Report on the meeting of the CCEM working group on electrical methods to monitor the stability of the kilogram – August 2014

This was an informal meeting of the working group, which was held on Saturday 23rd August 2014 at CPEM 2014 in Rio de Janeiro, Brazil. The report also includes further information gathered in February and March 2015 both from the participants in the August 2014 meeting but also from the 2015 meetings of the CCM, CCEM and some CCM working groups.

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Glossary

BIPM	Bureau International des Poids et Measures
BIPM	International Bureau of Weights and Measures
CCEM	Consultative Committee for Electricity and Magnetism
CCM	Consultative Committee for Mass and Related Quantities
CCM-WGG	CCM Working Group on Gravimetry
CIPM	International Committee for Weights and Measures
CODATA	COmmittee on DATA for science and technology
CPEM	Conference on Precision Electromagnetic Measurements
EMPIR	European Metrology Programme for Innovation and Research
EMRP	European Metrology Research Programme
EURAMET	EURopean Association of national METrology institutes
FPGA	Field Programmable Gate Array
h_{90}	A stable value of the Planck constant derived from $K_{\mathrm{J-90}}$ and $R_{\mathrm{K-90}}$
IAC	International Avogadro Coodination
ICAG	International Comparison of Absolute Gravimeters
INRIM	Istituto Nazionale di Ricerca Metrologica - Italy
IPK	International Prototype of the Kilogram
$K_{\mathrm{J-90}}$	Conventional value of the Josephson constant
KRISS	Korea Research Institute of Standards and Science - Korea
LNE	Laboratoire National de métrologie et d'Essais - France
METAS	Federal office of metrology – Switzerland
MSL	Measurement Standards Laboratory – New Zealand
MST	Measurement Science and Technology
Nd:YAG	Neodymium-doped Yttrium Aluminium Garnet
NIM	National Institute of Metrology - China
NIST	National Institute of Science and Technology – USA
NMI	National Measurement/Metrology Institute
NMIJ	National Metrology Institute of Japan – Japan
NPL	National Physical Laboratory - United Kingdom
NRC	National Research Council – Canada
OFHC	Oxygen-Free High Conductivity
PJVS	Programmable Josephson Voltage Standard/Source
PTB	Physikalisch-Technische Bundesanstalt – Germany
$R_{\mathrm{K-90}}$	Conventional value of the von Klitzing constant
SNS	Superconductor-Normal-Superconductor
Special Issue of Metrologia	Special issue - Watt and joule balances, the Planck constant and the kilogram, *Metrologia* **51** No 2 April 2014. Individual papers are identified by the letter S followed by their starting page number in the issue.
VNIIM	D.I. Mendeleyev Institute for Metrology - Russian Federation
XPS	X-ray Photoelectron Spectroscopy
XRCD	X-Ray Crystal Density
XRF	X-Ray Fluorescence spectroscopy

IAC: the Avogadro constant by the X-Ray Crystal Density (XRCD) method.

Two further laboratories are interested in the XRCD technique: VNIIM and KRISS. VNIIM has applied for funding to acquire two spheres of natural silicon. KRISS has a sphere interferometer for volume measurements and they have performed a comparison with NMIJ. They plan to measure surface properties using an ellipsometer.

The IAC have improved molar mass measurements by using Tetra Methyl Ammonium Hydroxide to digest the silicon samples rather than Sodium Hydroxide. This technique avoids the sodium residues which can collect in critical parts of the mass spectrometer and may bias the measurement.

Silicon-28 spheres labelled AVO-28-S5 and AVO-28-S8, which had metallic surface contamination, have been decontaminated and polished to improve both their roundness and the uncertainties of the masses of the surface layers. The radius of sphere AVO-28-S5 deviates from that of a perfect sphere by less than 34.5 nm and the radius of the repolished sphere AVO28-S8 deviates by less than 20 nm.

Many of the instruments involved in the measurement have been improved and, apart from the measurement of the lattice spacing of silicon, at least two routes are now available to measure each of the quantities needed for the full determination. NMIJ and PTB have measured the volume. The mass of the spheres was measured by PTB, NMIJ and BIPM. The properties of the surface layers have been measured by NMIJ and PTB using ellipsometry and XPS/XRF the two techniques lead to a consistent estimate of the mass of the surface layers. INRIM has measured the silicon lattice spacing and PTB are preparing to make a second measurement of this quantity.

The IAC have submitted a paper to Metrologia on their latest measurements of the Avogadro constant. They quote a relative standard uncertainty of 20 x 10^{-9}; the paper was accepted for publication in February 2015.

NRC: the Planck constant via the Watt Balance

NRC measurements of the Planck constant were published in the Special Issue of Metrologia (S5). Their result is currently the lowest uncertainty measurement of the Planck constant with a relative standard uncertainty of 18 x 10^{-9}.

They have been working on improving the operation of the balance especially the long term problem of excess noise in the moving phase of its operation. A long investigation led to the elimination of excess strain in the beam splitter of the laser interferometer. This produced a reduction of the noise by a factor of 9. The resulting improvement in the resolution of the moving phase will simplify the investigation into a number of effects which may produce uncertainty contributions at the level of a few parts in 10^9. These include further tests of the independence of the measurement on coil velocity and investigations into the magnitude of hysteresis effects in the field of the magnet caused by the current direction at the end of the previous weighing phase.

NIST: the Planck constant via the Watt Balance

NIST described work on both the NIST-3 and NIST-4 watt balances. The NIST-3 balance has been operating for over 15 years and has produced a number of measurements of the Planck constant in that time. The apparatus was extensively modified in 2012 before a blind measurement campaign was mounted in the period from December 2012 to June 2013. The blind was removed at the watt balance technical meeting in June 2013 and a new result was calculated. This result was in agreement with results published by the IAC and the NRC. Further work was carried out in the period to December 2013 and the results were published in the Special Issue of Metrologia (S15).

The modifications included overhauling the programmable Josephson array voltage reference system (PJVS) and replacing the array. The mains grounding arrangement of the electrical measuring system was changed and the leakage resistance to mains ground of the PJVS and the current-source was increased. The alignment procedures for the balance were improved and the balance knife and its associated flat were replaced. Procedures for mass exchange and knife-edge hysteresis erasing were tested. However the reason for the observed shift in value could not be discovered. A relative shift of a few parts in 10^8 could be attributed to changes to the mass scale but as the NIST-3 balance was a research device the configuration of the instrument was constantly in change and previous configurations were impossible to reproduce in during the 2012/13 tests. The measured value of the Planck constant started to increase in 2010 after improvements to the electrical measurement system were made which may have eliminated leakage paths to ground and ground loops. In the 2012/13 configuration, leakage resistances have been thoroughly investigated. The measurements have yielded a value of the Planck constant having a relative standard uncertainty of 45×10^{-9}. This measurement differs by 112×10^{-9} from the value obtained in the period from 2005 to March 2010 and no single reason for this shift could be identified. The measurements from March 2010 to March 2011 agree with the 2013 measurements if one takes into account a shift of the working mass standard K85 due to a mismatch of the BIPM-US mass scales.

At the end of 2014, NIST corrected their new result in order to take into account the newly found shift of the mass unit as maintained by the BIPM. This reduces their latest number relatively by 35×10^{-9}. In order to give guidance to CODATA, the NIST researchers have combined all measurements that were taken with the NIST-3 watt balance between 2003 and 2014 into a single result. This final result is $h/h_{90} -1 = 77(57) \times 10^{-9}$. The relative uncertainty of this result reflects the fact that the data has shifted at the beginning of 2010 by a relative amount of 70×10^{-9}. Half of this shift was assigned as an uncertainty to account for an unexplained systematic effect.

As it will be difficult to make substantial improvements to the uncertainty of the NIST-3 balance further work has been concentrated on the NIST-4 balance which is has now been designed and fabricated. It is being assembled and will be tested in the period from 2014 to 2015. The magnet is complete and exhibits good field uniformity over the expected moving range of the coil. A gravitational survey has been made of the room which houses the apparatus and a gravitational model has been derived from this. Sufficient measurements have been made to allow accurate transfers of the gravimeter measurements to the position of the watt balance working mass. The apparatus and its vacuum chamber have been assembled and they are working on the moving phase of the measurement.

The NIST watt balance team plans to publish a result before the deadline for the 2017 CODATA adjustment of the fundamental constants. The goal is to have a measurement of the Planck constant with a relative uncertainty that is smaller than the one obtained with NIST-3.

Following in the footsteps of Terry Quinn, the NIST group has built a LEGO® watt balance to promote the forthcoming redefinition of the kilogram and have published details of its construction and operation.

NIM: the Planck constant via the Joule Balance

By 2013 the first prototype of the NIM joule balance NIM-1 reached an uncertainty of 8.9×10^{-6} which was the limited by self-heating of the coils and the resolution of the balance. The design of a new balance, NIM-2, was started in 2013 and it is intended that its construction will be complete by 2015. The coil design has been optimised to decrease self-heating. The balance will incorporate a stabilisation system to avoid problems arising from non-ideal balance knives and the swing and vibration of the suspended coil will be minimised using a laser-based locking system which has already been built. The exciting coil will be moved using a driving stage which is linear at the µm level in a 20mm range. The new apparatus is much smaller than NIM-1 and will be vacuum compatible.

A commercial mass comparator of 5 kg capacity has been ordered for the weighing phase of the measurement. It has a resolution of 1µg and a repeatability of 10 µg. The new suspended system including the coil has a mass of about 4.5kg.

To decrease self-heating, which was a problem for NIM-1, an electromagnet, using a closed ferromagnetic circuit, has been designed and built. The outer ferromagnetic ring acts as a magnetic shield preventing the suspended coil from affecting the outer coils. The electromagnetic force generated has been increased to 500g, 2.5 times of that of NIM-1 while the power dissipated in the exciting coil is 7.5W. This increase in force allows the weighing of a 1 kg mass by current reversal. The field is homogenous over a length of 40 cm some 10 times that of NIM-1 which will ease the requirements on the length measurements. To damp unwanted motions of the coil a 3-dimensional magnetic multi-pole damping device is being designed with a U-shaped iron yoke and 8 permanent magnets. This design ensures that its leakage field attenuates rapidly with distance. The translation stage, the active vibration isolation base and the vacuum chamber are being designed and will be ready by the end of 2014. The system is expected to be mounted in its vacuum chamber by the end of 2015; results at the level of a part in 10^7 or better are expected by 2017.

METAS: the Planck constant via the Watt Balance

The balance makes use of a custom made weighing cell. At present the 3rd generation cell is mounted in the balance and has a load capacity of 1.8 kg with a resolution of approximately 3 µg. The cell is designed to be relatively robust and can be locked to prevent damage during adjustment of the other parts of the balance. The 4th generation weighing cell is under test and it is of similar design to the 3rd generation cell but its resolution is better than 1 µg. The weighing cell is integrated into translation stage but is locked while they work on the moving phase of the measurement. They have implemented a variable mechanical stop for mass exchange with a range of 16 mm with 0.5 mm steps. Velocity control is achieved using a linear motor incorporating a voice coil with position feedback via an optical encoder with 100 nm resolution. The coil velocity is controlled using a software based Proportional, Integral, Derivative (PID) feedback system. An optical signal with a frequency proportional to coil velocity is generated by a Fabry-Perot interferometer and its frequency is measured using two time interval analysers (TIA) made by Brilliant Instruments. The coil moves over 30 mm at approximately 1.3 mm/s generating 1 V which is measured using an Agilent 3458A voltmeter.

Their magnet has been assembled and, after some initial problems, the field was made uniform over a 10 mm travel. They have two sets of working masses of 250,500 and 1000 g. The masses are made of OFHC Copper with a hardening layer of 10 µm of Trigold (Au 75%; Cu 21%; In 4%). This gives the masses good resistance to wear as the outer layer is about ten times the hardness of copper.

Their next jobs include the mounting of their Michelson interferometer, plus work on the control software, measurement strategy and the procedure for combining the results from the two measurement phases. They will build and integrate the environmental monitoring systems for the apparatus and the systems for measuring the coil position and angle. The vacuum chamber cabling will be completed and they aim to be able to run full measurement cycles before the end of 2014. The work is fully funded and with 1.2 equivalent staff plus external partners. They aim to have a result with an uncertainty of 5 parts in 10^8 by mid-2017.

French Watt Balance Project: the Planck constant

The assembly and initial testing of the balance is complete and it has been aligned for operation in air. Various mechanical methods have been used to verify the alignment of the guiding stage and the magnetic circuit. The misalignment of the guide device from the vertical and the magnetic induction from the horizontal does not exceed 10 µrad. Five capacitive sensors are used to measure the pitch, roll and yaw of the balance beam and allow the adjustment of the beam to horizontal to within a few hundred µrad. An adjustable mass under the beam adjusts the sensitivity of the balance. Tests were made to determine the sensitivity of the balance which was found to be comparable for mass up and mass down conditions of the static phase. The sensitivity of the beam is in the range from 10 to 500 rad/kg and the measured relative stability on ABA weighing sequences is 2×10^{-8} in 4 h. The position and tilt of the coil in the air gap of the magnetic circuit can now be adjusted so that the coil moves approximately 2 µm and its orientation changes by 1 µrad for a reversal of the current in the coil during setup and it moves less than 10 µm during measurements. The position of the coil in both the static and dynamic phase is monitored by new heterodyne interferometers based on an improved compact design. A dedicated FPGA monitors the optical phase of each interferometer with sample rate of 750 kHz and a resolution of a few nm. The apparatus operates in air which requires that corrections be made for the refractive index and buoyancy of air. They have implemented a monitoring system with uncertainties on pressure of ±10 Pa, temperature of ±0.1 °C, relative humidity of ±1.5 % and CO_2 content of ±200 ppm. The balance has been operating for over 1 month and has made 240 measurements at approximately 5 to 8 measurements/day.

A value of $h = 6.626\ 068\ 8(20) \times 10^{-34}$ Js has been extracted from their data. It differs in relative terms by $-\ 0.05\times10^{-7}$ from the h_{90} value and by -1.1×10^{-7} from that of the 2010 CODATA adjustment of h. The relative standard uncertainty associated is 3.1×10^{-7}, thus larger than these differences. Together with this result, an overall description of the LNE watt balance and the analysis of the main contributions to the uncertainty budget are described in a paper accepted for publication in Metrologia. Currently, the major contributions to the published uncertainty arise from voltage measurements, velocity measurements and suspension alignments. These contributions are not yet a limitation of the LNE experiment and it will certainly be possible to reduce them. To achieve this, several works are planned notably:

- Voltage measurements during static and dynamic phases will be made directly against a 1 V programmable Josephson voltage standard available in the laboratory;
- Some improvements will be implemented to adjust the verticality of the six gaussian laser beams (going through the position detectors and the corner cubes of the coil) using a mercury pool and a 1.1 m focal length telescope. The interferometer beams will be aligned to the vertical to better than 150 µrad;

- The contribution to the uncertainty of the measurement caused by parasitic forces and torques combined with horizontal and angular velocities will be checked by introducing controlled misalignments;
- Another 500 g mass artifact, made from Pt-Ir alloy provided by the English company Johnson-Matthey, and polished, adjusted and calibrated by the BIPM will be used for the next campaign of measurements, notably because its magnetic susceptibility is lower than that of Alacrite and its density is higher.

These improvements will be followed by a new campaign of Planck constant measurements with the watt balance operating in air.

The project is fully funded with a 3.3 permanent staff, 1 postdoc (full time) plus support of other groups in interferometry, gravimetry, Josephson voltage measurement and mass measurement. Part of this work was funded by the European Metrology Research Program (EMRP) with the European Association of National Metrology Institutes (EURAMET) and the European Union in the framework of the kNOW joint research project.

BIPM: the Planck constant via the Watt Balance

The BIPM watt balance has made initial measurements and they have reduced their type A uncertainty by almost a factor of three to 5×10^{-7}. They are now working on alignment and the elimination of sources of noise. They have addressed some vibration problems caused by local air conditioning plant and have measured the vibration of the apparatus. Some large low frequency peaks were identified: one associated with the structure at 14 Hz has been resolved and the exact cause of an 18 Hz peak arising from the suspension has still to be identified. The definitive magnet has been assembled and has been characterised. Its field is uniform to 2×10^{-4} in the region where the moving measurement is made. They have implemented a scheme to dynamically correct the coil trajectory using piezo electric actuators on the coil support structure. They have aligned the electric plane of a watt balance coil along with the adjustable reference mirror fixed onto it with a total uncertainty of about 150 µrad. They now need to transfer the alignment to a smaller mirror fixed onto the coil and then align the magnetic field of the magnet. They are designing a more open support structure for the apparatus which will ease access to the apparatus whilst also increasing rigidity and stability and are aiming to avoid resonant frequencies below 50 Hz. The simulation of the new structure using finite element analysis is underway and vibration test measurements using accelerometers will start soon. A new compact, stable, vacuum compatible interferometer is being developed using an iodine stabilized Nd:YAG laser as light source. It is a heterodyne interferometer employing separated parallel beams with maximal common mode path and promises small non-linear errors and a high signal-to-noise ratio. The design provides easy alignment of the beams to one another and to the vertical. The current in the coil is measured by the voltage drop across a known resistor. The voltage is measured by opposing it by a voltage produced from a NIST SNS PJVS operated at a frequency of 18.34 GHz.

The next steps in the work involve completing the improved apparatus by installing the new “open” supporting structure, fully implementing the improved dynamic alignment mechanism, installing the new high-precision interferometer and the new position sensors and adding a second PJVS for the measurement of the induced voltage.

In the first half of 2015 the apparatus will be aligned and control and data acquisition programs will be improved with the intention of having a fully aligned and operational apparatus ready for a measurement campaign in air in the second half of 2015. The apparatus will then be operated

under vacuum with an expected uncertainty on the Planck constant determination of a few parts in 10^7 in 2017.
The work is fully funded with a team mainly composed of two full time permanent staff and two full time fixed-term staff.

MSL: the Planck constant via the Watt Balance

MSL are working on a watt balance which uses a pressure balance with a rotating cylinder and a stationary piston which holds the coil. As there is no piston-cylinder contact and the piston-cylinder gap is less than 1 μm the aerodynamic bearing produces no static friction and the strong piston centring forces generate a well-defined axis for the moving measurement. The coil is rigidly fixed to the piston. The high level design of the apparatus is complete and they are working on the detailed design and the construction of the system. The design and modelling of their magnet is described in the Special Issue of Metrologia (S101) and they have constructed a facility for measuring the temperature coefficient of the magnetization of the permanent magnet which is described in MST 25 (2014) 085902. For the voltage measurements they are planning to use a NIST PJVS which is expected to arrive in late 2014. The timing devices for sampling the interferometer output during the moving phase are being tested. They have measured the frequency and stability of the laser intended for the interferometer and are planning absolute measurements of their local gravity for February 2015. They are assessing the influence of piston eccentricity and tilt in the cylinder on the effective area of the piston. This would affect the accuracy of the balance during weighing. They estimate that the effect should be no greater than 1 part in 10^8. Considerable effort has been spent on the magnet design which exhibits axial and mirror symmetry and is shielded from external field influences in a similar way to the BIPM magnet design. The 0.6 T magnet allows the use of a coil with a relatively small diameter of 240 mm with a stiff coil support. It has been designed to be insensitive to magnetization arising from the 12 mA weighing current in the coil and the choice of permanent magnet material will provide a low temperature coefficient. The field uniformity is expected to be ±20 ppm in the central ±20 mm of the 100 mm long 16 mm wide gap.

The project receives some strategic investment funding and is in-part funded directly by MSL with an additional modest level of funding for equipment. The project involves over 10 people who contribute when needed. The overall effort is estimated to be equivalent to 1.5 full-time staff. They are aiming to have their first measurements in mid to late 2015.

KRISS: the Planck constant via the Watt Balance

KRISS did not present a report at the meeting but they have published a paper (S96) in the Special Issue of Metrologia describing the design of their balance. They have provided some more details of their work which are summarised below.

The KRISS watt balance project started at 2012. The underground laboratory for the project was built in 2014. They have measured the rms velocity of the ground vibration in the laboratory to be less than 0.4 μm/s. A gravity survey was undertaken to produce a gravity map of the laboratory before the installation of the watt balance. The absolute gravity and gravity gradient were measured at two points on the 4 m × 5 m block on which the watt balance will be installed. The relative gravity was measured at 63 points on the block spaced by 0.5 m.

The coil will be moved using a linear guide using a modified piston gauge. The deviation from linear motion of a prototype of the piston guide was less than 1 μm over a 40 mm travel distance. This guide will move the coil and the 5 kg capacity weighing cell using a linear motor. A counter weight is used to reduce the driving force for the assembly to less than 1 N. The main system including the translation guide, weighing cell and magnet stage has been fabricated. The permanent magnet assembly, which is in production at a German company, will be delivered in 2015. It uses NiFe alloy sheets, sandwiched between SmCo sectors, to reduce *B*-field variation with temperature. Their aim is to start measurements in 2016 and report a result with an uncertainty in the region of 5 x 10^{-8} before the deadline for the 2017 adjustment.

They are working on the project with an effort equivalent to 3 full time staff with a funding of 0.5 M$ per year (2015-2017).

NPL: the Planck constant via the Watt Balance

NPL have published the theory and some designs for a new generation of watt balances. The paper was published in the Special Issue of Metrologia (S132) and describes the conditions under which a watt balance becomes insensitive to the alignment requirements previously thought necessary for its successful operation. This theory leads to a variety of possible designs of watt balance, over a range of masses from kilograms to milligrams. One design, described in the paper, takes advantage of the precise vertical motion of a rigid frame which is supported using a seismometer-like flexure suspension. The frame carries the coil and interferometer reflector and acts as the mass pan. Construction of a prototype of this type of watt balance, designed to work in the 100 g range, has been started at NPL.

The work was funded as part of an NPL Fellows strategic research project. The possibility of a European EMPIR project, part of which would investigate applications of the technique over a range of masses, is being investigated.

The results of a collaboration between KRISS and NPL on the mechanical characteristics of knife edges was also published in the Special Issue of Metrologia (S114).

Since late 2013 NPL has been working with Derby University where, as part of their project work, students are constructing simple watt balances based upon a modified loudspeaker. This forms part of our work to promote the forthcoming redefinition of the SI.

BIPM extraordinary calibrations

Michael Stock gave a talk on the BIPM extraordinary calibrations with respect to the IPK. The objective of this work is to provide improved traceability to the IPK for NMIs involved in the determination of the Planck constant or the Avogadro constant. This measurement campaign has identified an offset of the “as-maintained’ BIPM mass scale (traceable to measurements against the IPK in 1992) with respect to the IPK in 2014. This is likely to have an impact on the measurements of the Planck constant that have already been made. BIPM will provide information on how to correct previous results to those NMIs concerned, before the CODATA deadline for accepting results for the 2015 fundamental constants adjustment. The findings will be published in a series of papers.

Gravimetry

As part of the CCM and WGG meetings held between the 23rd and the 27th February 2015 it was confirmed that the next ICAG will be held in 2017 with its dates to be confirmed. The key comparison ICAG 2017 will be organised by NIM at their Changping Campus.

Discussion on preparations for the redefinition of the kilogram

There was a discussion of the present state of the preparations for the redefinition of the kilogram. The uncorrected results up to August 2014 show reasonable agreement between high precision measurements of the Planck constant which paves the way for a redefinition in 2018.

At the CCM meetings in 2015 corrections for the recently discovered offset of the BIPM mass scale were available for the NRC, IAC, NIST and LNE results. A plot of results referenced to the IPK is shown in Figure 1 below. It can be seen that there is very good agreement between the NRC and IAC results and, although the NIST relative standard uncertainty is technically larger than the 5×10^{-8} required by the CCM, the difference is small - only 0.7×10^{-8} and results from the NIST-4 balance are expected with reduced uncertainties. Horst Bettin of PTB suggested that the IAC result for the Avogadro constant could be split into individual results from PTB and NMIJ which would provide two results with relative standard uncertainties of approximately 30×10^{-8} to meet the CCM conditions. This plus the expectation of further results from a number of laboratories, as discussed in the reports above, indicate that, in February 2015, the measurements needed to support the redefinition process are in a good state.

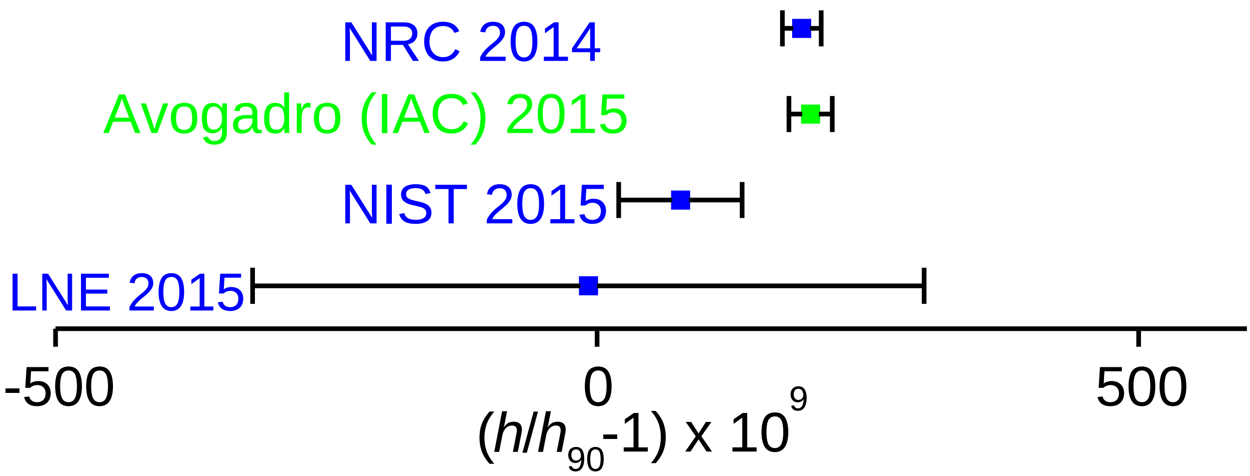

Figure 1- Recent measurements of the Planck constant

The roadmap for the redefinition of the kilogram indicates that, up to a deadline of the 1st July 2017, results of measurements of the Planck constant will be incorporated by CODATA into a calculation of the value of the constant which will be used in the new definition of the kilogram. Discussion at the CCM meeting in 2015 recommended that the CIPM clarify the requirements for results to be included in the CIPM sponsored CODATA calculations. The clarification has been made and requires that any results to be included by CODATA must either be published or accepted for publication by the 2017 deadline. This requirement is not as stringent as the original CCM request for results to be published by the deadline, but will still require that papers be submitted well in advance to allow for the refereeing process. In setting a date for submission of their paper, groups should verify the CIPM publication requirements and be aware that they may need to allow additional time for the publication process. This is could be caused both by the increased workload of specialist referees at this time and by the possibility of increased time spent correcting the papers as the referees will be looking to ensure the highest quality from papers that will affect the redefinition process.

In the discussions in the August meeting we considered ways of helping to ensure that the reported results, in the rather short and critical period up to the deadline in 2017 were of the quality expected. We recognised that this is always the aim of all the groups concerned but sometimes this process can be aided by extra support, or a second opinion, on an aspect of their work from a fellow NMI. We recognised that mutual assistance between NMIs is a natural aspect of their operation and the group agreed that the usual operation of this mechanism should provide sufficiently prompt help if it was requested.

Next Meeting

The next meeting is scheduled to be on Saturday 9th July 2016 at the CPEM 2016 conference in Ottawa Canada.

I A Robinson
8th April 2015