIJ and TERADA ELECTRIC WORKS Co., Ltd developed a portable high-precision DC current meter with clamp type current sensors, which can measure DC current up to 60 A.

Photograph of developed portable high-precision DC current meter with clamp type DC current sensors

Clamp type current sensors have been widely used in the industry because of its usability; however, improvement of the measurement accuracy has been demanded.

We developed a high-precision clamp type DC current sensor with new structure and DC current meter, which has auto-correct functions of measurement errors. At present, the accuracy of the developed current meter is estimated to be 0.1 %, which is one-tenth of the conventional products.

The size of the current meter is: 406 mm (length) × 499 mm (width) × 192 mm (height), and the weight is about 8.2 kg. The current meter can run with built-in battery for 4 hours.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160728/pr20160728.html

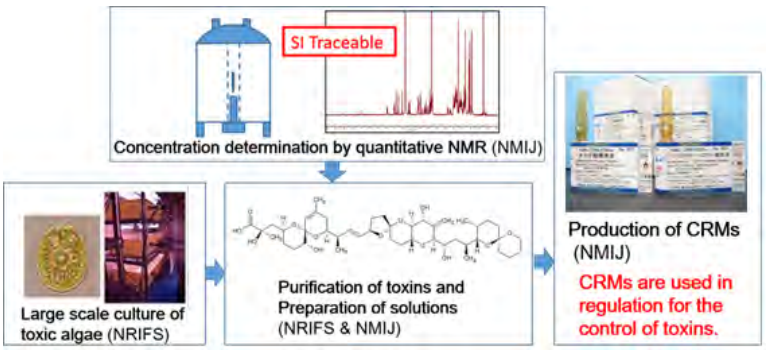
Development of CRMs for the diarrhetic shellfish toxins to ensure food safety

Taichi Yamazaki, Migaku Kawaguchi and Akiko Takatsu

Accumulation of bio-toxins in marine products causes serious health risk; therefore many types of monitoring programs have been established in many countries. The mouse toxicological test has been widely used for many years as a monitoring method; however instrumental analysis of bio-toxins has been gradually introduced these days. By going through this step, in 2016, the liquid chromatography tandem mass spectrometry (LC/MS/MS) was introduced to Japan as an official testing method for detecting the diarrhetic shellfish toxins in marine products. The reliable standard solutions produced by large-scale syntheses of toxins are essential for this method. However, the large-scale syntheses were difficult because the toxins are natural products having complicated structures.

In collaboration with National Research Institute of Fisheries Science (NRIFS), NMIJ has developed two kinds of diarrhetic shellfish toxin (Okadaic acid and Dinophysistoxin-1 (DTX1)) standard solutions. The raw materials were produced by NRIFS using their technique of large-scale culture for toxic algae. The primary standard solutions were prepared from these materials and NMIJ has determined the concentrations of the toxins using developed quantitative NMR technique, which could determine the low concentration of large organic molecules directly. The determined values were evaluated in a collaborative study. The developed certified reference materials (CRMs) are now used in toxin monitoring to ensure the safety of marine products in Japan.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160405/pr20160405.html

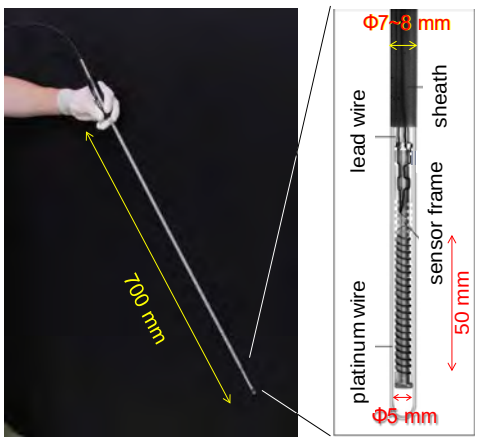


Development Scheme of CRMs for the diarrhetic shellfish toxins

High precision thermometer for temperature measurements near 1000 °C

Januarius Widiatmo

For high precision temperature measurements, platinum resistance thermometers (PRTs), which utilize platinum wire at the sensor part, are widely used. These PRTs, both the industrial type and the standard type (SPRT), however, become less stable at high temperature due to some thermal strain formed across the platinum wire. For providing highly stable thermometer applicable at temperatures near 1000 °C, NMIJ and CHINO Corporation have developed an SPRT (R800-3T). The structure of platinum sensor of the developed SPRT is modified from that of the existing model (R800-3L).



Photograph of the new PRT and its sensor part diagram

The modified structure can significantly reduce the influence of thermal strain formed at high temperatures. Furthermore, several heat treatments are carefully evaluated to obtain high stability. The new model SPRT has been stable within 0.001 °C at the use near 1000 °C.

The stability was evaluated by NMIJ based on the national standards of temperature. This SPRT answers the need of highly stable transfer standard for calibration and testing, and improves international comparison of temperature standards among national metrology institutes up to the silver point (961.78 °C). Application of this highly stable SPRT for precise measurements as well as precise temperature control is also expected.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160627/pr20160627.html

Deformation measurement for structural health monitoring using a digital camera

Hiroshi Tsuda and Shien Ri

In Japan, there are a lot of infrastructures built in the high-growth period around 50 years ago. The development of a low cost and reliable structural health monitoring technique is essential to ensure the safety of these aged infrastructures. Deformation measurement is one of the inspection methods for evaluating the structural health of bridges. Deformation of bridges is conventionally measured by the expansion or contraction of a piano wire connected between the bridge floor and the ground under the bridge. However, the conventional technique has several problems for example, time-consuming setup, high cost. Furthermore, the installation of the piano wire is impossible in case of bridges spanning a deep valley or sea. The NMIJ developed a novel measurement technique that can overcome such conventional difficulties. In this technique, pictures of repeated pattern targets attached to the bridge wall are taken with a digital camera. Then, the digital images of repeated patterns are analyzed through the sampling Moiré method and the deformation is evaluated. We demonstrated deformation measurement of a bridge over a valley by means of a setup where a digital camera was placed on the bridge column. This technique features comparable accuracy to conventional one despite low cost and easy setup. The aged deterioration of bridges can be diagnosed from deformation measurement at regular intervals. The developed measurement technique is expected to be widely applied to the future inspection of various infrastructures.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160831/pr20160831.html

Photo left:
A picture showing the experiment of bridge deformation measurement.

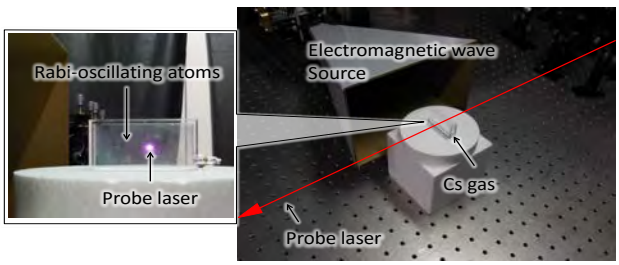
Photo right:
An enlarged view of wall-mounted targets

Measurement technology of electromagnetic wave using resonance of Cs atoms

Moto Kinoshita and Masanori Ishii

The NMIJ has developed a new technique for measurement of electromagnetic waves based on a resonance phenomenon of Cs atoms. A Cs atom periodically reciprocates its quantum states by interacting with electromagnetic wave at the frequency of 9.2 GHz. This reciprocation and its frequency are called the Rabi oscillation and the Rabi frequency, respectively. Since the Rabi frequency is proportional to the strength of the interacting electromagnetic wave, it can be measured from the Rabi frequency without any antenna element made of metal. The NMIJ has developed the technique which accurately measures strength of electromagnetic waves through obtaining the Rabi frequencies caused by the interaction between electromagnetic waves and Cs gas enclosed in a glass cell using a probe laser.

Our technique, in which a compact glass cell is used, allows to measure distribution of electromagnetic waves in detail as fine as 1 cm. In addition, a wireless and remote measurement can be achieved by the probe laser. Our technique is expected to be applied to visualization of spatial electromagnetic fields and upgrading electromagnetic compatibility (EMC) tests.



Photograph of measurement of electromagnetic waves radiated from a standard gain horn antenna using Cs atoms

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160711/pr20160711.html

Simple growth method of carbon nanotubes on three-dimensional (3D) objects using catalyst-support layer developed by alumina grit blasting

Hiromichi Watanabe and Juntaro Ishii

Carbon nanotube (CNT) array is considered as an ideal black coating media used in optical / thermal devices. However, CNT array is not yet commercially available black coating media. This is because the generic method to grow CNTs directly on metallic objects involves the sputter deposition for coating an oxide layer used as the buffer layer between the objects and the catalyst for the CNT growth. In general, it is difficult to deposit a layer over the entire surface of complex 3D objects, such as inner-surfaces of cylindrical tubes and cavities, by sputter deposition that are conducted in vacuum chambers.

The feature of present method is to develop the catalyst-support layer by air-blasting treatment with fused-alumina grit instead of sputter deposition. The blasting treatment can be conducted without a vacuum chamber and easily allows the inner surfaces of cylindrical tubes to be subjected to the treatment via adjustment of the spouting nozzle position of the blast media.

Using the present method, we plan to enhance the effective emissivity of blackbody cavities and minimize stray radiation within various optical instruments such as spectrometers and astronomical telescopes.

More detail :
H. Watanabe, J. Ishii, K. Ohta, Nanotechnology, 2016, 27, 335605.

Comparison between images of tungsten crucible before and after the CNT growth on the inner surface.

Calibration service of ^{223}Ra started for treatment of symptomatic bone metastases

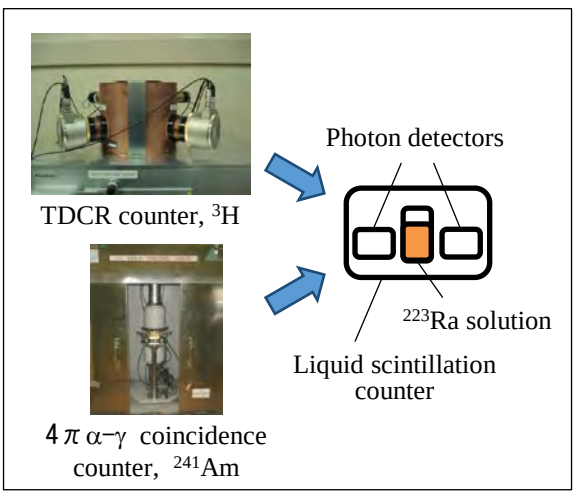
Yasushi Sato

The radiopharmaceutical of Xofigo® (^{223}Ra dichloride solution) is used to treat metastatic cancer in bone and has been on the market since 2013 in the US and EU, followed by Japan in 2016. The radioactivities of the radiopharmaceuticals need to be measured when they are used in the treatment; therefore the national standard of ^{223}Ra has been demanded. The calibration method of ^{223}Ra radioactivity was established at NMIJ by collaborative research with Japan Radioisotope Association.

A liquid scintillation counting technique is adopted to calibrate ^{223}Ra radioactivity. The ^{223}Ra is an alpha emitter; however it coexists with seven descendant radionuclides which emit both alpha and beta particles. In this situation, it is difficult to measure absolute quantity of radioactivity. Therefore, the calibration method for the scintillation counters was as follows: the detection efficiencies of the particles were estimated in NMIJ by standard sources of ^{241}Am as an alpha emitter and ^{3}H as a beta emitter; $4\pi\alpha$–γ coincidence counting method and TDCR method have been used to standardize the ^{241}Am source and the ^{3}H source, respectively.

The calibration service of ^{223}Ra started at NMIJ on 1st August 2016.

More detail (in Japanese):
http://www.aist.go.jp/aist_j/press_release/pr2016/pr20160801/pr20160801.html



Schematic diagram of calibration

Featured events

GCC delegation for measurement standards visit NMIJ

On 31st May, the Gulf Cooperation Council (GCC) delegation visited NMIJ to improve the quality of measurement standards in GCC area. Mr. Adel Hassan A. R. Fakhroo (Head of Delegation, State of Qatar) and 13 members from 6 countries visited Gas and Humidity Standards Group, Large Flow Standards Group, Force and Torque Standards Group and Metrology Training Center of NMIJ.

Director General of DRI visits NMIJ

On 2nd June, Mr. Win Khang Moe, Director General of Department of Research and Innovation (DRI), Myanmer, Dr. Kyaw Soe Lwin, Deputy Director of DRI, Mr. Myint Wai, Director of Department of Trade Promotion and Consumer Affirs, and Dr. Myo Aung Kyaw, Vice Chairman, Myanmar Rice Federation and Dr. Myo Aung Kyaw, Vice Chairman, Myanmar Rice Federation visited Legal Flow Metrology Group, Mass Standards Group and Time Standards Group of NMIJ, and had a discussion about "Activities of APLMF WG on Grain Moisture Measurements".

CIML member of India visits NMIJ

Mr. Badri Narayan Dixit, Director of Legal Metrology, Government of India (CIML member), and Mr. P. V. Rama Sastry, Joint Secretary of Consumer Affairs visited NMIJ on 6th June. They visited Legal Flow Metrology Group, Legal Weighing Metrology Group, Mass Standards Group and Gas Flow Standards Group of NMIJ. They also visited Japan Electric Meters Inspection Corporation (JEMIC) and Tatsuno Corporation in Tokyo.

General Director of CMS/ITRI visits NMIJ

Dr. Tzeng-Yow Lin, General Director of Center for Measurement Standards (CMS) / Industrial Technology Research Institute (ITRI), Taiwan and Dr. Yu-Ping Lan, Director of Measurement Standards & Technology Division of CMS/ITRI visited NMIJ on 5th September. After the short discussion with Dr. Yukinobu Miki, Director General of NMIJ, they visited standard laboratories of Length, Dimension, Small Mass and Time. In this visit, the miniature replica of "Shin Maang Jia-Liang" which is an ancient measurement standard for volume was gifted.

"Public Open Day": many visitors enjoy science talks and demonstration experiments

The "AIST Public Open Day" was held on 23rd July and more than 6000 people visited the event. The purpose of this event was to offer visitors especially children an opportunity to show and share science and measurement technology as a fun event.

The new members and volunteers of NMIJ ran a "hands-on" booth for science talks and demonstration experiments. Many children experienced and found the importance of the measurement through various kinds of measurement activities. Also they enjoyed making photo-elastic kaleidoscopes with our young metrologists using mysterious characteristics of Optics. The next "Public Open Day" will be held on 22nd July 2017.

Contribution to the MEDEA project

The NMIJ has been actively supporting training programs for Asian economies in cooperation with APMP, APLMF and PTB in Germany. This project organized by these organizations is called MEDEA (Metrology-Enabling Developing Economies in Asia). Under this project, a training course on mass standards was conducted at Borobudur Hotel in Jakarta, Indonesia from 30th August to 1st September 2016. This course had been planned as an APLMF training course in cooperation with APMP and the host institute, Directorate of Metrology (DoM) under the Ministry of Trade. Mass was selected as the target quantity as an important base unit in metrology.

The APLMF has conducted training courses on non-automatic weighing instruments (NAWI) for over 20 years. This training course was designed for the officers and scientists in APLMF and APMP who calibrate and/or verify standard weights in accordance with OIML R 111 "Weights of classes E1, E2, F1, F2, M1, M1-2, M2, M2-3 and M3". The contents were composed of lectures and a practical activity.

In total, 21 metrologists from 13 economies and 20 local observers took part in this training course. Four NMIJ experts, Masaki Ueki, Tsuyoshi Matsumoto, Tsutomu Horikoshi and Nobuhiko Azami participated in the training course as instructors.

Invited talk of Dr. Barry Inglis in "Japan Metrology Forum 14th Lecture Meeting"

Dr. Barry Inglis, President of CIPM was invited to "Japan Metrology Forum 14th Lecture Meeting" in Tokyo on 29th September 2016. The meeting was held by the Japan Metrology Forum and NMIJ aiming to impart the benefits provided by the revision of the International System of Units (SI) which will be deliberated in 2018.

Dr. Inglis gave a lecture titled "Towards a Revised International System (SI) of Units of Measurement." In his lecture, a proposal for its revision based on the redefinition of the seven base units in terms of fundamental constants was presented after a short introduction of the history of the SI, together with the reasons for the revision and the likely impact on international metrology.

Minister of MOST of Thailand visits NMIJ's booth in "INTERMEASURE 2016"

"INTERMEASURE 2016" (Measurement, Test and Control Technology Show 2016), one of the biggest measuring instruments exhibitions in Japan was held from 28th to 30th September at the Tokyo Big Sight (Tokyo International Exhibition Center).

The NMIJ ran a booth presenting resent research topics and promoting near-future revision of SI.

Dr. Pichet Durongkaveroj, Minister of Ministry of Science and Technology (MOST) of Thailand and Dr. Luxsamee Plangsangmas, Governor of Thailand Institute of Scientific and Technological Research (TISTR) visited the show on 29th September. They stopped by the NMIJ booth and exchanged questions and answers.

Visitors

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
Ms. T. N. T. Mai	Politecnico di Torino, Italy	Apr. 01-Sep. 31	Master degree internship: Design of low-noise, high-speed readout electronics for electrical metrology experiments
Dr. H. Chiou	ITRI, Taiwan	Apr. 12	Technical visit to Pressure and Vacuum Standards Group, Acoustics and Ultrasonics Standards Group
Mr. W. M. Al-Falis, Mr. A. S. Al Harbi	Saudi Quality Council	Apr. 21	Technical visit to Radio-Frequency Standards Group, Quantum Electrical Standards Group, Dimensional Standards Group
Dr. Y. Yang	CMS/ITRI, Taiwan	Apr. 25-Jun. 03	Visiting researcher
Dr. D. Jarrett	NIST, USA	May 21-Jun. 11	High resistance measurements collaboration
Mr. A. H. A. R. Fakhroo and 13 members	GCC, State of Qatar and 5 countries	May 31	Technical visit to Gas and Humidity Standards Group, Large Flow Standards Group, Force and Torque Standards Group , Metrology Training Center of NMIJ
Mr. W. K. Moe, Dr. K. S. Lwin	DRI, Myanmar	Jun. 02	Technical visit to Legal Flow Metrology Group, Mass Standards Group, Time Standards Group
Mr. B. N. Dixit, Mr. P. V. R. Sastry	Government of India	Jun. 06	Technical visit to Legal Flow Metrology Group, Legal Weighing Metrology Group, Mass Standards Group, Gas Flow Standards Group
Dr. H. Park, Dr. J. Kim	KRISS, Korea	Aug. 23	Discussion on establishment of an accelerator-based neutron standard field
Dr. H. Choi, Dr. W. Kang	KRISS, Korea	Aug. 29	Technical visit to Gas Flow Standards Group, Liquid Flow Standards Group
Dr. T. Lin, Dr. Y. Lan	CMS/ITRI, Taiwan	Sep. 05	Discussion on future collaboration and technical visit to Length Standards Group, Dimensional Standards Group, Nanoscale Standards Group, Mass Standards Group, Time Standards Group
Dr. B. Inglis	NMIA, Austraria CIPM President	Sep. 28-29	Technical visit to NMIJ laboratories and discuss with Research Promotion Division of NMIJ Invited speech for the Japan Metrology Forum 14th Lecture Meeting

Peer review and international comparisons

The NMIJ dispatches the peer reviewers to NMIs on their requests (if available). In the recent half year, five researchers assessed to three NMIs for CIPM-MRA on-site peer reviews. Also, NMIJ has participated in the following key comparison within this period.

NMIJ Participants	KCDB Code	Field	Title	Pilot Lab
Dr. H. Abe	CCT-K6.2	Humidity (dew point) -70 °C to -30 °C	Comparison of frost-point temperature standards (Protocol submitted CCT in Oct. 2014)	NIST

Selected research reports

1) M. Tanabe, K. Amemiya, T. Numata, D. Fukuda, "Spectral supralinearity of silicon photodiodes in visible light due to surface recombination", Applied Optics, 2016, 55(11), 3084-3089
2) K. Hashiguchi, D. Lisak, A. Cygan, R. Ciuryło, H. Abe, "Wavelength-meter controlled cavity ring-down spectroscopy: high-sensitivity detection of trace moisture in N_2 at sub-ppb levels", Sensors and Actuators A: Physical, 2016, 241, 152-160
3) K. Shirono, M. Shiro, H. Tanaka, K. Ehara, "Proficiency tests with uncertainty information: Detection of an unknown random effect", Measurement, 2016, 83, 144-152
4) S. Wada, N. Furuichi , "An influence of obstacle plate on uncertainty of flowrate measurement using ultrasonic Doppler velocity profile method", Flow measurement and Instrumentation, 2016, 48, 81-89
5) T. Kobayashi, D. Akamatsu, Y. Nishida, T. Tanabe, M. Yasuda, F. L. Hong, K. Hosaka, "Second harmonic generation at 399 nm resonant on the $^1S_0$-$^1P_1$ transition of ytterbium using a periodically poled $LiNbO_3$ waveguide", Optics Express, 2016, 24, 12142-12150
6) H. Watanabe, J. Ishii, K. Ota, "Novel growth method of carbon nanotubes using catalyst-support layer developed by alumina grit blasting", Nanotechnology, 2016, 27, 335605
7) H. Nozato, A. Ota, W. Kokuyama, H. Volkers, T. Bruns, "An enhanced primary shock calibration procedure to reduce the zero shift effect of piezoelectric transducers by using a virtual amplifier ", Measurement Science and Technology, 2016, 27(8), 095007
8) T. Yarita, T. Otake, Y. Aoyagi, M. Numata, A. Takatsu, "Difference between consensus value of participants' results and isotope-dilution mass spectrometric results in proficiency testing for pesticide residues in husked wheat", Anal. Sci., 2016, 32, 557-563
9) Y. Liu, Z. Cao, C. Wu, D. Fukuda, L. You, J. Zhong, T. Numata, S. Chen, W. Zhang, S.C. Shi, C.Y. Lu, Z. Wang, X. Ma, J. Fan, Q. Zhang, J.W. Pan, "Experimental quantum data locking", Physical Review A, 2016, 94 (2), 020301
10) K. Iwakuni, S. Okubo, O. Tadanaga, H. Inaba, A. Onae, F.-L. Hong, H. Sasada, "Generation of a frequency comb spanning more than 3.6 octaves from ultraviolet to mid infrared", Optics Letters, 2016, 41, 3980-3983
11) Q. Wang, S. Ri, H. Tsuda, "Digital sampling Moiré as a substitute for microscope scanning Moiré for high-sensitivity and full-field deformation measurement at micron/nano scales", Applied Optics, 2016, 55, 6858-6865
12) S. Yamauchi, K. Akamatsu, T. Niwa, H. Kitano, H. Abe, "Novel humidity sensor using heat pipe: Phase transition thermally balanced sensor designed for measurement of high humidity at high temperature", Sensors and Actuators A: Physical, 2016, 250, 1-6
13) K. Iwakuni, S. Okubo, K. Yamada, H. Inaba, A. Onae, F.-L. Hong, H. Sasada, "Ortho-para dependent pressure effects observed in the near infrared band of acetylene by dual-comb spectroscopy", Physical Review Letters, 2016, 117, 143902
14) N. Furuichi , Y. Terao, S. Ogawa, L. Cordova, T. Shimada, "Inter-laboratory comparison of small water flow calibration facilities at extremely low uncertainty", Measurement, 2016, 91, 548-556
15) T. Hayashi, K. Ueda, "Ambient pressure compensation for hermetically sealed force transducers", Measurement, 2016, 91, 377-384

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