APMP Member Report 2021

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[National Physical Laboratory (NPL), UK

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Please submit this report to APMP-Secretariat@nim.ac.cn no later than 14 November 2021.

Section 1: General Managment

In February NPL published the results of of a Technology and Measurement Foresighting exercise which identifies major trends in the future of society and industry, analyses which technologies will be vital to enable them, and explores their implications on metrology. The results are available on our web-site https://www.npl.co.uk/foresighting.

Sir David Grant has ended his 6 year term as Chairman of the NPL Board and has been succeded by Prof. Graeme Reid (Professor of Science and Research Policy at University College London).

A consortium led by NPL has secured £22.6m funding to estabish an Advanced Machinery & Productivity Institute (AMPI), which will be based in Greater Manchester. The AMPI will stimulate and support the rapid growth of the UK's machinery manufacturing sector as it transitions to highly integrated digital solutions with sophisticated automated and autonomous robotic systems. This is part of NPL's strategy of widening its presence across the UK in order to former closer links with stakeholders.

Following the death of eminent NPL Scientist Martin Seah in June, the international surface analysis community is commemorating his life and contributions. A special issue of Surface and Interface Analysis (SIA) is currently being edited by NPL, which has attracted many contributions. SIA is the journal where many of Martin's seminal papers were published. International conferences, such as the American Vacuum Society are also planning special sessions next year.

Section 2: Technical Highlights

Mass

NPL's next-generation Kibble balance build is progressing well, and we will be delivering the balances to our collaboration partners next year.

We have also developed equipment for the dynamic measurement of rotational power. Initial work has been undertaken in collaboration with manufacturers and users of eSports equipment, but it is planned to look at applications for electric vehicles and green power generation.

Length

NPL (and other European labs) are making measurements of the HCN absorption spectrum in the 1550 nm regime, seeking to add this to the Mise en Pratique for the metre. NPL will use this as an in situ metre realisation in its frequency scanning interferometry system, being developed as an indoor equivalent to GNSS for factory volumes (tens of µm accuracy).

NPL's updated 633 nm iodine-stabilised computer-controlled metre realisation lasers are nearing completion. In-built computer control allows laser status and control across ethernet. Initially for use within NPL, we may commercialise the design shortly.

A new 10 m laser rail is being constructed for the testing of interferometers up to 10 m travel range.

NPL performed in situ measurements of critical dimensions in the engines used in the *BepiColombo* mission which is now approaching Mercury. The work is highlighted on the EURAMET website.

Following the formal international adoption of new secondary realisations of the metre based on the lattice parameter of silicon, NPL has co-authored two papers with European and American colleagues in order to support nanoscale dimensional measurements for nanotechnology. The papers are: The lattice parameter of silicon: a secondary realisation of the metre (https://iopscience.iop.org/issue/0957-0233/31/12) and Algorithms for using silicon steps for scanning probe microscope evaluation (https://doi.org/10.1088/1681-7575/ab9ad3).

NPL has completed a high-speed Atomic Force Microscope (AFM) which can scan a 4.5 µm x 4.5 µm region with an average speed of 8 mm/second and a 2 MHz data collection rate. The scan range can be extended to regions of several hundred micrometres using image stitching. https://dx.doi.org/10.1088/1361-6501/ab7ca9

NPL has co-authored a paper on the new *Mise en Pratique* for the metre – a review of approaches for the practical realization of traceable length metrology from 10^{-11} m to 10^{13} m, https://doi.org/10.1088/1681-7575/ac1456

Temperature

The NPL led EMPIR project Realising the Redefined kelvin is making good progress with regards trialling thermodynamic approaches to realising and disseminating the kelvin above 1300 K and below 25 K. Non-uniqueness studies of platinum resistance thermometers are robustly quantifying one of the remaining main sources of uncertainty in their calibration. New capability for traceable surface thermometry by phosphor thermometry has been developed and tested. Guides on body temperature measurement under the auspices of the CCT have been prepared and are available

from the CCT website. Significant developments in applying novel traceable thermometry methods to help with nuclear decommissioning challenges have been advanced in 2021 with the aim of deployment in the coming years.

Quantity of Material

A new CCQM task group has been launched to expand global accessibility to reference materials for underpinning long-term monitoring and emissions authentication of carbon dioxide in the atmosphere, with internal consistency of 0.01 µmol mol-1. The World Meterological Organisation's (WMO) carbon dioxide scale system enables the production and value assignment of gas reference materials with incredibly high precision. This high degree of consistency is essential for atmospheric monitoring applications where small temporal and spatial changes are important. The reported consistency between tertiary reference materials is of the order of 0.01 µmol mol-1, which is approximately a factor of 10 smaller than the standard uncertainties of reference materials with traceability to the SI. This relationship is maintained in a database, and the value of any reference material can be traced back to the primary set defining the scale. Changes in scale can then be propagated to all reference materials by the relationships contained in the database.

Setting up and evaluating a robust economic system based on the mitigation of carbon dioxide is expected to require multiple measurement sites around the world, including urban areas. This is expected to increase world-wide demand for appropriate carbon dioxide in air reference materials. The CCQM-GAWG chaired by Paul Brewer, is working towards meeting these requirements with this new task group which includes the WMO Central Calibration Laboratory, maintained at NOAA ESRL GML (USA) and National Metrology Institutes with relevant capabilities. Several NMIs, including NPL, are preparing to establish National and Regional scales with differences close to the internal consistencies currently achieved by the WMO. To minimise any potential biases between scales, equivalence equations will be maintained using CIPM MRA on-going key comparisons.

Materials Metrology

In a study recently published in Nanoscale (https://doi.org/10.1039/D1NR03361A), researchers from the Surface Technology group at NPL demonstrated the use of nuclear magnetic resonance (NMR) proton relaxation as a method for characterising the sonication assisted liquid phase exfoliation of graphene. This technique can indirectly estimate the graphene yield in a dispersion and the results showed strong correlations with existing standardised techniques.

A new state-of-the-art Mechanical Test Facility (MTF) confirms NPL as the UK's centre of excellence for materials assurance. The MTF is furnished with a comprehensive range of mechanical test equipment from NPL's partner Instron, to address the current, emerging and future requirements of research and industrial application. This facility, combined with NPL's extensive expertise in materials characterisation and assurance, provides a unique capability for research and commercial testing services covering a broad range of advanced materials such as composites, metals, ceramics, additive manufacturing and coatings. Additionally, digitalisation of the MTF ensures that NPL is at the forefront of materials data analytics and uncertainty analysis that can support virtual product assurance, enable variable fidelity simulation and innovative analysis processes. This digitalisation of the laboratory supports Industry 4.0 through the development of cyber-physical platforms to reduce the number of physical test iterations for materials assurance.

New results have been obtained in a collaboration with the University of Manchester on the wear and friction performance of ALM tool materials. The collaboration has resulted in a peer reviewed

paper that is being published in the journal Wear. A key feature of the work is the use of the unique NPL in situ (SEM) microtribometer which enabled the mechanisms of damage from simulated abrasion to be determined at high resolution and related to the microstructure of the material.

Accurate measurement and characterisation techniques help to ensure the reliable performance of photovoltaic products in the field, contributing towards the UK and worldwide Net Zero targets. An alternative approach for high resolution photocurrent imaging of photovoltaic devices has been introduced by NPL, that uses Digital Light Processing (DLP) technology combined with Compressed Sensing. Through this new compressive sampling and reconstruction procedure, a much higher resolution can be achieved than previous implementations of such imaging methods. The work has been a collaboration between NPL scientists from multiple groups, who developed the methodology and experimental setup, realised the measurements and developed the algorithms for the image reconstruction steps. The work was published as an invited paper in the Solar RRL journal (Wiley).

Section 3: CIPM MRA Related Matters

Mass

NPL coordinated the update of Mass CMCs to account for the transition to new definition of the SI unit of mass and the use of a consensus value for the kilogram.

NPL has also coordinated input on strategic research priorities for the CCM draft strategic plan.

Length

Two gauge block key (K1) comparisons are starting planning, one in EURAMET (likely piloted by NPL) and one at CCL level (likely NRC Canada piloting).

NPL is coordinating a small task group looking into digitalisation of the SI metre, meaning granting machine readable access to the critical information associated with metre realisations, such as the well-known 633 nm He-Ne laser. The idea is to allow automatic download, in machine readable format, of the data, such that this can be included automatically in digital calibration certificates.

Section 4: Future plans

Mass

Development of Kibble balance technology to maximise impact looking at point-of-need realisation of the SI and micro-Kibble balance technology and applications.

Application of rotational power measurement capability and development of next-generation mega-newton range hydraulic force machines.

Length

NPL is continuing to support Hexagon Metrology UK in their supply of commercial copies of the NPL Gauge Block Interferometer. NPL plans to start a major update of the control software in 2022 to allow ongoing support of the system with more modern software/computing.

NPL is building a new '1D machine' which is an automated length measuring system designed to measure 1D lengths including diameters (ring, plug), long gauge blocks, step gauges. A copy of the machine will be delivered to a research organisation in the UK and NPL plans to offer commercial copies of the machine.

Temperature

NPL is organising a joint Euramet-COOMET workshop at the end of April 2022 on "Realising the redefined kelvin: Turning the MeP-K into reality" to be held in conjunction with the Euramet TCT 2022 meeting. It may be possible for APMP NMIs to participate in this meeting as it is planned to be a hybrid event. Contact Graham Machin of NPL if you are interested in attending.

Materials

NPL, in collaboration with the Crick Institute, have won a Welcome Trust grant to demonstrate high resolution chemical imaging and reveal new insights into biological and metabolic processes. The aim of the research is to remove critical obstacles to the wide adoption of chemical imaging in biomedical and pharmaceutical research.