Bureau International des Poids et Mesures

Consultative Committee for Photometry and Radiometry (CCPR)

Report of the 21st meeting
(23–24 February 2012)
to the International Committee for Weights and Measures

Comité international des poids et mesures

Note:

Following a decision of the International Committee for Weights and Measures at its 92nd meeting (October 2003), reports of meetings of the Consultative Committees are now published only on the BIPM website and in the form presented here.

Full bilingual versions in French and English are no longer published.

M. Milton,

Director BIPM

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR PHOTOMETRY AND RADIOMETRY

as of 23 February 2012

President

Dr F. Hengstberger, member of the International Committee for Weights and Measures, GTMS (Pty), Pretoria.

Executive Secretary

Dr M. Stock, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Agency for Science, Technology and Research [A*STAR], Singapore

Centre for Metrology and Accreditation [MIKES], Espoo

Centro Nacional de Metrología [CENAM], Querétaro

Federal Institute of Metrology METAS [METAS], Bern-Wabern

Hungarian Trade Licensing Office [MKEH], Budapest

Institute for Optico-Physical Measurements, Rostekhregulirovaniye of Russia [VNIIOFI], Moscow

Instituto de Optica “Daza de Valdés” [IO-CSIC], Madrid

Istituto Nazionale di Ricerca Metrologica [INRIM], Turin

Korea Research Institute of Standards and Science [KRISS], Daejeon

Laboratoire National de Métrologie et d’Essais [LNE], Paris

Measurement Standards Laboratory of New Zealand [MSL], Lower Hutt

National Institute of Metrology [NIM], Beijing

National Institute of Standards and Technology [NIST], Gaithersburg

National Measurement Institute, Australia [NMIA], Lindfield

National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba

National Metrology Institute of South Africa [NMISA], Pretoria

National Metrology Institute of Turkey [UME], Gebze-Kocaeli

National Physical Laboratory [NPL], Teddington

National Research Council of Canada [NRC], Ottawa, Ontario

Physikalisch-Meteorologisches Observatorium Davos and World Radiation Center [PMOD/WRC], Davos Dorf

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig

Slovak Institute of Metrology/Slovenský Metrologický Ústav [SMU], Bratislava

VSL [VSL], Delft

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres

Observers

Commission internationale de l'éclairage [CIE], Wien

World Meteorological Organization [WMO]

1 OPENING OF THE MEETING, MEMBERS AND OBSERVERS PRESENT, INTRODUCTIONS

The Consultative Committee for Photometry and Radiometry (CCPR) held its 21st meeting at the International Bureau of Weights and Measures (BIPM) headquarters at Sèvres, France, on Thursday 23 February 2012 and Friday 24 February 2012.

The meeting was chaired by the CCPR President, Dr F. Hengstberger (CIPM member).

The following were present: P. Blattner (METAS), J. Campos Acosta (IO-CSIC), J. Dubard (LNE), N. Fox (NPL), X. Huang (A*STAR), E. Ikonen (MIKES), M. Kühne (Director, BIPM), D.H. Lee (KRISS), Y. Lin (NIM), P. Manson (NMIA, APMP), C. Matamoros (CENAM), N. Nel-Sakharova (NMISA, AFRIMETS), K. Nield (MSL), Y. Ohno (NIST), M.L. Rastello (INRIM), D. Sabol (SMU), F. Sametoglu (UME), V.I. Sapritsky (VNIIOFI), K. Stock (PTB), T. Zama (NMIJ/AIST), J. Zwinkels (NRC).

Experts from member institutes: J-R. Filtz (LNE), G.T. Fraser (NIST), T. Goodman (NPL), B. Khlevnoy (VNIIOFI), J. Lundeen (NRC-INMS), M. Nadal (NIST, SIM), K. Rochford (NIST), B. Rougié (LNE), W. Schmutz (PMOD, expert of METAS), A. Sperling (PTB), G. Ulm (PTB).

Observers: CIE was represented by P. Blattner (METAS, CIE Div.2 Director); WMO was represented by W. Schmutz (PMOD).

Guests: A.P. Alvarenga (INMETRO), M. Šmíd (CMI, EURAMET), T.J. Quinn (emeritus Director, BIPM), H.-L. Yu (CMS/ITRI).

Also attending the meeting: R. Goebel (BIPM), M. Stock (Executive Secretary of the CCPR, BIPM), C. Thomas (Co-ordinator of the KCDB, BIPM).

Apologies were received from: G. Andor (MKEH), A. Dalhuijsen (VSL).

The Director of the BIPM, Prof. Kühne, welcomed the attendees to the BIPM.

The President of the CCPR, Dr Hengstberger, opened the meeting and reminded the delegates that the technical work of the CCPR was mainly carried out within the working groups of the CCPR, and as such the reports of the Working Groups (WGs) should avoid too much technical content.

Dr Hengstberger invited the attendees to briefly introduce themselves.

2 APPOINTMENT OF THE RAPPORTEUR AND FINALIZATION OF THE AGENDA

Ms Nield was appointed as rapporteur for the meeting. The draft agenda (CCPR/12-02) had been distributed before the meeting and was accepted by the members with no additional items requested.

3 APPROVAL OF THE MINUTES AND MATTERS ARISING FROM THE MINUTES OF THE LAST MEETING

Dr M. Stock, BIPM, noted that the minutes of the previous meeting had been published on the BIPM website on 4 August 2010 and as such they had already been accepted. A minor revision had been made to these minutes in April 2011 which clarified the meaning of a sentence.

Agenda Item 2009/9 Report of the Working Group on Strategic Planning.

Action A1: WG-SP TG4 is to distribute to the full CCPR the final draft of the position paper "Radiometry, photometry and "the candela": evolution in the classical and quantum world" for information and comments, around February 2010.

This has been done.

Agenda Item 2009/11: Discussion on the proposed reformulation of the definition of the candela.

Action A2: The President will inform the CCU about the position of the CCPR with respect to the rewording of the candela definition in "explicit-constant form". He will indicate that the CCPR basically agrees with the proposal with slight modifications (lumen expressed as candela steradian and removal of the word "spectral"). He will confirm that the quantity of "luminous efficacy of radiation" is well established in the field of photometry. In respect to the subsequent sentences (explicit-unit definition) he will explain that the constant K_{cd} has been introduced, the subscript "cd" representing the candela. He will inform the CCU about the reason behind adding an additional subsequent sentence expressing the radiant intensity as photon intensity, both quantities being well established in the IEC/CIE International Lighting Vocabulary (ILV). He will indicate that not all members agree on the necessity to add the last sentence. He will ask the CCU to assist on the correct formulation of the unit of the quantity "photon intensity" (whether it should be "photons per second per steradian", "number of photons per second per steradian" or just "per second per steradian"). The President will distribute his letter to the CCU to the members of CCPR for information.

Dr Hengstberger submitted the improved text to the CCU with the main point that the CCPR would like to include photon intensity into the definition – this however was not a unanimous request of the whole CCPR. The CCU decided that they were not in favour of including photon intensity in the definition. There is a possibility that this information could be incorporated into the *mise en pratique* of the candela. The CCU accepted two other requests. (The CCPR reply to the CCU is included as an appendix to the CCPR 2012 minutes).

Agenda Item 2009/12: Future Working Group Structure of the CCPR.

Action A3: The President will inform the CIPM that different task groups are being formed within the CCPR according to the established CIPM rules. The task groups will, if necessary, ask advice from invited experts from competent institutions and organizations. The following

task groups were established: Few photon metrology (within WG-SP), fibre optics (WG-SP) and comparison analysis (WG-KC).

This was reported at the previous CIPM meeting. The needs of few photon metrology for optical communication and data analysis were noted.

Agenda Item 2009/15.2 CIE report.

Action 4: CCPR President to inform the CIE about the possible new form of the definition of the candela.

This has been done.

4 DOCUMENTS PRESENTED TO THE CCPR MEETING

The President submitted a list of five working documents to the meeting. The complete list of these working documents and those added after the meeting is given in Appendix 2. The documents are available on the restricted-access section of the CCPR web page.

No specific additional working documents were submitted to the meeting. However, Dr Zwinkels requested that the *CCPR WG-SP Membership Criteria* be added to the working documents (CCPR/12-06).

5 REPORT OF THE WORKING GROUP ON CALIBRATION AND MEASUREMENT CAPABILITIES (WG-CMC)

Dr Nel-Sakharova, chair of WG-CMC and AFRIMETS representative, presented the report of the WG-CMC.

The working group met on 21 February 2012 at the BIPM headquarters. The meeting was chaired by Dr Nel-Sakharova. Members from AFRIMETS, APMP, COOMET, EURAMET and SIM were present plus 23 observers.

Dr Nel-Sakharova reported that Revision No. 11, draft 1 of the CCPR classification of services, had been approved at the meeting. Changes to this document included: 3.5 radiant flux, spectral (3.5.0 - General source, 3.5.1 – Tungsten lamp) and 5.8 radiant flux, total (5.8.0 – General source, 5.8.1 – LED). In addition, it was also decided at the WG-CMC meeting to include in Revision 11 service 2.7 Responsivity, solar, irradiance (2.7.1 - Broadband detector).

Also presented at WG-CMC were new service categories for:

- 4.17 Refractive index, spectral
    - 4.17.1 Solid material
    - 4.17.2 Liquid material
- 4.18 Angle of plane of polarization, spectral
    - 4.18.1 Solid material
    - 4.18.2 Liquid material
- 4.19 Ellipsometric angles Ψ, Δ, spectral
    - 4.19.1 General material.

Refractive index has been listed within the CCL for the past 10 years, however it was noted that there was only one CMC listed. It was proposed that the CCPR would have duplicate service categories for these quantities. It was further noted that because COOMET is conducting a supplementary comparison on refractive index (COOMET.PR-S3) under the CCPR, there would be an application for this CMC on the conclusion of the comparison.

Dr Nel-Sakharova presented details of the discussion on supporting evidence for CMCs where comparison results have been delayed. She reported that two proposals had been made on this issue:

- The earliest draft key comparison report that may be submitted as supporting evidence for a CMC will be the Draft B report of that comparison.
- NMIs not participating in a comparison would have their affected CMCs greyed out and would have up to five years to undertake a comparison in support of these CMCs. Should the CMC be consistent with the comparison result, the CMCs could be re-instated without a review.

Both proposals were approved by the CCPR.

Dr Nel-Sakharova reported that the procedure for monitoring the impact of key comparisons on published CMCs in document CIPM MRA-D-05 needs to be followed up. In particular RMO TCPR chairs need to ensure that this consistency checking procedure is implemented within their RMO. Implementation of this procedure will be reported at the next CCPR WG-CMC meeting.

On the topic of CMCs for refractive index, Prof. Kühne noted that if the CCPR wished to have these duplicate service categories it is important that there should be agreement between the CCL and the CCPR on the placement of these service categories, to avoid having the same quantities in the service category lists of several fields. Prof. Kühne noted as an action that the CCPR and the CCL should agree on the location of these service categories.

Dr Hengstberger commented that a similar situation already exists in, for example, wavelength where the CCL had much lower uncertainty requirements for this service category, so that in this context the users knew which CC to approach for the submission and review of the CMCs.

Dr Hengstberger agreed that there is a grey area for some service categories. The CCPR and the CCL have already had some agreement on this in the past and to date there is only one CMC

listed under the CCL service category, whereas there is more activity in the CCPR than in the CCL. The CIPM had accepted that separate entries would be possible.

Prof. Kühne asked Dr Thomas for her advice on this issue. Dr Thomas reported that there is only one CMC on refractive index in the field of the CCL from Poland and she asked if the CCPR uncertainty for this quantity differed from the uncertainty obtained by the CCL. Dr Nel-Sakharova commented that a difference existed for wavelength but not for refractive index where the uncertainties and requirements were the same but the user groups are quite different.

Dr Thomas said that separate entries would not present a problem to the KCBD but the terminology needs to be harmonized: currently it is reported as “index of refraction” and also “refractive index”. Prof. Kühne replied that in order to avoid duplicate effort there should be agreement on a single location for these service categories. Dr Hengstberger commented that there was currently no clear rule on this matter and that he would discuss the situation with the CCL President.

AP 1 Dr Hengstberger will discuss with the CCL President the best location for refractive index and related CMCs and report back to the CCPR.

6 REPORT OF THE WORKING GROUP ON KEY COMPARISONS (WG-KC)

Dr Ohno presented this report and noted that the WG-KC has met three times since 2009: at the NPL, Teddington, UK, in July 2010; at the Newrad 2011 conference in Maui, Hawaii, in September 2011; and at the BIPM headquarters on 22 February 2012.

All members were present at the meeting held on the 22 February 2012. There are currently 8 permanent members and one temporary member; MSL, the pilot laboratory of CCPR-K6.2010. As the other comparison pilot laboratories are already WG-KC members there will be no new additional temporary members.

6.1 Status of ongoing CCPR key comparisons

Two comparisons from the first round of comparisons are still in progress and one of the second round is already under way.

CCPR-K2.c – Spectral responsivity 200 nm to 400 nm (PTB, contact: Dr Werner).

This comparison used three different types of detectors (PtSi-n-Si and Si photodiodes and Si traps). There have been some issues with the analysis of this comparison, in particular the consistency check. The CCPR uses the weighted mean with cut-off by default and in this case the consistency is not good. At the meeting of the WG-KC in 2010 it was agreed to use the Mandel–Paule method together with the Chi-squared test after visual outlier rejection. The temporal drift of the detectors, as determined by the pilot, also needs to be taken into account.

The pilot was asked to prepare a proposal on the rejection of outliers. The Draft A report for this comparison should be issued soon.

CCPR-K5 – Spectral diffuse reflectance (NIST, contact: Dr Ohno)

Draft B for this comparison is under review for approval by WG-KC.

CCPR-K6.2010 – Spectral regular transmittance (MSL, contact: Dr Koo)

The second round of comparison K6 is currently under way. This comparison is experiencing difficulties because the filters prepared by MSL are still stabilizing (particularly the 50 % and 10 % transmitting filters). Monitoring will continue for another three months. The comparison measurements are expected to start in November or December 2012.

CCPR-K3.20XX – Luminous intensity (NRC, contact: Dr Gaertner)

The technical protocol is under development and artefact selection is under way.

CCPR-K4.20XX - Luminous flux (NMIJ, contact: to be appointed)

The technical protocol is being developed. There is an issue with artefact selection as Polaron lamps are no longer commercially available. However, a stock of older Polaron lamps, which could be used, should exist at several NMIs.

CCPR-K2b.20XX – Spectral responsivity 300 nm - 1000 nm (KRISS, contact: Dr Lee)

The call for participants closed on 31 January 2012 and 16 laboratories applied: KRISS (pilot), A*STAR, CENAM, IO-CSIC, LNE, MSL, NIM, NIST, NMIA, NMIJ, NMISA, NPL, NRC, PTB, UME, VNIIOFI, VSL. Since the number of candidates exceeded 12, a selection process will be carried out. A request to select participants will be sent to each RMO TCPR chair.

CCPR-K2a.20XX – Spectral responsivity 900 nm – 1600 nm (NPL, contact: to be appointed)

The call for participants was completed on 22 February 2012 and 12 laboratories applied: NPL (pilot) A*STAR, IO-CSIC, LNE, NIM, NIST, NMIA, NMIJ, NMISA, NRC, PTB, VNIIOFI. No selection process will be required.

Dr Hengstberger noted the CIPM view that no laboratory should be penalized from non-selection for the CIPM loop. For example, should a laboratory need to improve its CMC beyond the uncertainty achievable in the RMO loop, this would be a strong argument for them to be involved in the CIPM loop.

Dr Thomas asked for details of the K5 comparison, in particular the format of the data, because a significant amount of work will be required to publish it in the KCDB. For some areas, such as ionizing radiation, only the unilateral degrees of equivalence are published.

Dr Hengstberger said that the CCPR had already adopted the same policy. Dr Ohno commented that this had already been implemented in the CCPR reporting guidelines.

6.2 Task Groups

WG-KC has three task groups:

Pilot comparison of spectral transmittance in the UV, chair Dr Nel-Sakharova (NMISA).

Investigation into materials to be used as artefacts has started. Spectral transmittance in the UV could, in the future, become a regular KC.

RMO linkage, chair: Dr Woolliams (NPL)

Key comparison reports should include all information that would be required for linking. Dr Woolliams proposed that this requirement be added to the guidelines for publication – G2 (CCPR KC Report Preparation).

Comparison analysis, chair: Dr Woolliams (NPL)

A workshop was held on comparison analysis at the NPL in 2010. Dr Woolliams proposed the development of guidelines on implementing the least squares approach (LSA) method for comparison analysis.

Dr Koo, Dr Clare and Dr White (MSL) submitted a document on the LSA to the WG-KC meeting. The MSL is developing software to carry out this analysis. This program will be used for the data analysis of CCPR-K6.2010, but will be generic enough to serve as a basis for a future comparison analysis toolbox. There is a strong need to demonstrate to the community that the LSA will produce the same result as the step-by-step method.

6.3 Schedule of the second round of comparisons

Dr Ohno presented the current schedule for the second (current) round of comparisons.

Start Date	KC ID	Quantity	Pilot
2012	K6.2010	Regular spectral transmittance	MSL
2012	K3	Luminous intensity	NRC
2012	K4	Luminous flux	NMIJ
2013	K2.b	Spectral responsivity 300 nm to 1000 nm	KRISS
2013	K2.a	Spectral responsivity 900 nm to 1600 nm	NPL
2014	K1.a	Spectral irradiance 250 nm to 2500 nm	NMIA
2015	K5	Spectral diffuse reflectance	MIKES
2016	K1.b	Spectral irradiance 200 nm to 350 nm	NIST
2017	K2.c	Spectral responsivity 200 nm to 400 nm	PTB
2019	K2.d	Spectral responsivity 10 nm to 200 nm	PTB

6.4 Guidelines

The WG-KC has seven guidelines under development or published:

CCPR-G1 Guidelines for membership of WG-KC (September 2009)

CCPR-G2 Guidelines for CCPR KC Report Preparation Rev 3 (published: Rev.2 September 2009)

CCPR-G3 Guidelines for acceptance of CCPR KC participants (September 2009)

CCPR-G4 Guidelines for preparing CCPR KCs (Draft 2.0)

CCPR-G5 Guidelines for CCPR and RMO bilateral KCs (Draft 3.1)

CCPR-G6 Guidelines for RMO PR KCs (Draft 2.2)

CCPR-G7 Guidelines for Supplementary Comparisons (Draft 1.1)

These guidelines are developed in co-operation with the RMO TC chairs.

Dr Quinn asked about the use of LSA in the comparison analysis and if the approach used is similar to that of CODATA. In the field of fundamental constants it has been observed that care is needed in the rejection of supposed outliers, because the outliers may in fact be correct. Therefore, if necessary, the uncertainties are adjusted until all data are included.

The use of LSA in CCPR-G2 also leads to the weighted-mean with cut-off after the removal of "obvious" outliers. It is hoped that the method will be easier to implement than the step-by-step analysis.

Dr Fox noted that LSA was used in the previous CCPR-K1a, and that the increase in uncertainty was due to artefact instability – that in this case, there was a physical explanation for the increase in the uncertainty.

Dr Hengstberger clarified that the weighted mean with cut-off had to do with the maximum weight that any laboratory could have in the calculation of the KCRV and was not a means for removing outliers.

Dr Ohno presented the most recent version of CCPR-G2 (rev. 3, draft 2) for approval. This document is now limited to CCPR key comparisons with an additional guide being produced for RMO comparisons (CCPR-G6). There is a new section 4 in the G2 document. This describes the process to identify outliers and the consistency check. At the WG-KC meeting on 22 February 2012 it was decided to implement the Chi squared test in place of the Birge ratio as the latter test was stricter. An additional clause in section 7 of G2 has been added to direct the pilot to request that participants check the consistency of their CMCs against their KC result when the reporting process has been completed.

A section 6 has been added to the Appendix of G2 which outlines the Chi-squared consistency check. Dr Lin (NIM) commented that this and the Birge ratio were in fact equivalent and that there should be a choice as to which was implemented. He gave a brief presentation on the equivalence of Birge ratio and Chi-squared showing that if consideration is given to the number of participants in the comparison then these two tests become equivalent. Dr Ohno replied that if this was true then the current choice was still acceptable but that this equivalence should be investigated further by the task group on comparison analysis.

AP2: TG for comparison analysis to investigate the relationship between Birge ratio and chi-squared.

Dr Ohno requested approval for the publication of CCPR-G2. Dr Hengstberger requested that any concerns be presented – there were none and the document was approved.

AP3: Dr Ohno to proceed to a final check of CCPR-G2 Rev. 3 and publication on the CCPR website.

Guidelines 4 and 5 concern CIPM and RMO comparison preparation. Approval for publishing these documents will be requested by email.

AP4: CCPR-G4 and CCPR-G5 to be reviewed by WG-KC and to be submitted to CCPR for approval for publication by email.

6.5 Schedule for the next CCPR WG-KC meeting

It was proposed that the next meeting of the WG-KC will be in conjunction with the CIE mid-term meeting to be held in Paris on 12 to 19 April 2013.

Dr Hengstberger indicated that because the next CCPR meeting will be held in 2014, it is important that all WGs meet at the same time at the BIPM in 2013 and requested that this be considered by the BIPM.

Prof. Kühne noted that from 12 to 19 April 2013 the CCQM is scheduled to hold meetings at the BIPM headquarters, so this would not be a convenient time. Dr M. Stock clarified that the request was for either before or after the CIE meeting. Dr Goodman commented that due to the CIE timetable, the following week would be better and that 22 to 23 April 2013 would be the best option. Availability would be checked and these dates confirmed.

AP5: Availability of BIPM for WG-KC and WG-SP meetings 22 to 23 April 2013 to be confirmed (Dr M. Stock).

7 REPORT OF THE WORKING GROUP ON STRATEGIC PLANNING (WG-SP)

The WG-SP was established in 2005 and the first meeting held in 2006. The WG-SP currently has 12 NMI members (INRIM, KRISS, LNE, METAS, MSL, NIST, NMIJ, NMISA, NMI-VSL, NPL, NRC, PTB) and two *ex-officio* members (Dr M. Stock – Executive Secretary of the CCPR and Dr Hengstberger – President of the CCPR).

The WG-SP has established eight task groups, of which TG1, Terms of Reference, and TG3, CCPR Structure, were dissolved at the previous CCPR meeting in 2009. Dr Zwinkels outlined the status of the remaining six TGs.

TG2: WG-SP Membership Criteria, chair: Dr Blattner (METAS)

Version 1.3a of the criteria document has been prepared and approved by TG2 and the WG-SP. It has been submitted to the CCPR for approval.

TG4: SI, chair: Dr Rastello (INRIM)

The TG prepared a position paper on the possible reformulation of the candela which was published in *Metrologia*, 2012, **47**, R15–R32. Following publication Dr Rastello, the TG Chair, has been reviewing the reasons given by the CCU for the rejection of the photon being used as a unit in the CCPR proposed explanatory text for the candela definition. This feedback had been distributed to the WG-SP for a possible response.

The rejected text was:

"Thus we have the exact relation K_{cd} = 683 lm/W. The effect of this definition is that the candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watts per steradian. This radiant intensity corresponds to a photon intensity of $(683 \times 540 \times 10^{12} \times 6.626\,068\,96 \times 10^{-34})^{-1}$ photons per second per steradian."

Dr Rastello commented that there were two arguments supporting this rejection:

1. The above sentence does not bring any supplementary information. The CCPR needs to look in more detail on the effects of expressing K_{cd} not in lumen per watt but lumen/photon/s.
2. The photon is not a unit but an entity. Within the SI brochure when talking about an entity the unit is 1. Dr Bastie (LNE) said that the photon is a "special" entity in that a photon carries an energy related to the frequency associated with it.

Dr Quinn, who had attended the CCU meeting, commented further that the document received from the CCPR made it very clear that there were different opinions within the CCPR with respect to the recommended phrase and, therefore, the CCU felt that this issue needed to be resolved more fully within the CCPR before re-submission to the CCU. It was noted that the contents of the SI brochure require full agreement from within the CCPR. Further discussion of this question within the CCPR is necessary before going back to the CCU.

TG5: *Mise en pratique*, chair: Dr Ohno (NIST)

The TG organized a workshop on the *mep* for the candela on 22 February 2012 with 31 attendees, including four invited CIE experts. An outcome of this workshop was the recommendation to the CCPR that a joint CCPR/CIE task group be formed to prepare an updated and comprehensive joint publication on "Principles Governing Photometry". Decisions are to be made on how best to proceed with the preparation of the *mep* for the candela.

TG6: Discussion forum on fibre optics, chair: Dr Dubard (LNE)

A workshop on 'fibre optic metrology needs' was held at the NPL in 2010. A new TG (TG9) was created at the workshop, chaired by Dr Morel (METAS), to deal with the subject of optical time-domain reflectometry (OTDR). This TG will undertake the development of a technical protocol for a comparison of OTDR length in order to underpin CMCs.

There has not been an opportunity to arrange an additional workshop since the first workshop in 2010.

It was noted that in the IEC there is a TC86 (WG4 of TC86, "Test and measurement methods") which covers the subject of this TG. Dr Nel-Sakharova and Dr Dubard attended national standards meetings which discussed this topic. There are already some comparisons under way for these quantities in EURAMET.

Dr Hengstberger noted that in many NMIs the fibre optics group is not in the same group as the photometric and radiometric fields; this creates some gaps in the interactions between these fields. It is encouraging that this task group is working towards closing the gap. Dr Hengstberger

encouraged the TG to recognize how important the CCPR regards this link and to make proposals (such as the proposals made in UV radiometry) to form a new WG so that this area could be treated fully within the context of the CCPR.

TG7: Discussion forum on few photon metrology, chair: Dr Lee (KRISS)

A special session "Few Photon Metrology", at which eight presentations were made on this topic, was held at the Newrad 2011 conference, Maui, Hawaii, on 19 to 23 September 2011. An online forum has been created for this community.

TG8: Discussion forum on THz metrology, chair Dr Rochford (NIST, Boulder)

The CCEM had nominated a liaison person, Dr Anderson (NIST, chair of CCEM WG-SP), who is no longer available for the task. Dr Olthoff (NIST) will replace him temporarily, until the next CCEM meeting in March 2013.

A survey was undertaken of NMI capabilities and traceability needs as part of the CCPR 2012 questionnaire. The possibility of a formal THz comparison at 2.5 THz (PTB, NIST, and others) is being investigated.

7.1 Priority Goals for WG-SP during 2012 to 2014

Dr Zwinkels reported on and listed the following priorities for the WG-SP during 2012 to 2014.

- Establish one or more joint CCPR-CIE task group(s) to:
    - Prepare an updated and comprehensive publication on "Principles Governing Photometry", including all photometric quantities and CIE photopic, scotopic and mesopic functions.
    - Possibly prepare recommendations on photobiological and photochemical quantities and units.
- Advance the aims of the current discussion forums by creating new technical-based WGs and by organizing workshops in support of these activities.
- Complete the *mise en pratique* for the definition of the candela.

Dr Hengstberger noted that the discussion forum on fibre optics is an area almost mature enough to form into a WG.

7.2 Recommendations to the CCPR 2012

Dr Zwinkels outlined the following recommendations.

REC 1: Approve WG-SP membership criteria (V1.3a) **CCPR/12-06**, which has been fully agreed upon within WG-SP.

Dr Zwinkels outlined the membership rules to the meeting. Dr Hengstberger invited comments or concerns from the members – there were none. There were no objections or abstentions to approving this document.

AP6: WG-SP membership criteria v1.3a will become CCPR-G8 and will be published on the CCPR website.

REC 2: If REC 1 is accepted then WG-SP TG2 should be dissolved.

This was agreed by the meeting.

REC 3: Change of terms of reference and chairmanship of TG5. The terms of reference are to be modified to prepare a concise (1-3 pages) *mise en pratique* for the definition of the candela that references the joint CIPM/CIE publication "Principles governing Photometry". The Chairmanship is to be changed from Yoshi Ohno (NIST) to Joanne Zwinkels (NRC).

This change was agreed at the meeting.

AP7: Dr Ohno and Dr Zwinkels to propose modified terms of reference and to coordinate the work on the *mise en pratique* for the definition of the candela (1-3 pages) with the work of updating the document on "Principles Governing Photometry".

REC 4: To create a joint CCPR-CIE task group to develop a joint CIPM/CIE publication "Principles Governing Photometry".

Dr Hengstberger commented on the current 1983 BIPM document and suggested that it would seem impractical that two essentially identical documents, one published by each organization, are available. It was noted that the document would be made freely available on the BIPM website but for a fee on the CIE website. This is a common practice for other similar documents as, for example, CIPM/ISO guides. In conclusion, this document will make a very useful reference document for the photometry community.

Prof. Kühne asked for details of the document and the timeline for availability for uploading to the BIPM website. Dr Hengstberger replied that it would take up to 2 years and the document would be 20 pages in length. The publication will be available in both English and French and will incorporate mesopic photometry – therefore covering the full range of visual photometry. The related CIE standard will be available in about one year, in 2013. Dr Zwinkels added that other CIE publications would be referenced in the document.

Dr Hengstberger stated that the CIE was recognized as the International Standardization body for light and lighting, so the document currently under discussion would itself become an international standard. Dr Ohno noted that the document will not cover the reformulation of the definition of the candela. Prof. Kühne noted that the next opportunity to revise the definition of the candela will be in 2014. It was recommended that work on the document should proceed in two steps: the first to include the mesopic functions, followed by the new formulation of the candela definition. Dr Goodman said the document will be available for download and would therefore be easy to revise, if needed.

Dr Hengstberger asked if there were any objections to the formation of a joint CCPR/CIE task group, there were none. The creation of the TG was approved.

AP8: Joint TG of the CCPR /CIE be formed, chaired by Dr Ohno, to produce a revised publication on "Principles governing photometry".

8 UPDATE ON THE EXPECTED CHANGES OF THE INTERNATIONAL SYSTEM OF UNITS, THE SI

Dr M. Stock gave a presentation on the current status of the preparations for the new SI.

Currently there are three units which are defined based upon fundamental constants or reference constants (the metre – c, the ampere – μ_0, and the candela – K_{cd}), three on material properties (the second – ^{133}Cs, the kelvin – H_2O, and the mole – ^{12}C), and one on an artefact – the kilogram. The new SI would have six definitions based on fundamental constants and only the second based upon material properties. Definitions based on potentially unstable material artefacts would no longer exist. The new SI would have strong interdependence between the definitions, similar to the present SI.

Dr Hengstberger commented on the definition of the second, stating that it might be redefined in the distant future based upon another fundamental constant, the Rydberg constant.

The current draft chapter 2 of the future SI brochure states that the SI is the system of units scaled so that:

- the ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ is exactly 9 192 631 770 hertz, Hz,
- the speed of light in vacuum c is exactly 299 792 458 metre per second, m s^{-1},
- the Planck constant h is exactly 6.626 06X × 10^{-34} joule second, J s,
- the elementary charge e is exactly 1.602 17X × 10^{-19} coulomb, C,
- the Boltzmann constant k is exactly 1.380 65X × 10^{-23} joule per kelvin, J K^{-1},
- the Avogadro constant N_{A} is exactly 6.022 14X × 10^{23} reciprocal mole, mol^{-1},
- the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 × 10^{12} hertz is exactly 683 lumen per watt, lm W^{-1}

The symbol X represents the digits to be added at the time when these revised definitions are adopted.

This is considered very elegant with the distinction between base units and derived units no longer necessary. However, the concept of base units will be kept, with the base units defined in explicit constant form.

There will be a re-formulation (not re-definition) of the candela to bring it into explicit constant form plus explanatory text following this definition. The proposed re-formulation is as follows:

"The candela, cd, is the unit of luminous intensity in a given direction; its magnitude is set by fixing the numerical value of the luminous efficacy of monochromatic radiation of frequency 540 × 10^{12} Hz to be equal to exactly 683 when it is expressed in the unit s^3 m^{-2} kg^{-1} cd sr or cd sr W^{-1}, which is equal to lm W^{-1}."

Following requests from the CCPR, this is a slight modification from the previous definition in that the word "spectral" has been removed and replacing "lumen, lm" with "candela steradian, cd sr", so that the full dimension is now written using the base units. The use of photon intensity is not incorporated into either the definition or the explanatory text at this stage.

Dr M. Stock presented the currently available data for the Planck constant, which includes one measurement based upon the 2007 result of the NIST watt balance, with an uncertainty of 3.6 × 10^{-8}, and the outcome of measurements using the enriched silicon spheres, published in 2011, with an uncertainty of 3.0 × 10^{-8}. When considered as determinations of h, they differ by about 18 × 10^{-8}, which is significantly larger than the combined uncertainty.

Dr M. Stock presented an update on the watt balance experiments that are currently in operation. He reported that the NRC had applied a correction which had not been applied while the apparatus had been operated by the NPL. He noted that the CCM had requested that prior to the redefinition of the kilogram, three experimental results should be available for the Planck constant with uncertainties below 5 × 10^{-8} and determined by at least two different methods. The results should be consistent to within a few parts in 10^8, which is significantly less than the current spread in the data. There might be more data on the Planck constant from other experiments by 2014, the year of the next General Conference on Weights and Measures, but

this timeline is very tight. If experimental progress is slow, the CCM might change its requirements, but this is unlikely.

On the topic of the definition of the candela, Dr Quinn commented that when the present definition was formed it was initially proposed to define the lumen not the candela as the base unit. The candela was chosen because the CIPM felt it would be too difficult to change the base unit from the candela to the lumen at that time. Dr Quinn asked if it is now the time to do this? This decision would be up to the CCPR to propose. Prof. Kühne commented that this could be confusing as the CCU would ask why this change had not been proposed previously. Dr M. Stock highlighted parallels with the ampere and the coulomb and that changes to base units could cause confusion. This also seems to be a question of secondary importance in the new SI since the distinction between base and derived units will lose importance. This topic will be considered in internal discussions within the CCPR Task Group on the SI (TG4).

9 REPORTS BY RMO TC CHAIRS

AFRIMETS: Dr Nel-Sakharova presented the report for AFRIMETS.

There are six sub-regional groups within AFRIMETS:

- CEMACMET: Cameroon, Central African Republic, Chad, Equatorial-Guinea, Gabon, Republic of Congo
- EAMET: Kenya, Uganda, Rwanda, Burundi
- MAGMET: Algeria, Morocco, Tunisia, Mauritania
- SADCMET-MEL: Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe
- SOAMET: Benin, Burkina-Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, Togo
- NEWMET: Egypt, Ethiopia, Ghana, Libya, Nigeria, Sudan; with Sudan and Libya joining since 2011.

AFRIMETS has 5 technical committees:

- TC1: TC 1A – Metre convention affairs, TC 1B – OIML Issues
- TC2: TC 2A – S&I metrology education, TC 2B – Legal metrology education
- TC3 – Metrology infrastructure
- TC4: TC 4A – S&I metrology legislation, TC 4B Legal metrology legislation
- TC5 – Metrology awareness.

AFRIMETS has a working group for photometry and radiometry, WG-PR, the members of which are KEBS (Kenya, EAMET), NIS (Egypt, NEWMET) and NMISA (South Africa, SADCMET). The WG-PR is chaired by Dr Nel-Sakharova.

AFRIMETS is running five comparisons; one of these is a PR comparison for luminous intensity which will be linked to the previous round of CCPR-K3.a. The protocol has been submitted to the CCPR WG-KC. In addition, there is one planned comparison for luminous flux which will be linked to the previous round of CCPR-K4.

APMP

Dr Manson (NMIA) presented the activities of APMP on behalf of Dr Kim (KRISS). The APMP TCPR has Members from 23 economies within the Asia-Pacific region and 2 Associate Members (NMISA, South Africa and KazInMetr, Kazakhstan).

There have been three APMP TCPR meetings since 2009 at which 13 to 15 NMIs have participated. Technical workshops were held in association with both the 2010 and 2011 meetings covering the topics of:

- 2010 - Precision measurements and new applications in photometry and radiometry
- 2011 - APMP TCPR comparison reports and key developing issues of economies in the TCPR.

Five APMP TCPR guidelines have been prepared which handle the CMC and key comparison processes and the selection of APMP participants in CCPR comparisons. These guidelines run in parallel with their equivalent CCPR guidelines.

Dr Manson noted that five NMIs have had their CMCs reviewed, leading to an increase of 41 CMCs. He noted that the APMP TCPR had reviewed the CMCs of 18 NMIs from three RMOs.

Dr Manson noted that two key and supplementary comparisons have been completed and that there are another 15 key, supplementary or pilot comparisons which are either ongoing or planned. He commented that due to large artefact drift in APMP.PR-S2 (fibre optic power responsivity) a reference value could not initially be calculated; this drift has now been checked and the draft A report is in preparation. In addition, APMP.PR-K3.b (illuminance responsivity) has been cancelled as a consequence of the CCPR decision to use lamps in the 2nd round CCPR-K3.

COOMET

Dr Khlevnoy presented the activities of COOMET. There are six ongoing comparisons of which luminous intensity is a key comparison and the remaining five are supplementary comparisons. In addition there are planned comparisons for: spectral irradiance (key comparison, bilateral), surface colour (supplementary, 3 NMIs), transmitted colour (supplementary, 3 NMIs).

With regards to the supplementary comparison for refractive index there are participants from APMP and EURAMET as well as COOMET. Dr Khlevnoy commented that the request for this supplementary comparison had come from the photometry and radiometry community, not the length metrology groups. Although the measurement deals with angle, in the main it is perceived

as an optical property of materials and suggested that the best place for the service category to be held is within the area of PR CMCs. He further questioned where the CCL would find reviewers for CMCs if they were to oversee this? Dr Hengstberger noted that he had already accepted the action item (AP1) to discuss this with the President of the CCL, and that duplication of service categories should be avoided.

Prof. Kühne noted that there was a commercial company participating in the angle of rotation comparison and asked what was the background to this situation? Dr Khlevnoy commented that this had been at the recommendation of PTB due to the participating company's expertise; however its result will not be included in the final report - it is simply participating for scientific merit. Dr Hengstberger noted that this was similar to the situation for comparisons within the CCQM.

Dr Fox commented on the precedent that this might set and that such inclusions should be approached with caution. Prof. Kühne further stated that this might lower confidence in the NMIs and also be considered as an endorsement for the commercial company.

Dr K. Stock noted that there would be no mention of the company in the report. Dr Khlevnoy clarified that the company did not participate in the comparison at the same level but contributed the equipment and artefact used in the comparison. Prof. Kühne noted that the comment about the CCQM applied mainly to pilot studies. Dr Fox added that a company should not be included in the participant list if it only gave advice. Dr K. Stock confirmed that the company concerned is not listed in the technical protocol. The warning was noted that such inclusion could be used for commercial advantage.

EURAMET

Dr Šmíd presented the activities of EURAMET. He outlined the status of comparisons since 2009: 2 planned, 1 in progress, 2 measurements completed, 1 in pre-draft A, 2 draft A, 2 draft B in circulation and 3 results published. He noted that two sets of EURAMET CMCs had been submitted for inter-regional review since 2009; these had now been revised and published. In addition, EURAMET had reviewed the CMCs for APMP, SIM and COOMET in both 2010 and 2011.

Dr Šmíd outlined the 29 projects of the EURAMET TCPR. These activities cover traceability, comparison, co-operation and consultation. He continued by detailing the European Metrology Research Programme (EMRP), which has evolved from the iMERA programme of 2005. Dr Šmíd gave an overview of the development of this programme and the outcome of the recent call cycles. One call has been made per year since 2009. Dr Šmíd gave an overview of TCPR related projects which were successful in the 2010 call and which are currently active, these being:

- ENV03 – Traceability for surface spectral solar ultraviolet radiation (Solar UV)
- ENV04 – Metrology for Earth observation and climate (MetEOC)
- IND06 – Metrology for industrial quantum technologies (MIQC).

Dr Manson, NMIA, asked about participation of RMOs in EURAMET comparisons and the size of EURAMET and COOMET. Dr Manson also enquired if the EURAMET region has a policy to restrict access to regional comparisons? Dr Šmíd replied that there is no such policy as this is the only way to link the whole region to the CIPM comparisons, but the consequence is that

EURAMET has to co-ordinate large regional key comparisons. Dr Fox added that one of the mechanisms EURAMET is investigating to reduce the burden is the use of double-loop processes with multiple pilot laboratories. Dr Šmíd stated that this had been already done in one comparison and it was not yet clear if this was the most efficient method. Dr Blattner commented that to-date the subscription to comparisons had not been an issue. Dr Hengstberger commented that different RMOs will need flexibility to handle participation in RMO key comparisons depending on the circumstance.

SIM

Dr Nadal presented the activities within SIM. There are currently six members of the SIM TCPR: CENAM (Mexico), NRC (Canada), INTI (Argentina), INMETRO (Brazil), NIST (Boulder) and NIST (Gaithersburg).

Within SIM there is one ongoing comparison, SIM-PR.K4 (luminous flux), and three planned comparisons: SIM-PR.K6 (spectral regular transmittance), SIM-PR.K3 (luminous intensity) and SIM-PR.Sx.1 (bilateral between NIST and INMETRO for cryogenic radiometers via trap detectors to link to CCPR-S3).

Dr Nadal outlined SIM's current work to develop guidelines for selection criteria for participating in CCPR comparisons. Dr Hengstberger asked if the selection criteria could be detailed. Dr Ohno reported that the following were considered in the selection process:

1. Member of CCPR

2. Willing to serve as a regional link

3. Independent realization of the unit or scale

4. Consideration of participant measurement capability

5. If the NMI is the pilot then it is automatically a participant.

Dr Hengstberger commented that the RMOs could benefit from reviewing each others guidelines for this process. Dr Nadal enquired about the route for a NMI that wanted to improve its CMCs? Obviously the laboratories capable of achieving the smallest uncertainties should be selected to participate in CCPR key comparisons. However, could there be the case that a laboratory wanting to improve its claim should have consideration for key comparison participation? Dr Fox commented that it would only be the case if a NMI wanted to claim something significantly better than other participants.

10 REVIEW OF PROGRESS MADE BY CCPR MEMBER LABORATORIES SINCE ITS 20TH MEETING

Dr Hengstberger noted that the VNIIOFI report was to be added to the list of tabled country reports.

The written progress reports and the presentations given at this meeting are available in the list of password protected working documents.

CENAM – Mr Matamoros presented progress at the CENAM.

INRIM – Dr Rastello presented progress at the INRIM.

IO–CSIC – Dr Campos Acosta presented progress at the IO-CSIC.

KRISS – Dr Lee presented progress at the KRISS.

LNE – Dr Dubard presented progress at the LNE.

METAS – Dr Blattner presented progress at the METAS.

MIKES – Prof. Ikonen presented progress at the MIKES.

Dr Hengstberger noted that the situation for absolute radiometry is continuously changing. From black bodies, to room temperature electrical substitution radiometers, to self-calibrated photodiodes and trap detectors, to cryogenic radiometers and now predictable devices are re-emerging in the form of PQEDs. It is interesting to see these technologies evolve to higher accuracies. Having a breadth of technologies to realize radiometric scales is of benefit to the radiometric community.

MSL – Ms Nield presented progress at the MSL.

NIM – Dr Lin presented progress at the NIM.

NIST – Dr Fraser presented progress at the NIST Gaithersburg; Dr Rochford presented progress at the NIST Boulder.

Dr Manson enquired if all the carbon nanotubes were made at NIST Boulder. Dr Rochford replied that some are now commercially available.

Dr Hengstberger enquired about the reflectance of the vertically aligned nanotubes and their electrical properties. Dr Rochford replied that these nanotubes were of the semiconductor type and the absorptance greater than 99 %. Dr Fox commented on the blackness in the thermal infrared of these materials and usefulness of a broad wavelength range which is superior to anything else available to date.

NMC, A*STAR – Dr Huang presented progress at the NMC, A*STAR.

NMIA – Dr Manson presented progress at the NMIA.

NMIJ/AIST – Dr Zama presented progress at the NMIJ/AIST.

NMISA – Dr Nel-Sakharova presented progress at the NMISA.

NPL – Dr Fox presented progress at the NPL.

Dr Hengstberger commented on the collaborative approach between NMIs and the WMO in the remote sensing activities and that it was pleasing that measurements which were traditionally made with respect to special scales were now made on a common basis, the SI.

NRC – Dr Zwinkels presented the progress of NRC-INMS.

Dr Manson commented on the monochromator-based cryogenic radiometer. Dr Zwinkels replied that the monochromator concept was developed in-house by Dr Boivin but the instrument was supplied by CRI. She added that the uncertainties achieved with this system were comparable with those of laser-based systems as shown in the CCPR-S3 comparison.

PTB – Dr K. Stock presented progress at the PTB Braunschweig; Dr Ulm presented progress at the PTB Berlin.

VNIIOFI – Prof. Sapritsky presented progress at the VNIIOFI.

Dr Filtz asked about the facility for heat flux and in particular what kind of source shall be measured. Prof. Sapritsky answered that the facility will be used to compare heat flux sensors with radiometers.

The President thanked the NMIs for their presentations and invited the observers, the CIE and the WMO, to present their reports.

11 LIAISON WITH OTHER ORGANIZATIONS (CIE, WMO)

CIE

Dr Blattner, currently Director of the International Commission on Illumination (CIE) Division 2, presented the report from the CIE. The CCPR is represented at the CIE by Dr Ohno. Dr Blattner referred to the CIE-CIPM agreement and its history since 2007. The current structure of the CIE board was presented; Dr Anne Webb is the current CIE President. The CIE is divided into seven active divisions with Division 2 covering the area of the physical measurement of light and radiation.

Since 2009 the CIE has produced 21 new technical reports and 5 new standards or draft standards. As the CIE is seen as a professional standardization organization efforts have been made to achieve faster turnaround in the production of CIE publications. A new code of practice has been adopted to achieve this goal. In addition to the production of reports there have been 7 workshops and conferences since 2009.

Dr Blattner highlighted the recent publication of the new edition of the "International Lighting Vocabulary", CIE S 017/E:2011. This publication is currently being translated into Russian and Spanish. The production of the following publications was also noted:

- CIE 191:2010, recommended system for mesopic photometry and its application.
- CIE 198:2011, is an extensive document based on the GUM pertaining to measurement uncertainty in photometry. Associated with this publication is a software tool to facilitate the determination of uncertainties in measurements.
- CIE 200:2011, CIE supplementary system of photometry.
- CIE 201:2011, published by D6 to provide recommendations on the minimum exposure to UV, this is relevant to the production of vitamin D for example.
- CIE 202:2011, update of CIE 64:1984, Spectral responsivity measurements of detectors, radiometers and photometers.
- DS023-2012, Draft Standard prepared by CIE TC2-40, update of CIE 69:1967, characterizing the performance of illuminance and luminance meters.

Dr Blattner outlined the function of new technical committees of the CIE established since the previous CCPR meeting and commented that there was a significant focus on LED technologies in these committees.

- TC2-68 Optical measurement methods for OLEDs used for lighting
- TC2-71 CIE Standard on test methods for LED lamps, luminaires and modules
- TC2-72 The Evaluation of Uncertainties in Measurement of the Optical Properties of Solid State Lighting Devices, including coloured LEDs
- TC2-73 Measurement of Quantities Relating to Photobiological Safety of Lighting Products
- TC2-74 Goniospectroradiometry of Optical Radiation Sources
- TC2-75 Photometry of Curved and Flexible OLED and LED Sources
- TC2-76 Characterization of AC-Driven LED Products for SSL Applications.

Dr Blattner encouraged members to consider contributing to the work of the CIE through the technical committees of the CIE.

Dr Blattner highlighted the CIE Conference meeting and associated D2 meetings to be held in Hangzhou, China, in September 2012 and noted that the mid-term CIE meeting will be held in Paris, France, in April 2013 and that the 28th session of the CIE would be held in Manchester, UK, in June 2015.

WMO

Dr Schmutz presented the report from the World Meteorological Organization (WMO). He commented that shortly after the last CCPR meeting the formal Memorandum of Understanding (MoU) between BIPM and WMO was signed and that the WMO is now a signatory to the CIPM MRA. Three laboratories have been designated for participation in activities within the CIPM MRA. These laboratories are:

- Physikalisch-Meteorologisches Observatorium Davos/World Radiation Centre (PMOD/WRC), for solar irradiance. PMOD had already been a designated institute of the METAS.
- Swiss Federal Laboratories for Materials Testing and Research (EMPA), for surface ozone measurements.
- National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA/ESRL), for carbon dioxide, methane, sulphur hexafluoride and carbon dioxide concentrations.

Dr Schmutz gave an outline of the BIPM-WMO workshop on “Measurement challenges for global observation systems for climate change monitoring: traceability, stability and uncertainty”, which was held at the WMO headquarters, Geneva, Switzerland, in April 2010.

Dr Schmutz reported on the WMO CMCs in the KCDB. These include:

- Responsivity, solar irradiance, pyrheliometer
- Responsivity, solar irradiance, pyranometer

He also outlined the proposed CMC on global solar UV irradiance.

Dr Schmutz detailed the current EMRP-ENV03 “Solar UV” collaboration, coordinated by Dr Gröbner (PMOD/WRC). This programme aims to enhance the reliability of spectral solar UV measurements, develop new techniques and devices with traceable measurements better than 2 %.

The World Radiation Centre maintains the World Standard Group (WSG) for the realization of the World Radiometric Reference (WRR); this has been the conventional primary standard for the WMO since 1970. Every five years a measurement campaign is carried out (equivalent of a key comparison for the solar community) to maintain the dissemination of the world radiation reference value. In the previous measurement campaign of September to October 2010, 42 countries participated. The current status of the WSG is that it is stable.

The CSAR project (Cryogenic Solar Absolute Radiometer) is a research partnership with the NPL, the start of which was presented at the 2009 CCPR meeting; its purpose is to replace the WRR with an SI traceable realization of the unit W m^{-2}. Currently the agreement between the CSAR and WRR measurements is 0.3 %. Final replacement of the WRR will require 5 to 10 years for completion.

The absolute solar constant measurements from PREMOS/PICARD, since 2010, show that the first SI traceable measurement gave a value of 1361 W m^{-2}. PREMOS TSI is traceable to the NPL and the NIST Boulder. This experiment is ongoing.

The WMO is active in THz metrology in collaboration with the PTB and it is currently developing a detector-based absolute standard for THz radiation; a working prototype of the detector has been built.

The President commented that the CCPR was pleased with the progress made at the WMO in these areas.

CORM

Dr Ohno presented the report for the Council for Optical Radiation Measurements (CORM). The main activity of CORM is an annual conference with the recent focus being on solid state lighting with an interest in photometry and colorimetry of lighting. CORM has two active committees: light sources, and SSL measurement. CORM has a membership of about 200.

The next conference is from 30 May to 1 June 2012 at the NRC, Canada.

Dr Zwinkels added that the major outcome of CORM is technical reports; in addition it also issues a newsletter twice a year. She outlined the sessions of the CORM 2012 meeting.

12 REPORT ON LIAISON WITH CCT WORKING GROUP 5 " RADIATION THERMOMETRY"

Dr Fox presented the report which covers the efforts in the assignment of temperatures to high temperature fixed points (HTFPs) using radiation thermometry. CCT WG5 has five work packages in support of this study.

Dr Fox noted that in the past there had been issues in assigning temperatures above the Cu point. The current solution is to assign definitive temperatures for a sub-set of HTFPs, namely Co-C, Pt-C and Re-C. This study is the topic of WP5 of CCT WG5, in which the assignment of definitive temperatures will be achieved by multi-lateral measurement campaigns. The work is scheduled to start in June 2012. The target date for completion is 2015.

In addition, some of this work is being funded through an EMRP activity, InK (Implementing the New Kelvin), which has four objectives of which radiometric measurement is contributing to the first three of these:

- WP1: assign definitive thermodynamic temperatures to the aforementioned sub-set of HTFPs
- WP2: investigate dissemination routes for high temperatures via radiometers or HTFPs
- WP3: determine the world's lowest uncertainty data set of $T - T_{90}$.

Dr Fox outlined a possible forthcoming key comparison of high temperature scales which are to be discussed at the next CCT WG5 meeting. He noted that the previous key comparisons had not satisfactorily probed this temperature range nor claimed uncertainties.

Dr Fox reported progress on the *mise en pratique* for the definition of the kelvin and the Supplementary Information to the ITS-90. He noted that primary radiometry would be the first thermometry method to be cited in the *mise en pratique.*

Dr Fox commented on the real collaboration between the CCT and the CCPR on sources and radiometric techniques for assigning the fixed point temperatures, with the prospect that the developments in radiometry will be disseminated to and within the temperature community.

The President of the CCPR commented that it was pleasing to see the results of the collaboration between these two communities.

13 MEMBERSHIP ISSUES OF THE CCPR AND ITS WORKING GROUPS

CMI (Czech Republic) has applied for observer status of the CCPR and INMETRO (Brazil) has requested full membership.

The President invited Dr Šmíd (CMI) to give a presentation on the activities of the CMI.

Dr Šmíd outlined the development of radiometry at the CMI since 2004 and referred to his previous report at the 2009 CCPR meeting.

More recently the CMI has:

- Realized an IR spectral responsivity scale which has included the use of an AC-DC method based on a pyroelectric detector and a trap detector.
- Developed facilities for characterizing the uniformity of response and temperature sensitivity of response of detectors.
- Developed capability to investigate the linearity of response of photodetectors.

- General activities in photometry, radiometry and fibre optics.
- The CMI actively participates in the EMRP and the iMERA projects, including the quantum candela project. As an extension of this, the CMI is now offering calibration capabilities for photon counters.

The President of the CCPR invited Dr Alvarenga (INMETRO) to give a presentation on the INMETRO's activities.

Dr Alvarenga outlined progress at the INMETRO in the areas of photometry and radiometry, these included:

- Independent realization of the candela.
- Capability for spectrophotometry of reference materials, including diffuse reflectance and regular transmittance.
- Colorimetric characterization of displays.
- Colorimetric and photometric characterization of LEDs, OLEDs, CFLs and lighting and signaling.
- Realization and dissemination of thermodynamic scale of temperature based on radiometric measurements.
- Detector responsivity calibration via photon counting techniques.
- Participation in SIM regional and bilateral comparisons:
    - SIM2.2, SIM 2.6.P - Intercomparison of wavelength scale and photometric scale of spectrophotometry laboratories, 1998, 1999.
    - SIM.PR-K4 – Luminous flux, in progress.
    - Luminous intensity, bilateral with BNM/INM, 1999.
- Sixteen CMCs in the photometry and radiometry field listed in the BIPM database.

The two representatives were asked to leave the room while the membership applications of the CMI and the INMETRO were discussed.

The President of the CCPR commented on the disparity in the request for status from the two laboratories and asked if observer status would not be more appropriate for the INMETRO in the first instance. Dr Fox stated that observer status should be recommended as the first step to ensure consolidation and demonstration of commitment.

The President asked for further comments. Dr Fraser (NIST) asked how long observer status would continue. The President said that this would be at least until the next meeting of the CCPR. He repeated that both institutes could apply for observer status now and membership at the next meeting when the outcome of comparisons (regional) could be reviewed.

The President went on to state that this was also the case for laboratories with little current research activity to review their membership status and change to observer status, where appropriate. It is preferred that such action be initiated by the laboratories themselves. This is consistent with the President's request at the 20th meeting of the CCPR (2009).

Dr Thomas noted that observers could not participate in CCPR key comparisons; this point was acknowledged.

The President reported to the applicants that he would recommend observer status for both laboratories to the CIPM. At the next meeting of the CCPR they could apply for full membership - this procedure being consistent with previous applications for membership to the CCPR.

Decision: Observer status has been offered to CMI and INMETRO.

14 ANY OTHER BUSINESS

Dr M. Stock requested permission for presentations to be made available on the secure area of the CCPR web pages. The participants agreed.

Dr Fox referred to the CCU and the proposed explanatory text for the candela definition. The status of the discussion should be made clear in the minutes (see section 7). Dr Rastello agreed with this proposal.

15 NEXT MEETING DATE

There was a proposal for the date of the next meeting to be in alignment with Newrad 2014, which will be held in Finland on 23 to 27 June 2014. The organizers of Newrad 2014 have suggested that the working group meetings could be held in Finland with the CCPR meeting being held in Paris for one day.

The President asked for any alternate proposals: there were none.

Dr Ohno commented that the split between venues may mean that all members might not attend both sets of meetings; Dr Fox agreed. The President asked the BIPM Director about the feasibility of holding the CCPR and the related working group meetings at the BIPM in 2014.

A decision was made that the next CCPR meeting and associated WG meetings would be held during the week after the Newrad 2014 conference, from 30 June to 3 July 2014.

Further to the discussions about the working group meetings proposed for April 2013, in connection with the CIE mid-term meeting from 12-19 April 2013, it was noted that these meetings could be held at the BIPM if the meetings could be completed within one day, 22 April. Dr Zwinkels replied that it was unlikely that the meetings could be managed in one day.

The possibility of the CIE making a room available for the WG meetings should be explored. Dr Fox enquired if the LNE could make space available for the meetings. Dr Dubard replied that he would check and reply.

AP9: Enquire as to logistic for holding CCPR-WG meetings at the CIE mid-term meeting venue or at LNE.

The President thanked the participants for their attendance. The meeting closed at 1:15 pm.

Appendix 1
RESPONSE OF THE CCPR TO THE CCU PROPOSAL TO REFORMULATE THE DEFINITION OF THE CANDELA

(SEPTEMBER 2009)

The CCPR basically agrees with the logic of the CCU proposal as well as with the wording proposed by the CCU, with some slight modifications (lumen expressed as candela steradian and removal of the word "spectral"). The explicit constant definition, as modified by the CCPR is:

The candela, unit of luminous intensity in a given direction, is such that the luminous efficacy of monochromatic radiation of frequency 540×10^{12} hertz is equal to exactly 683 candela steradian per watt.

The CCPR confirms that the concept of "luminous efficacy of radiation" is well established in the field of photometry. In respect to the explicit unit definition following the explicit constant definition, the CCPR proposes the introduction of the constant K_{cd}, the subscript "cd" referring to the Candela. For this explicit unit definition following the explicit constant definition, the CCPR proposes:

Thus we have the exact relation $K_{cd} = 683$ lm/W. The effect of this definition is that the candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watts per steradian. This radiant intensity corresponds to a photon intensity of $(683 \times 540 \times 10^{12} \times 6.626\,068\,96 \times 10^{-34})^{-1}$ photons per second per steradian.

The CCPR wishes to inform the CCU about the motivation to add the last sentence, expressing the radiant intensity as photon intensity, both quantities being well established in the IEC/CIE lighting vocabulary. The additional sentence arises from a compromise between proponents of a radiant intensity formulation and of a photon intensity formulation within the CCPR. The addition of this alternative expression does not change the current explicit unit definition in any way, but makes the proposed version acceptable to both sides in this ongoing debate within the CCPR.

In its proposal above, the CCPR used the unit "photons per second per steradian" for photon intensity. It did this in correspondence with the proposed redefinition of the ampere, in which the unit of "elementary charges per second" is used for electrical current. The CCPR would like to ask the CCU to confirm that the unit of the quantity "photon intensity" used in the CCPR proposal is acceptable or whether it should be "number of photons per second per steradian", or just "per second per steradian".

We are aware that the exact value of the photon intensity will depend on the exact value chosen by the CCU for the Planck constant h and leave the insertion of the correct value for the photon intensity to the CCU once it has defined the constant h.

Appendix 2
WORKING DOCUMENTS SUBMITTED TO THE CCPR AT ITS 21ST MEETING

Documents restricted to Committee members can be accessed on the restricted–access CCPR website. There are no open working documents of this meeting.

CCPR/12-01	Convocation
CCPR/12-02	Draft agenda – V2.0
CCPR/12-03	Schedule for CCPR WG meetings, V3.0
CCPR/12-04	Report of the 20th CCPR meeting of 2009
CCPR/12-05	Questionnaire on laboratory progress
CCPR/12-06	CCPR WG-SP membership criteria, V1.3a
CCPR/12-liaison-CCT WG5	Report to CCPR on progress of CCT WG5
CCPR/12-liaison-CIE	CIE liaison report
CCPR/12-liaison-WMO	WMO liaison report
CCPR/12-pres-CENAM	CENAM activities presentation
CCPR/12-pres-CMI	CMI activities presentation
CCPR/12-pres-INMETRO	INMETRO activities presentation
CCPR/12-pres-INRIM	INRIM activities presentation
CCPR/12-pres-KRISS	KRISS activities presentation
CCPR/12-pres-LNE	LNE activities presentation
CCPR/12-pres-METAS	METAS activities presentation
CCPR/12-pres-MIKES	MIKES activities presentation
CCPR/12-pres-MSL	MSL activities presentation
CCPR/12-pres-NIM	NIM activities presentation
CCPR/12-pres-NIST-Boulder	NIST Boulder activities presentation
CCPR/12-pres-NIST-Gaithersb.	NIST Gaithersburg activities presentation
CCPR/12-pres-NMC,A*STAR	NMC, A*STAR activities presentation
CCPR/12-pres-NMIA	NMIA activities presentation
CCPR/12-pres-NMIJ	NMIJ activities presentation
CCPR/12-pres-NMISA	NMISA activities presentation
CCPR/12-pres-NPL	NPL activities presentation
CCPR/12-pres-NRC	NRC activities presentation

CCPR/12-pres-PTB	PTB activities presentation
CCPR/12-pres-VNIIOFI	VNIIOFI activities presentation
CCPR/12-report-CENAM	CENAM progress report
CCPR/12-report-CMI	CMI progress report
CCPR/12-report-INMETRO	INMETRO progress report
CCPR/12-report-INRIM	INRIM progress report
CCPR/12-report-IO-CSIC	IO-CSIC progress report
CCPR/12-report-KRISS	KRISS progress report
CCPR/12-report-LNE	LNE progress report
CCPR/12-report-METAS	METAS progress report
CCPR/12-report-MIKES	MIKES progress report
CCPR/12-report-MSL	MSL progress report
CCPR/12-report-NIM	NIM progress report
CCPR/12-report-NIST	NIST progress report
CCPR/12-report-NMC-ASTAR	NMC, A*STAR progress report
CCPR/12-report-NMIA	NMIA progress report
CCPR/12-report-NMIJ	NMIJ progress report
CCPR/12-report-NMISA	NMISA progress report
CCPR/12-report-NPL	NPL progress report
CCPR/12-report-NRC	NRC progress report
CCPR/12-report-PMOD/WRC	PMOD/WRC progress report
CCPR/12-report-PTB	PTB progress report
CCPR/12-report-UME	UME progress report
CCPR/12-report-VNIIOFI	VNIIOFI progress report
CCPR/12-RMO-AFRIMETS	AFRIMETS report to the CCPR
CCPR/12-RMO-APMP	APMP report to the CCPR
CCPR/12-RMO-COOMET	COOMET report to the CCPR
CCPR/12-RMO-EURAMET	EURAMET report to the CCPR
CCPR/12-RMO-SIM	SIM report to the CCPR
CCPR/12-WG-CMC	Report of WG-CMC to the CCPR
CCPR/12-WG-KC	Report of WG-KC to the CCPR
CCPR/12-WG-SP	Report of WG-SP to the CCPR