Replies to the CCPR questionnaire

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Reply to the questionnaire by BNM (France)

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The implementation of the MRA is based mainly on key comparisons, quality system and CMCs. The very large number of key comparisons organized at the same time has increased dramatically the work load of the staff working in our laboratory in the field of photometry and radiometry. An important amount of time was also spent in putting in right format procedures and other documents due to the necessity of having a formal quality system according to the ISO 17025 standard. The preparation of CMCs for the laboratory and their validation at the regional and inter-regional level was also time consuming. This great deal of extra work done without extra staff has delayed the activities devoted to the research on new standards and the improvement of existing standards. It has also involved extra cost in running the laboratory.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

For the time being and the present activities of our laboratory their is no real change due to the MRA. Probably it is too early to have a clear evidence of the benefits or disadvantages of the MRA. Nevertheless we could probably foreseen a better confidence in the metrological results all over the world and in some cases a better cooperation between NMIs.

3) Given the announcements on the restructuring of the BIPM and the ***attached*** *explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.*

In the field of photometry the major duty of the BIPM is to keep record of the evolution the realization of the candela and lumen. If we look at the two last comparisons of luminous intensity and luminous flux we can see that the magnitude of the "world mean candela" has changed (CCPR recommendation P2 1986, CCPR recommendation P1 2001). In order to be able to follow the evolution of quantities using photometric units over a long period of time we need to have record of the various changes of the "realized candela" (CGPM resolution 4 1999). Also it seems very important that the BIPM be able to continue to carry out this activity by keeping, with the appropriate standards the value of the successive realization of the candela and the links which exist between the "world mean candela" and the individual realization by NMIs (results of the comparisons).

Another important point to be considered is the future of the calibration services provided by the BIPM and eventually to look at the best way to continue it or to transfer it to some other calibration laboratories.
4) Supply an assessment of the value of the CCPR inter-comparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

International comparisons have a long history in the field of photometry and radiometry because in this specific field of the metrology they are essential due to the difficulty in realizing the units with an accuracy much lower than the needs for industry. Also it is essential to continue them.
But due to the implementation of the MRA a too large number of comparisons has happened at the same time. A better distribution of these comparisons in time is the first improvement to achieve.
Another important point is also to give to the comparison and to the study of the results a more scientific basis. At present time we are arguing on the way to determine the reference value of the comparison using various statistical methods or if it is possible to accept modified values by a NMI which have found a mistake in its measurement instead to look at the physical reasons which could be put into evidence by the discrepancy between results obtained by different methods. Very often, in the past, after a comparison it was usual to establish a working group to try to explain the discrepancies between laboratories. It is a little frustrating to see the large amount of work for realizing a comparison used only for the validation of the CMCs an not also for the improvement of the measurements.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

The inclusion of the CMC in the MRA database is necessary to participate in the process of the MRA and to achieved the mutual recognition of calibration certificates. But, up to now, it is not clear that in the field of photometry and radiometry ,the end users are really interested in it. It could be very useful to have precise information on the connections to the database.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

No activity in this field

(b) spectral radiometric quantities

Spectral responsivity of detectors :
- Improvement of the monochromator based experimental set-up.
- Development and characterization of trap detectors based on GaAsP photodiodes for the UV range.
- Characterization of large area silicon trap detectors and attempt to model their spectral responsivity for interpolation of the spectral responsivity in the visible range.
- Development of an experimental set-up for calibrating detectors in photon counting mode using parametric down conversion.

Spectral irradiance :

- Realization and characterization of a spectral irradiance scale in the UV range (200-400 nm) based on filter radiometers.

Spectral radiance :
- Realization of a monochromatic standard of spectral radiance at 830 nm using an integrating sphere and a laser diode. This source will be used by the temperature team to measure the thermodynamic temperature of black bodies by a radiometric method.

(c) photometric quantities

Improvement of the conservation of the luminous intensity unit by using simultaneously standard lamps and standard photometers.

Calibration of broad-band blue-light radiometer used for the measurement of the irradiance level of the light emitted by lamps for the treatment of the bilirubin on new-born child.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

- Characterization of Fiber Bragg Grating (FBG) using an Optical Low Coherence Reflectometer. The set-up includes a broad-band source and a Michelson interferometer.

- Building of a high temperature blackbody (3000°C). Calibration of radiometers and sources in UV range

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Calibration or test methods for the following topics:
- Lighting using Light Emitting Diodes (LED): flux, intensity, colorimetry
- Photometry and colorimetry for the characterization of display screens
- Low-level radiometry (photon counting). Characterization of light sources compatible with Night Vision Goggles

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

- Photometry of light emitting diodes used in the lighting applications.
- Photometry and colorimetry of visual displays.
- Measurement of appearance of the object.
- Colorimetry of effect painting.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

Collaboration on Fiber Optics research projects:
- Chromatic dispersion of fiber and fiber optics components (eg FBG)

- Polarization Mode Dispersion (PMD): calibration of polarisation analyser

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

Up to now the distribution of activities between CCPR and CIE was clear enough to avoid major overlap in their working programs. CCPR was working mainly on units and primary realization of the units and CIE was working mainly on the use and the practical aspects of measurement. Moreover a large number of CCPR members were also CIE members giving in practice a good relationship between both organization. But, as CCPR activities, due to the MRA and the CMC database, seem to move toward a wider field of types of measurements a better connection in a more formal way could be useful for both organizations.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

Due to the MRA it seems useful for the CIPM to develop more formal links with other international organizations working more or less in clause connection with metrology. In the past CIE has played and is still playing a major role in photometric and colorimetric measurements also it seems perfectly acceptable to have a MOU between CIPM and CIE.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

- “Measurement of a fibre optics refractive group index at 1.55 µm using the low coherence interferometry technique”;
  A.F. OBATON, P. BLANCHARD, C. LUPI;
  Proceedings of the 10th International Metrology Congress, St Louis, France, 22-25 October 2001.
- “A vacuum Blackbody cavity for radiometric calibration of Gardon gauges”;
  J.R. FILTZ, M. LIEVRE, T. VALIN, D. LEMONNIER and D. BLAY,
  Proceedings of the 10th International Metrology Congress, St Louis, France, 22-25 October 2001.
- “Etalonnage de détecteurs fonctionnant en régime de comptage de photons à l’aide de la conversion paramétrique optique dans les cristaux”,
  A. Bellouati, A. Razet, J. Bastie, M. E. Himbert,
  Proceedings of the 10th International Metrology Congress, St Louis, France, 22-25 October 2001.
- “Modélisation de la sensibilité spectrale des détecteurs pièges du BNM-INM. Interpolation et perspective d’extrapolation”,
  S. Briaudeau, J-M. Coutin, F. Chandoul, J. Bastie,
  Proceedings of the 10th International Metrology Congress, St Louis, France, 22-25 October 2001.

- "La réalisation d'une échelle d'éclairement énergétique spectrique dans le proche ultraviolet (domaine spectral 200-400 nm)",
  I. Abu-Kassem, J. Bastie, F. Lepoutre,
  Proceedings of the 10th International Metrology Congress, St Louis, France, 22-25 October 2001.
- "Realisation of the luminous intensity unit at the French national institute of metrology"
  J. Bastie, J-M. Coutin
  International Metrology Conference celebrating the 50th anniversary of the Romanian institute of metrology, Bucharest, Romania, 18-20 September 2001
- "Réalisation et qualification métrologique d'une échelle d'éclairement énergatique spectrique dans le proche ultraviolet (domaine spectral 200-400 nm)",
  I. Abu-Kassem,
  PhD thesis, Paris, 11 December 2002.

14) Have you got any other information to place before the CCPR in advance of its next meeting?

No

Paris 6 May 2003

CENAM answers to CCPR questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

In one hand the load of work by the interregional review process, but on the other hand the increment of experience with the exchange of technical information and proper discussion of our capabilities. We noticed that this process helped us to review in detail all our capabilities (including uncertainty budgets) and had developed proper documentation for each service. Also, with the review processes, we have enriched our view for further developments and extension of our capabilities.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

Benefits: Support and recognition of the services provided by NMIs is the first advantage, providing some kind of "uniformity" as a result of the discussions between NMIs. Anyway, is pretty soon to obtain proper conclusions.
Disadvantage: As a young NMI, we face several difficulties (internal and external) that increase the workload in the administrative aspects and difficult our development.
Improvement of the MRA? No comments at this moment.

3) Given the announcements on the restructuring of the BIPM and the attached explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

We have little experience about implications of this decision, our first priority is provide trazability inside the country. The main problem we see is the coordination of the comparisons, we were thinking on a comparison with BIPM to obtain link to KC, but this will not be possible.

4) Supply an assessment of the value of the CCPR inter-comparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

CENAM has been involved recently in the CCPR comparison (K1.a) and this activity has encouraged us to review and improve our measurement system and related procedures.
About the present scheme for the comparisons, it is evident that the large number of participants brings really long periods of time from the beginning of the comparison to results and degrees of equivalence. The number of participants should be reduced and those participants of the CCPR comparisons should be encouraged to promote regional comparisons to maintain consistency and simplicity.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

As a young institute, one of our mayor problems is to obtain the confidence of national customers, who up to now are used to obtain trazability to foreign NMIs (mainly NIST) through calibration laboratories (not all of them acredited) from aboard.
The goal will be the recognition of CENAMs capabilities by the home market and, hope in the near future, increase of customers; the benefit expected is the reduction of TBTs to national industry.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

UV radiation bench

We have set up a radiometric bench for UV measurements, now working at 365 nm, and planned to be extended to other wavelengths in UV.

(b) spectral radiometric quantities

Control and Optimization of a detector comparator facility

Due to the failure of the electronic control of our commercial system, it was necessary to design a new control system. At the same time, some components and the measurement procedure will be improved. The facility will cover the spectral range of 250 nm to 2 500 nm. This project will be finished by the end of 2003.

System for non-linearity measurements of photodetectors

A system for measuring detector non-linearity based on the absolute flux-addition method has been installed. Additionally it allows changing the detector temperature between 20ºC and 55ºC. It also allows measurements at defined laser wavelengths in the VIS and NIR up to power levels of 10 mW.

Control and Optimization of source measurement system

We have re-designed the electronic instrumentation associated to the measurement system for spectral radiance and irradiance, the project will be finished in the next months.

(c) photometric quantities

Luminous flux national standard

We have declared the Mexican National Standard for luminous flux for incandescent lamps. The plan is to develop an absolute system based on the Ohno method in the near future.

Luminous intensity trazable to cryogenic radiometer

We are still working on the trazability of the candela to our cryogenic radiometer, we plan to obtain our own scale by the end of the year.

(d) Other fields

Reference polarimeter

We have started a project to develop a system for polarimetry. The system has been designed and is being assembled. The project is planned to be finished by end of 2004.

Fiber standards for OTDR calibration

A project for establishing calibration methods for optical fiber standards used for the calibration of OTDR length and attenuation scales was started, and is planned to be finished by the beginning of 2004.

Final remarks: CENAM, with 9 years of existence, is establishing the QS 17025 standard to promote pair visits assessment. Had obtained ISO 9001 certification of the calibration services at the beginning of 2003.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

None at the moment.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

None at the moment.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Not able to comment at the moment.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

We will look for cooperation with several NMIs, but this will be according to our progress in the implementation of the systems under development.
Also, CENAM is encouraging its own staff to study PhDs, with projects in collaboration with other NMIs. Some of the fields we are interested on are: UV radiometry, detector based radiometry of sources, and absolute system for luminous flux, design of new reference materials for optical measurements (color, refractive index, polarimetry).

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

No comment about this item.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

Yes, give proper support to this activities and influence in a positive way on the decisions that affect the CCPR and NMIs work at the services level.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

References to the Simposio de Metrología can be obtained from the web page of CENAM:
www.cenam.mx/publicaciones/gratuitas/

Cryogenic radiometer facility of the CENAM and first international comparison
K.D. Stock, H. Hofer, J.G. Suarez Romero, L.P. Gonzalez Galvan, W. Schmid, Metrologia **37** (2000) 269

Calibración de medidores de potencia óptica utilizados en sistemas de fibra óptica (Calibration of optical power meters used in optical fiber systems)
M. López, W. Schmid, Publicación Técnica CENAM, CNM-MFO-PT-003 (internal report)

Determinación de no-linealidad en detectores fotovoltaicos de Si (Measurement of nonlinearity of silicon fotodetectors)
M. López, G. Ramos, W. Schmid, Proceedings - Simposio de Metrología 2001, B3 1-3, Querétaro, México, 2001

Medición de la no-linealidad de fotodiodos de Ge e InGaAs a diferentes longitudes de onda y tamaño de haz (Measurement of the nonlinearity of Ge and InGaAs photodiodes at diferent wavelenghts and beam diameters)
M. López, G. Ramos, W. Schmid, Proceedings - Simposio de Metrología 2002, 298-301, Querétaro, México, 2002

Trazabilidad e incertidumbre en mediciones de potencia óptica (Traceability and uncertainty optical power measurements)
W. Schmid, Proceedings – Tecnolaser 2003, La Habana, Cuba, 2003

Efecto del ancho de banda espectral y del intervalo de datos en la calibración de la escala de longitud de onda de espectrofotómetros UV-VIS (Wavelength and data interval effects on the calibration of UV-VIS spectrophotometers)
G. Valencia, Proceedings – Simposio de Metrología 2002, 429-433

Sistema de medición polarimétrico, calibración y comparación con placas de cuarzo de control. (A polarimeter, calibration and comparison with quartz plates)
V. Fajer, G. Valencia, S. Pedro, J. Mora, R. Valdivia, J. López, H. Fernandez, Proceedings – Simposio de Metrología 2002, 254-258

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire: Reply by the CSIR-NML of South Africa

1. In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs?

The CSIR-NML initiated a process to implement a quality system and to demonstrate its competence in order to fulfill the requirements of the MRA. The CSIR-NML plans to have all its laboratories accredited within a 3-year period, ending 2003. The Photometry and Radiometry laboratory is scheduled for accreditation in August 2003. Since the establishment of the MRA, the laboratory's capabilities have been subjected to an international peer review and to a large extend our activities have been devoted to publishing our Calibration and Measurement Capabilities in the database, participating in international comparisons and establishing a strategy to ensure that confidence in our capabilities is maintained through continued participation in relevant comparisons.

2. What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?

A major advantage of the MRA is the recognition of our capabilities by other NMIs and multinational companies. Local manufacturers of export commodities are able to calibrate their measurement equipment locally as the results are accepted by the OEM in another country. The major disadvantage of the MRA is the requirement for participation in a large number of comparisons, which is not always practical.

3. Given the announcements on the restructuring of the BIPM and the attached explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

The closure of the Photometry and Radiometry activities of the BIPM is not expected to have a huge impact on the activities of metrology in developed countries. Since detector-based methods are now used for the realization of both the lumen and the candela, the techniques of photometry and radiometry are much more closely related than in the past and can be realized independently by NMIs within small uncertainties. Research into areas of mutual interest is undertaken by NMIs and can be initiated or coordinated by the CCPR. However, NMIs of developing countries no longer have access to a free calibration service in this field. The services can be provided by other NMIs, but will have a cost implication.

4. Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

Value of CCPR intercomparison activities for CSIR-NML laboratory.

Along with some other considerations, the CCPR's schedule of comparisons is one of the important factors in prioritising the work of our laboratory, including work on the development of improved methods, improved software, data analysis techniques, and improved uncertainty determination. The results of these comparisons enable us to objectively evaluate our capabilities and, together with our associated entries in the CMC database, provide evidence supporting the BMCs claimed for accreditation purposes.

Main merits of processes.

The technical protocols are very comprehensive and comparison requirements are well defined. The comparison reports are also very comprehensive.

Main shortcomings of processes.

No suggestion. Negates

Suggestions for improvements.

No suggestion.

5. Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

Prior to the establishment of the MRA, the CSIR-NML entered into bilateral MRAs with the NMIs of the main trade partners of South Africa. The MRA negated the need for a large number of bilateral MRAs and the large number of associated bilateral comparisons.

6. Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

None.

(b) spectral radiometric quantities

Cryogenic radiometer

CSIR-NML's cryogenic radiometer set-up currently incorporates lasers for wavelengths 488 nm, 514.5 nm and 632.8 nm, and the highest power available is 6 mW (at the laser, 632.8 nm). After stabilisation and spatial filtering the radiant powers typically achieved are 200 µW down to less than 100 µW, but only through some compromise on beam quality. This gives rise to uncertainties higher than are ultimately attainable through the cryogenic radiometer.

During the past 2 years, work with the cryogenic radiometer involved adding a permanent enclosure to the set-up and the calibration of trap detectors against it. Further work will involve improvements, both in techniques and equipment to improve the uncertainties attained.

Spectral responsivity of detectors

Cavity-type pyroelectric detectors and silicon trap detectors have been introduced in the traceability chain for spectral responsivity, instead of older pyroelectric detectors and single-element photodiodes which had been used previously.

In the wavelength region 350–1000 nm the spectral responsivity scale at CSIR-NML is realised through a two-step process: Firstly, the absolute spectral responsivities of silicon trap detectors are calibrated against the cryogenic radiometer, at the laser wavelengths available with the cryogenic radiometer set-up. Secondly, the relative spectral response of the trap detectors is interpolated and extrapolated by making use of a cavity-type pyroelectric detector.

In the wavelength region 1 000–1 800 nm the spectral responsivity scale is realised through a similar two-step process: Firstly, the absolute spectral response of germanium or InGaAs photodiodes are calibrated against a room-temperature radiometer, using interference filters to obtain monochromatic light. Secondly, the relative spectral responsivities of the photodiodes are interpolated and extrapolated by making use of a cavity-type pyroelectric detector.

(c) photometric quantities

Regular spectral transmittance

A primary reference facility for regular spectral transmittance measurements has been established and is being characterized.

7. What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?

Measurement methods for LEDs

A project to investigate and develop measurement methods and standards for photometry and colorimetry of light-emitting diodes (LEDs) has been initiated.

Linearity Measurement

The laboratory made some improvements to its system for measurement of linearity. The system makes use of an existing aperture wheel (also previously built by CSIR-NML), which enables linearity determination through the flux addition method, i.e. alternately letting through either a beam A, or a beam B, or both beams A+B, or none. The improvements involves the following:

- Adding the ability to balance the two beams of radiation so that they are approximately equal in power. This makes processing the data much more straight forward, since no interpolation is necessary.
- Adding two filter wheels with neutral density filters to enable automated scaling of the radiant power through about 6 orders of magnitude, scaling by a factor of 2 each time.
- New software was developed for the system (LabView based).

Fibre optic metrology

Fibre optic metrology forms part of the Time & Frequency laboratory at CSIR-NML. The parameters covered are only: Spectral response and linearity of fibre optic power meters, attenuation, wavelengths of interest to fibre optics, and fibre optic time delay. In the past two years developments related to the fibre-optic metrology laboratory have been:

- A frequency / wavelength reference in the vicinity of 1 550 nm (see below)
- Modifications to existing hardware for linearity measurements and development of associated software to run under the Windows environment.

Frequency/Wavelength references

A stabilised diode laser system was developed for use as a frequency reference in the vicinity of the fibre optic communication wavelength 1 550 nm. Experimental results indicate that, without much optimisation, a wavelength accuracy of better than 0.1 pm (<10 MHz) is achieved. An added advantage of the system is that calibration of artefacts should be faster, simpler and more powerful than the monochromator-based approach that had been used thus far.

Further plans are: Improvements to the frequency stabilisation and extension to other wavelengths, including non-fibre optic wavelengths, also with the view of implementing frequency comb techniques in due course.

8. What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Wavelength measurement

Since wavelength measurement is becoming of increasing importance in fibre optic communication where DWDM (dense wavelength division multiplexing) is applied, it is perhaps appropriate for CCPR to give more attention to it? This does not seem to be adequately covered by the CCL, where 633 nm and shorter wavelengths are of interest. The frequency comb techniques currently seem to be applied for the visible wavelength range, whereas single mode fibre-optic communication takes place in the near-infrared (in the vicinity of 1 300 nm and 1 500-1 600 nm). It may be necessary for CCPR to clearly decide how to deal with wavelength: Either deal with it inside CCPR, or to liase with the relevant other CC.

9. What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry?

No suggestion.

10. Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?

- Development of an improved detector-element for the CSIR-NML room temperature absolute radiometer as well as improved electronics and new software, are planned.
- Development of frequency stabilised lasers as wavelength standards at fibre-optic communication wavelengths.

11. Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

Cooperation with the WMO is not enough. The requirements of the MOU need to be followed up on technical level to ensure that it is carried out in practice.

12. Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?

Yes. The activities of the CIE and the CIPM overlap. Each organization's responsibilities should be defined clearly.

13. Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

B Theron, "Key Comparisons in Photometry and Radiometry", SANCI Congress, Johannesburg, South Africa, October 2001.

P Botha, "Spectroradiometry Measurement and Application", SANCI Congress, Durban, South Africa, September 2002.

N van Tonder, "NML Colorimetry Laboratory", Colour Group Seminar on Colour Measurement and Application, Pretoria, South Africa, April 2002.

14. Have you got any other information to place before the CCPR in advance of its next meeting?

No.

Prepared by: N van Tonder
May 2003

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Replies of the Helsinki University of Technology (HUT) to the CCPR Questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The MRA has caused many new comparisons. Preparation and analysis of CMCs is another effect of MRA.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

The benefit of the MRA upto now is that it has caused a lot of new interaction and discussion between NMIs, which has sometimes facilitated transfer of knowledge and agreement of basic conditions for good measurements. In the future, MRA may be useful for customers and also for NMIs if they try to coordinate their activities.

MRA has caused a lot of work. If this is a disadvantage (as wasted effort) can be seen only later when the results of the work can be fully evaluated.

There may be risks if the text of MRA is exposed to large changes. MRA has worked surprisingly well. The interpretation of MRA could probably be unified without actually changing MRA.

*3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.*

The immediate effects of closure are related to BIPM's calibration services and piloting of CCPR key comparisons. Piloting is considered below. Nationally the lack of BIPM calibration services does not have any effect. Internationally it is clear that many NMIs would have preferred to use the services of BIPM. The arguments for the closure are not convincing. Future work at BIPM will show if the new areas are worth of transfer of the resources.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

CCPR comparisons are valuable for our laboratory. They are the most efficient way to obtain confidence for the capabilities of a small NMI and also to assess the capabilities of others. The comparisons generally take a long time. Those comparisons, which BIPM has piloted in recent years, were all carried out within a time period less than average. This may imply that, on the average, the comparisons will last even longer in the future.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.
CMCs in the database mean recognition of others for these services. They can be used to evaluate own capabilities relative to those internationally available. Presently it appears that our local customers do not use this information to any significant extent.

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities

A new monochromator based facility was recently taken in use for characterization of spectral responsivity of low-sensitivity industrial and medical UV meters. It can be used to study uncertainties of measurements of sources using broad band detectors. Correction factors calculated for different UV sources show large variations for a typical UV meter.

(b) spectral radiometric quantities

For characterizations of detectors, the xy-scanning method was applied to determine the spectral irradiance responsivity with wavelength tunable Ti:S laser [Noorma et al. 2003]. The method is based on producing a uniform, known spectral irradiance by a combination of equally spaced laser beams. The results are in agreement with conventional measurements using a monochromator.

New methods have been developed for the analysis of spectral irradiance responsivity measurements of narrow-band filter radiometers, where the responsivity integrated over wavelength is a critical factor [Kärhä et al. 2003]. The project also included an intercomparison between HUT, NPL and BNM-INM. The results emphasize the importance of wavelength scale for reliable characterization of narrow-band filter radiometers.

Further work on measurement of light source properties has been carried out in a project aimed at determination of radiation temperature using trap detector based filter radiometers. This is a joint project with the temperature laboratory of MIKES, which allows us to confirm the temperature scale around 1000-1500 C and interpolate or extrapolate outside the fixed points. Furthermore, research is in progress to extend our filter-radiometer based spectral irradiance scale [Kübarsepp et al. 2002] from 290 nm down to 250 nm and to analyse the effects of fitting a radiation law to the filter radiometer signals. Preliminary results of the latter work have led to correlation coefficients between spectral irradiances at different wavelengths and to a method of optimizing the center wavelengths of the filter radiometers.

(c) photometric quantities

We have improved the reliability of our luminous flux measurements based on the absolute integrating sphere method. Recent results are given in a comparison report [Hovila et al. 2002].

Photometric LED characterization methods have been studied for maritime applications. Collaboration with a manufacturer of LED buoy lanterns has led to identification of suitable methods and limitations in these calibrations.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

In spectrophotometry, transmittance/reflectance measurements are used to determine the (complex) refractive index of thin films for the purposes of communications industry [Haapalinna et al. 2002, Nevas et al. 2003]. Also, a setup has been developed which can be used to determine the transmission characteristics of small-size WDM filters in the temperature range 20-80 C. Finally, a goniospectrophotometric setup is under construction which will allow, e.g., absolute spectral diffuse reflectance measurements.

Our fiber optics work is focused on photonic crystal fibers (holey fibers) and tapered fibers for supercontinuum generation [Genty et al. 2002, Lehtonen et al. 2003]. Other recent research projects are related to wavelength reference for optical communication, frequency chirp measurements [Niemi et al. 2002], chromatic dispersion measurements [Niemi et al. 2001, Genty et al. 2002], fiber optic power measurements, polarization mode dispersion measurements, and determination of fiber nonlinearity.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

CCPR could consider if there would be a way to include fiber optics in the working program of the CCPR.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

I do not see unnecessary dublication of efforts between CIE and CCPR.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

This might be useful.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

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14) Have you got any other information to place before the CCPR in advance of its next meeting?

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire

Replies by IEN (Italy)

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

IEN activities have been only slightly affected till now, mainly for those aspects regarding quality assessment and participation in intercomparisons.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

Major benefits are the proven soundness of NMI results, the deep knowledge and publicity on the state of the art in different labs, and the possibility for clients to have information on what and where the best calibration and measurement capabilities are in the world.
Disadvantages are strictly related to the time constant of the mechanisms ruling the process, i.e. slow reaction to changes in the facilities or to new results. Moreover, the system seems to be not very sympathetic with research projects or new primary realisations as emphasis is mainly on agreement, not on the reasons of any eventual disagreement.
Improvements should be foreseen to speed up the reviewing process and the updating of the database, so that information will be available on actual capabilities.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

As a general remark, the worst effect is the loss of knowledge and impartial expertise. Nobody has been and will be in the position held by BIPM in the last 70 years. Moreover, NMIs are not in the position to support key comparisons as effectively as BIPM, particularly for those aspects related to the analysis of the results.
Impact will be significant internationally in particular for those aspects related to the co-ordination of activities among different regions and the promotion of new subfields.
Regionally, there will be almost no impact as Europe is rich of primary realisations and regional organisations or/and NMIs can cover almost any requirements from European industry. Problems can be foreseen instead in other regions.
Nationally, there will be no impact, as Italy had no contact in the past with BIPM in this field.
As to restructuring, probably it has not been recognised the increasing impact and need for standards in new fields like imaging technologies, photobiology and photochemistry, and communications.

Reasons not to close the section are not in the past but in the future work to be done in a co-ordinated way.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

The credible validation of measurement capabilities is the main merit. Shortcomings are in the participation of "clones", i.e. labs with not really independent realisations, polarising in some way the resulting key value. Probably it would make more sense to organise bilateral comparisons instead of ecumenical, long lasting, comparisons.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.
Invaluable from a scientific viewpoint, for validation and certification. On the contrary, the declared quantities are sometimes far from the industrial requirements.

6) Summarize the progress in your laboratory in realizing top-level standards of:

The main activity has been the realisation and maintenance of measurement capabilities for coherent radiation. Activity has been devoted to the extension of the measuring range from 1 mW to 1W for spectral power and to the extension of the spectral range to the near infrared (467 - 1100 nm). Studies of the internal loss mechanisms in silicon photodiodes are aimed to the realisation of new detectors with high quantum efficiency at cryogenic temperatures (liquid nitrogen). The sources facility for cryogenic radiometry has been extended to near-infrared wavelength range, from 700 nm up to 1100 nm, with a Titanium:Sapphire laser pumped with a high power solid-state laser at 532 nm.

The national SI standards of luminous intensity (candela), illuminance (lux), luminous flux (lumen), luminance (candela per square meter) and luminous exposure (lux second) are realised and maintained.
Research activity concerning the characterisation of devices (light sources, luminaries, glazing units, light sign, etc.) or components (retroreflectors, lamps, etc.) is carried out using state of the art laboratories. The aim is to investigate performance parameters and criteria able to provide the lighting engineers of realistic and useful data for plant design and product development.
The research activity is concentrated in the development of innovative measurement techniques and in the reduction of measurement uncertainty. The main active fields of investigations are:

- new types of detectors for the absolute measurement of photometric quantities;
- new mathematical methods for the analysis of experimental data;
- mathematical simulation of laboratory environments for evaluation and reduction of the stray light contribution in measurement uncertainty;
- innovative calibration techniques for CCD luminance meters at high level of luminance and development of a measurement system for the luminance distribution of large surface luminaries and light sources;
- goniometric measurement methodology of BRDF (bi-directional reflectance distribution function) and BTDF (bi-directional transmittance distribution function) for characterisation of diffusing and translucent materials and retroreflector;

- characterisation of optical surfaces by light scattering techniques;
- large sphere systems for the characterisation of translucent glazing units.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?
Focus has been on the realisation of standards for quantities like photon number and photon flux at the highest accuracy level with particular attention to the growing field of quantum information.
1 - Quantum radiometry
Co-operation in research started under the framework of the EUROMET project Two-photon Metrology with European Institutions (NPL and CNAM) e with NIST on the application of entangled photon states to metrology, particularly on absolute sources of photon number from visible to infrared, on absolute measurements of the radiance of thermal sources in the spectral region from 0,8 mm to 15 mm by parametric fluorescence and parametric amplification, and on absolute and QND measurements of UV and IR photon number.
2 - Quantum information
Research has been devoted to new measurement methods for quantum cryptography, together with studies on decoherence effects and mapping of entangled photons for quantum cryptography and on quantum computation by photon number measurements. Experiments are on single photon sources based on parametric fluorescence.
3 - Novel detectors
Activity is focused also on detectors working at liquid Helium temperatures, as they showed to be the only ones able to spectrally resolve photons in the wavelength range from ultraviolet to infrared. ASI (Italian Space Agency) supports research activity on superconductive tunnel junctions (STJ) and transition-edge sensors (TES). The activity has been devoted mainly to the study of superconductive films of molybdenum, titanium, and bilayer of molybdenum-silver. With transition temperatures T_c around hundreds of mK and transition widths around a few mK, they are suitable for producing TES, i.e., devices that can be applied to photon counting with intrinsic energy resolution. The study of titanium films also enabled the interference of electron-phonon and electron-impurity scattering for films with low impurities level to be evaluated.
Besides low T_c materials, we also studied MgB_2 films. MgB_2, whose superconductivity was only discovered in 2001 (T_c=39 K), represents a valid alternative to standard cuprates at high T_c.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Fibre metrology - Photon metrology - Colour measurement

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Quantum communication – Colour measurement

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

Cupertino in research under EUROMET has been demonstrated successful not only for European NMIs but also for NMIs outside Europe. IEN is interested in co-operation in research on two main topics:

1. Metrology of entangled photons: We propose the development of a new generation of primary standards and measurement techniques in the realm of quantum states of photons. The focus will be on the exploitation of the main resources of quantum correlation and entanglement for providing highly accurate measurement standards for classical and quantum communications and optical device characterisation. The main objectives are to surpass the limitation of classical optics in ultra sensitive measurements of crucial parameters of industrial and scientific interest, and to quantify the add-on value to primary metrology. Results are expected on intrinsically absolute standard methods for single-photon technologies and quantum information.

2. Metrology for the safeguard of cultural heritage: IEN is active in the protection and conservation of the Italian cultural heritage to solve multidisciplinary problems about technology, provenance, and dating, as well as about restoring, exhibiting and conservation issues. Fruition of works of art over long period of time often requires lighting systems designed to assure conservation and colour rendering according to the author intention. These goals require the measurement of the chromatic characteristics of any particular of the work of art, in order to correct some possible changes versus time and reduce colour difference due to artificial light sources, and to support restorations programs and lighting design. Moreover, monitoring of some physical characteristics (colour, geometry, size of fissures) of object surfaces is of utmost importance in the field of conservation and restoration of works of art. In order to get effective results a high repeatability in the localisation of the test points is required. At present repositioning is a tricky task, usually performed by manual empirical procedures which can be time consuming and expensive. The project aims at the study of tools for restoration and safeguard with exploitation of multimedia technologies. It will identify suitable instruments and methods. The focus will be on the exploitation of the main resources of active vision systems and spectral analysis for providing highly accurate measurements, The main objectives are to surpass the limitation of classical methods in the measurements of crucial parameters of historical and artistic interest. Results are expected in:
   - Physical characterisation techniques, i.e. 3-D colour study and spectral reflectance, to recover technology, provenance and dating information concerning with archaeology materials.
   - Techniques and tools for the automatic acquisition of 3D object, and computer-aided photometry research and diagnosis, for recording, restoration and maintenance of the cultural heritage.
   - Development of illumination techniques and devices applied onto works of art to improve colour-rendering properties and optimise maintenance care.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organisations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organisation (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

CCPR-CIE: effective interactions, as many delegates to CCPR are also officers in CIE

CCPR-WMO: not in my knowledge

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

CIPM - CIE MOU Yes, I do

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

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14) Have you got any other information to place before the CCPR in advance of its next meeting?
NO

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Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The IFA activities in P&R have been strongly affected by the CIPM MRA because of the CMCs proposal and study.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

Benefits: The MRA has improved the inter-relation of the NMIs and it gives an opportunity to know the activities and capabilities of each other.
Disadvantages: A lot of work with the CMCs analysis and the Quality Systems.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

We understand the reorganization of the BIPM because economic reasons, but we are very disappointed for the CIPM election of the P&R labs to be closed.. Those are good laboratories with good instrumentation (two cryogenic radiometers) and very high level experts working in.

The closure of the BIPM laboratories of P&R rise a feeling in the metrology family as if this metrology area is less important as the other ones.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

The CCPR comparisons are the most useful activities of the CCPR for the metrology activities of IFA, because they are the main scientific and technological connections with the other NMIs.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

The inclusion of our laboratory's CMCs in P&R in the MRA database means the IFA is more known around the international metrology world. Also it is an important status in our country.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

A model for the quantum efficiency of photodiodes to interpolate and extrapolate their responsivity is under study.

A new facility for characterizing CCD cameras and detectors using a dye laser and a large integrating sphere has been built.

(b) spectral radiometric quantities

Improvement of UV measurements, extending the spectral range down to 200 nm from the 230 nm where it is at present the lower limit.

Studies on the variation of irradiance of standard irradiance lamps as they are horizontally oriented.

(c) photometric quantities

A new realization of the lumen has been recently finished, based on illuminance measurements obtained with a goniophotometer. Furthermore, a new standard for luminance is under development.

Transmission and reflection properties of membranes with nano-holes filled with a metal are being studied to obtain pass-filters for different wavelengths.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?
Optical fibres metrology:

A general project on measurements based on non-linear optics is under development. Within it, a method for mapping chromatic dispersion based on FWN and OTD.

Analysis of Brillouin scattering is in progress.

In addition wavelengths standards based on lasers or FWM plus acethylene cells have been development.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Measurement and calibrations related with the photobiological and photochemical applications of light.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Infrared radiometry (>2µm)
Very high temperature radiators
Visual display metrology
High power lasers
Synchrotron radiation.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

Metrological characterization of CCD cameras to be used as measurement instruments.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

There are not too many high level institutions or experts in P&R. Then the current situation of the interaction between the international organizations is correct.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

It could be a useful initiative.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

- J. Campos, A. Corróns, A. Pons, P. Corredera, J.L. Fontecha y J.R. Jiménez. “Spectral responsivity uncertainty of silicon photodiodes due to calibration spectral bandwidth”. Meas. Sci. Techn. 12, pg 1926-1931, 2001.
- C. Montes, J. Campos, A. Pons, F. Heredia. “Tristimulus weights functions to calculate musts color coordinates from 10nm bandwidth spectral data”. Proceedings of the 9th Congress of the AIC. Rochester, NY. (2001).

- M.L. Hernanz, M. Gonzalez, P. Corredera. “Zero-dispersion wavelength mapping in single-mode optical fibers using CW four-wave mixing”. Proceedings. OFCM-01. Cambridge. U.K. (2001).
- M. Gonzalez, P. Corredera, M.L. Hernanz. “Single-end measurement of PMD using the interferometric meted”. Proceedings OFCM-01. Cambridge. U.K. (2001).
- P. Corredera, M.L. Hernanz, M. Gonzalez and J. Campos. “Anomalous non-linear behaviour of InGaAs photodiodes with overfilled illumination”. Metrologia 40 (2003) S150-S153.
- J. Campos, A. Pons and P. Corredera. “Spectral responsivity scale in the visible range based on single silicon photodiodes”. Metrologia, 40 (2003) S177-S180.
- J.L. Fontecha, J. Campos, A. Corróns and A. Pons. “An analytical method for estimating correlated colour temperature uncertainty”. Metrologia, 2002, 39, 531-536.

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire

Replies by KRISS

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

As a part of MRA, the quality system was officially implemented. During the establishment of the quality system, we had a chance to examine our activities from all angles. Especially in Photometry and Radiometry, we have concentrated on establishing a quality control system for calibration services. When we are to develop a new calibration service item, we will design an appropriate quality control policy for the calibration before anything else.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?

Nothing special

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

We are sending unstinted praise about the Photometry and Radiometry activities at the BIPM, which have remarkably contributed to harmonize the standard in this field for a long time. We sufficiently understand the explanation that the BIPM should pave new way to support the emerging science and industry with a limited resource. Through a series of KCs and CMC reviews, competence of major NMIs is known mature enough for the NMIs to take the place of the BIPM in technical aspects. The impact of the shutdown of the Photometry and Radiometry activities would not be critical to advanced NMIs. Nevertheless, the impact could not be neglected in some countries that have not established their own standards and relied on the BIPM.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

We consider the intercomparison as the last safety pin of quality control in our calibration and testing service. A series of activities that have to be done to complete an intercomparison enables our staffs to enhance their competence.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

Until now, the CMCs listed in the database have not seriously affected authority of the calibration certificates published by us. However, the client who requires the certificate equivalent to the NMI assigned by their buyer is steadily increasing. To meet such client's requirements, the inclusion of CMCs in the database will be getting more important.

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities
(b) spectral radiometric quantities

Modification of spectral responsivity comparator
To improve spectral responsivity comparator in the visible and NIR, the translator selecting the reference detector and detectors under test was changed to speed up comparisons more than three times. A three-axis translator for uniformity measurement has been added in the comparator so that the responsivity and its uniformity can be simultaneously measured in an experimental setup.

(c) photometric quantities

Fabrication of radiometric apertures by diamond turning machine
KRISS started to use the radiometric apertures fabricated by a diamond turning machine to realize the luminous intensity standard from the spectral responsivity. The apertures are being supplied by a research institute in Korea under quality control of KRISS.

Construction of radiometric aperture measurement system
KRISS has constructed a radiometric aperture measurement system, which measures the area by superposition of Gaussian beams, whose principle was been proposed by HUT. The data produced by the system is now stabilized and accepted as the area standard of the radiometric apertures.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?

Peer review in photometry and radiometry
In order to meet the requirements of the MRA regarding quality systems, the KRISS arranged for a peer review of technical competence in photometry and radiometry from April 29, 2002 to May 2, 2002. The review was based on the services declared in the associated CMCs. Members of the peer review team were Dr. Jim Gardner(NML, Australia), Dr. Gan Xu(SPRING, Singapore), and Dr. Howard Yoon(NIST, USA). The peer review was conducted in accordance with the terms of reference identified by KRISS. The review was based on the technical requirements of the ISO/IEC 17025. Particular attention was devoted to traceability, uncertainty calculations, qualification of the technical staff, calibration methods and method validation, and records and reporting of calibration results. As the result of the review, it was the opinion of the review team that the KRISS has the competence and infrastructure to provide calibration services in photometry and radiometry. However, the review team made several comments and recommendations aiming at improving the technical basis of the capabilities listed in the CMC. Corective actions following the recommendations was completed and the reviewers confirmed that the corrctive actions are satisfactory.

Development of wavelength reference absorption cell – Acetylene ($^{13}C_2H_2$)

KRISS has developed the Certified Reference Material (CRM) for 1520–1550 nm wavelength calibration. Developed CRM is an optical-fiber-coupled absorption cell containing acetylene ($^{13}C_2H_2$) gas. This is the wavelength calibration transfer standard of KRISS based on acetylene in 1.5 µm region. It is intended for use in calibrating the wavelength scale of wavelength measuring instruments in the 1500 nm region. About 50 accurately measured absorption lines of the R and P branch of the $\nu_1+\nu_3$ rotational-vibrational band of $^{13}C_2H_2$ are located between 1520-1550 nm. We have measured the lines using the wavelength meter calibrated with the frequency stabilized laser (1560.5 nm) and certified the CRM wavelengths with an expanded uncertainty (coverage factor k=2) of ±0.0007 nm.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Nothing special

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry?

1. Development of more ideal trap detectors beyond the wavelength range covered by silicon photodiode trap detectors.
2. Radiometric determination of thermodynamic temperature of the newly developed metal-carbon eutectic points to contribute the future version of the International Temperature Scale.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?

KRISS has interest in construction of the absolute radiation thermometer that can be used to determine the thermodynamic temperature of high temperature fixed points under development like the metal-carbon eutectic points. Calibrating the thermometer requires a monochromatic, tunable integrating source whose spectral radiance has to be determined with the top-level uncertainty. The source consists of many kinds of lasers, of which only maintenance would be burden to a small-scaled NMI.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

No idea

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?

No idea

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

1. Seung Nam Park, Jung Chul Seo, Dong Joo Shin and In Won Lee, "Realization of a spectral radiance scale at KRISS," Metrologia, **40**(2003) S196-S199.
2. C.H. Kang, S.N. Park and S.W. Kim, "A non-contact precision measurement of radiometric aperture area by Gaussian bean superposition," Proceedings of the OSK Annual Meeting 2003, pp.254-256.
3. Dong Hyun Yun, Joon Lyou, Won-Kyu Lee, Ho Suhng Suh, and Han Seb Moon, Wavelength Measurement of $^{13}C_2H_2$ Molecule, Proceedings of the Photonics Conference 2002. Conference Edition Opt. Soc. Korea. Part vol.1, 2002, pp. 167-168.

14) Have you got any other information to place before the CCPR in advance of its next meeting?

None

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire: replies of METAS

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ? 2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

There are several benefits out of the MRA, it has
- allowed structuring the whole field of PR, it also helps to identify common problems.
- improved harmonization of the services offered by the different NMIs.
- stimulated a faster introduction of the quality managment system to our lab.

However no direct benefit in respect to customers (new clients) has been noticed.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

There are several impacts due to the BIPM decision to close its photometry and radiometry activities:
-Politically speaking, it sends some wrong signals. Radiometry is more important than ever in a large field of applications like optical radiation hazards (laser safety, UV protection), global environments monitoring (earth radiation, atmospheric pollution), new light sources (UV-LEDs, OLEDs, high power laser diodes, deep UV lasers).
- The scientific history of the (BIPM-)Candela gets lost, including the associated know-how.

From our point of view the decision needs more clarifications: What is the status of CCPR. Is BIPM willing to keep the secretariat for CCPR? Who will give (free) primary traceability to other (mostly small sized) NMIs? However there are no direct consequences for METAS (we are traceable to NLP and will have our own primary realization in near future).

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

METAS has participated at several CCPR intercomparisons. These intercomparisons are very important for a high level validation of the measurement capability of the laboratories. However, we estimate that the overall time spent for an intercomparison (i.e. between initiating the intercomparison and publishing the results) was up to now too long. A critical point in the way that intercomparisons are carried out is that the pilot laboratory has access to the results of the others before he has to publish its own results. Sending the results to a third party institution/office (not participating) would help to clarify this problem (a future role of CCPR secretariat?).

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

The CMC database allows for the specialist in one specific field to make a comparison for one specific service between the different NMIs. However, care should be taken by comparing the different fields (or even whole NMIs). It is also very difficult to make an assessment in respect to third party users (not NMI related) of the database. Up to now we never had a "new" client because of the database. The process to achieve an agreement on publishing CMCs entries was/is rather long.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

METAS has purchased a cryogenic radiometer (Cryorad II from L-2 Standard and Technology). In a first step the system will be used for laser radiation (Kr+,Ar+,HeNe-Laser line) covering a (discrete) spectrum from 350 nm up to 800 nm in combination with some newly built transfer standards (Si-trap detector, reflection type, with Hamamatsu S6337 photodiodes). Later, it is intended to use a monochromatic light source for continuous scanning and covering a larger wavelength range. The laser based system should be ready for use by the end of September 2003.

(b) spectral radiometric quantities

METAS has built a 16 channel-filterradiometer consisting of a set of interference filters. Bandpass filters were used for straylight rejection. The filterradiometer covers a spectral range of 300 nm to 1000nm. A reflection type Si-Trap detector is used for signal detection. The filters are mounted on a precision rotation table. The temperature is stabilized to 0.05°C by peltier elements. Figure 1 shows the spectral transmittance of the different channels and the spectral responsivity of the trap detector. The filter radiometer will be used for the new realization of the METAS spectral irradiance scale. As a validation of the system we compared measurements of a FEL-1000W irradiance standard lamp done by the filterradiometer to the calibration done by PTB (see Fig. 2). The spread of the deviation is below 0.4%. We made similar measurement on high current Polaron type standard lamps calibrated by NPL. However we found some unexplained inconsistencies.

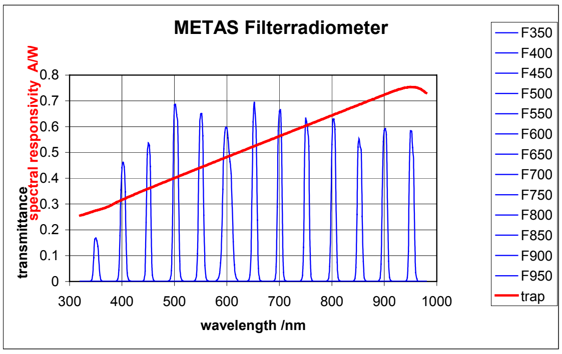

Fig. 1 spectral transmittance of the interference filter

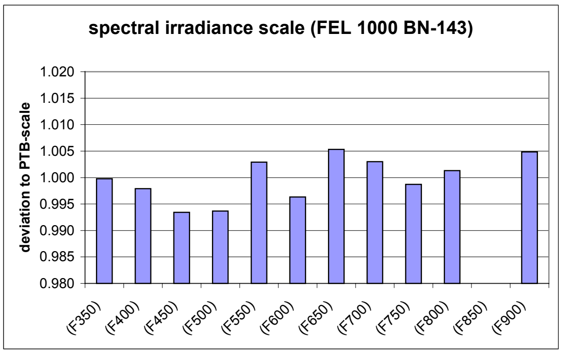

Fig. 2 deviation to the PTB scale

(c) photometric quantities

- New luminance standard consisting of a 25 cm integrating sphere, 4 light sources (20W, 2* 50W, 100W) and an internal photometer for monitoring the stability and long term drifts of the luminance standard. The 20W lamp has a mechanically variable attenuator.
- New flash measurement facility consisting of a fast photometer (2 µs raise time at 0.05 V/klx sensitivity range) and a high speed transient receiver.
- New 50 cm integrating sphere for photometric reflection and transmission measurements. The system allows different configurations (0/d,8/d included, 8/d excluded, d/d, regular).

(d) fibre optical quantities

-Realisation and validation of a measurement system for the calibration of the spectral attenuation of singlemode fibres.
-Realisation and full validation of an automated measurement system for power calibration. The main goals were to prevent from any contamination of the reference detectors during the mating process and to simplify the whole calibration.
- Setting up of an all-fibre optical low coherence reflectometer (OLCR). The system has a dynamic range of 120 dB and a spatial resolution of 10 µm.
-Uncertainty of wavelength calibration within the telecom wavelengh range has been reduced from 11 pm up to less than 1 pm (new reference wavemeter).
- Realisation and full validation of an automated measurement system for chromatic dispersion. METAS is initiating a EUROMET supplementary comparison on chromatic dispersion.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

METAS is changing its whole traceability scheme in the field of radiometry (see Figs 3 and 4). Up to now, we have three EUROMET traceability agreements with NPL. In a first step we will link the spectral irradiance scale through the filterradiometer to the spectral responsivity scale. Furthermore we will realize our own primary scale for optical radiation measurement by setting up a cryogenic radiometer facility. The next step will be to make our own realization of the fiber optical power scale by introducing a new kind of transfer detectors (to be defined). Finally, we would like to extent the wavelength range of our services down to the UV-C and up to the mid IR-B regions.

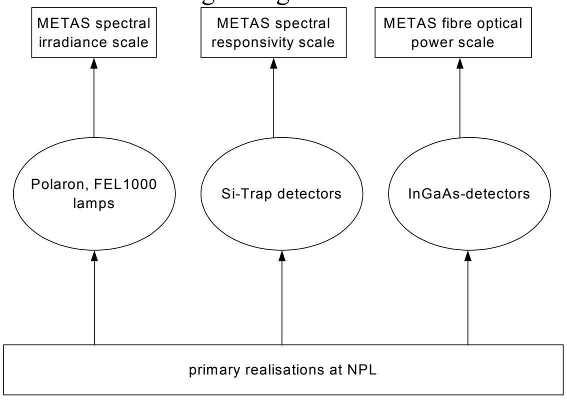

***Fig. 3** present traceability diagram for radiometric quantities*

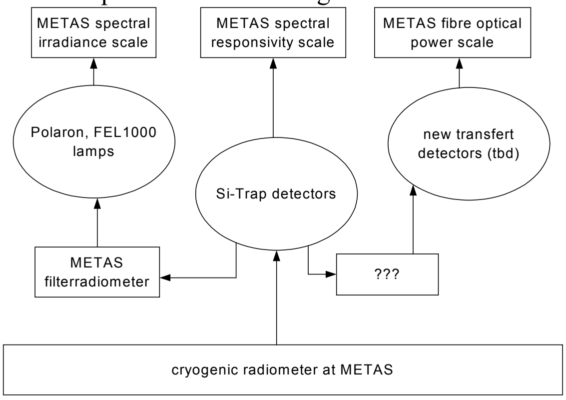

***Fig. 4** future traceability diagram for radiometric quantities*

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

In spite of the fact that BIPM is closing its activities in photometry and radiometry CCPR should continue its work. In particular measurement standards for photometric and radiometric quantities, coordination of key comparisons and CMC service categories. A future role could be that the CCPR secretary takes over part of the "administrative" work that the pilot laboratory has to do for key comparison (collecting the results, data processing, calculation of KCRV).

9) What priorities do you suggest for new research and development programs at NMIs in the area of Photometry and Radiometry ?

Every NMI has it own specialties and specific needs. It is up them to set up the priorities.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

We are looking for a partner for a cryogenic radiometer intercomparison at Kr+, Ar,+ and/or He-wavelength. If possible we would like start the intercomparison at the beginning of next year.

We are also seeking for collaboration for the realization of new transfer detectors for the fiber optics power scale.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programs and actual or potential duplication of efforts. 12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

Collaboration between different international institutions is important to coordinate research, exchange information but also to limit potential duplication of efforts. A formalized relationship may help to identify common topics and future goals, however it is not absolutely necessary. Technical and scientific exchanges is more important.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

-

14) Have you got any other information to place before the CCPR in advance of its next meeting?

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Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

MSL (New Zealand) Response to Questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

There has been a high cost in time, particularly in the first round two years ago, in preparing submissions of CMCs for Table C, in responding to queries and supplying further material and in participating in the regional refereeing process. This impacts disproportionately on smaller NMIs. This work has given us a better overview of our capabilities and a clearer understanding of how they compare with other NMIs but at the same time it did reduce the technical effort available for maintenance and development of standards.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

The major benefits include an acceptance of equivalence of our measurement scales. The process has increased the confidence of both ourselves and our clients in our scales. In addition, where clients are using reports traceable to other NMIs, the process has increased the confidence of both ourselves and our clients in the measurement scales of the NMIs to which those reports are traceable. We are in contact with clients encountering regulatory difficulties in international markets and the MRA will allow them to make better use of the traceability we provide. The disadvantage, or potential disadvantage, is that some New Zealand laboratories may obtain traceability overseas and this will weaken us as an NMI.

It has been our experience that, despite or perhaps because of the many documents circulated, the criteria for acceptance of CMCs are not well defined and are variously interpreted. In addition the path to be followed in gaining acceptance of CMCs has been ill defined and time consuming. Further improvement in processes here is desirable. The number of subcategories of capabilities on the VIM appears excessive. This and a desire to create separate entries for different uncertainty values or for each measurement condition or independent variable has led to a proliferation of entries in some CMC tables. The resulting tables are fragmented and not user-friendly.

3) Given the announcements on the restructuring of the BIPM and the ***attached*** *explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.*

The closure of this BIPM section has not helped the standing of Photometry and Radiometry in our NMI; it tends to send a message that other activities are more valuable. We have valued the involvement in international metrology of people of high technical competence who are independent of a national or regional agenda. In particular we have valued the work BIPM has done as a pilot laboratory in comparisons; in this they have been more successful at keeping comparisons on schedule than almost all others who have volunteered to take on the role of pilot laboratory.

The contraction or freezing of effort in physical metrology in order to put more resources into chemical metrology can be seen, albeit in a less dramatic form, in the New Zealand measurement system.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

We place a high value on participation in intercomparisons. They have been valuable in demonstrating our competence in several areas and also in one or two in demonstrating problems. The principal merit is that we can demonstrate to those to whom we provide traceability that our measurement scales are equivalent those of other countries and their clients can use this in their international activities.

The present process has shortcomings:

- It is under-resourced both at the pilot lab level and the NMI level. This leads to constant slippage of timetables.
- The uncertainty over timing creates difficulty for us with our funding agency in that we need to be able to predict 15 months ahead what we will complete in a contract year.
- There is a conflict between the obvious fact that for a fair comparison there can be no retrospective adjustment of scales or measurements yet if a comparison does disclose a problem in a scale or measurement procedure and the scale is amended to correct the problem it is the compared scale rather than the revision that goes on the public record; and there it remains for the rather long time that it takes to go through a further bilateral comparison and then gain the approvals needed for the revised scale to be entered into Table C.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

To the extent that capabilities have been included in Table C, we are now in a position to claim equivalence of our measurements to those of other NMIs when that is called for by overseas regulatory agencies. This has been a particular issue with the FAA and to a lesser extent with the FDA and various bodies in the European Union. In this connection it would be desirable if NMIs could persuade agencies in their country to require traceability to the MRA rather than to the national NMI, particularly when the agency's requirements impact on entities in other countries.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

Extension of the spectral responsivity scale so that it now provides traceability for radiometers used to monitor germicidal lamps around 254 nm.

(b) spectral radiometric quantities

Purchase of a UV laser and its use for UV spectral responsivity calibrations at 351 nm and 362 nm. Work has also been done with NPL in the calibration of 3 detectors over the range 254nm to 364 nm. The spectral response scale has been re-realized in the UV to remove an error in measurement practice that resulted in a minor stray light problem in the 1993 scale.

The spectral irradiance scale, which is traceable to NIST, has been strengthened by the purchase of three more calibrated lamps in 2001 and 2002.

(c) photometric quantities

All measurements for a further realization of illuminance responsivity on our standard photometers have been completed and the scale re-realization is nearly complete.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

Spectrophotometry: new scale of diffuse reflectance realized with traceability to NIST through standards of diffuse reflectance from 0.05 to 0.99. This scale was compared with that at HUT with good agreement at 0.99 but with differences at lower reflectances. Subsequently we have commissioned a larger integrating sphere but measurements with it do not significantly reduce the observed differences with HUT and these remain the subject of continuing investigation.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

More needs to be done within New Zealand to make users aware of the MRA and of how it affects their international trading. It is suggested that it might be more efficient, particularly for smaller NMIs, if publicity material on the MRA were to be prepared centrally by the BIPM. Such material might also carry more authority coming from BIPM.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

We would be interested in extending the modeling work done here on the internal quantum efficiency of silicon diodes further into the UV including attempts to understand and model photodegradation.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

There are a number of very able people who involve themselves in the affairs of both CCPR and CIE and this has facilitated an effective relationship between these two organizations. We see confusion over traceability in some of our clients working in meteorology and this suggests to us that there is work to be done in better defining the respective roles of CIPM and WMO and disseminating this information.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

The relationship between CIPM and CIE is a little different from the others listed in that the CIE has much more capability in the technical side of measurement than WHO,WMO or ILAC. Indeed in photometry CIE contribute significantly, through the definition of the photopic response function, to the “effective” definition of a primary unit. This greater capability increases the need for an effective demarcation of roles and makes it more difficult. It would be useful to explore the possibility of defining the relationship in an MOU.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

J F Clare. 2002. *Correction for nonlinearity in the measurement of luminous flux and radiant power*. Measurement Science and Technology; vol. 13, pp. N38-N41.

J F Clare. 2002. *A study of instrumental nonlinearity in measurement scales for the directional/hemispherical reflectance of diffusely reflecting surfaces*. Industrial Research Limited; Report no. 1077, 11pp.

G J Smith, I J Miller, J F Clare and B L Diffey. 2002. *The effect of UV absorbing sunscreens on the reflectance and the consequent protection of skin*. Photochemistry and Photobiology; vol. 75, pp. 122-125.

J F Clare. 2001. *New approach to nonlinearity corrections in spectrophotometry*. CORM 2001 Meeting; Gaithersburg, MD, USA.

K G Ryan, G J Smith, C L Dunford and J D Hamlin. 2001. *NIWA 2000/2001 Report: Solar UV radiation in centers of population.* Industrial Research Limited; Report no. 56110.05.

J F Clare. 2001. *Roof glare: how do we measure nuisance?*. 46th IESANZ Convention; Auckland, New Zealand.

P Saunders, A Trotter, H Edgar and D M J Cochrane. 2001. *In situ measurement of catalyst tube emissivity by means of a portable solid integrating sphere reflectometer*. Measurement Science and Technology; vol. 12, pp 622-626.

14) Have you got any other information to place before the CCPR in advance of its next meeting?

No.

The following is the reply from **NIM** to the CCPR questionnaire:

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

Both our institute and division pay much more attention to inter-comparisons now and recognize the importance of inter-comparisons than ever before. And it urges us to setting up a quality system in accordance to ISO 17025 which is a good reinforcement in some aspect to the existing system we have already had for many years. It also pushes us more actively involved in RMO activities. It accelerates improvements of top-level standards in photometry and radiometry.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

It almost has covered all aspects in the field of Radiometry and Radiometry. How about broaden to wider an area which is not traditionally included in CCPR scope?

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

As a neutral technical center in Photometry and Radiometry, BIPM played such an important role that there is no substitution. It will be very inconvenient for NMIs traced to BIPM. It may make governments and institutes feel that Photometry and Radiometry is less important than other fields in metrology, which is not good for development of Photometry and Radiometry.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

It shows the importance of relative quantities and standards to NMIs. It is a good opportunity checking measurement uncertainty, and a good way to find error source if there is.
The shortcoming of current processes is that it sometimes takes too long time. How about devising some simplified comparisons taking shorter time.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

In principle it should give our customer more confidence on our measurement result and attract more customer. But it does not appear so up to now.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

Improvement on cryogenic radiometer system has just started. New electrically calibrated radiometers have been developed for laser power and laser energy standards at high power or energy level.

(b) spectral radiometric quantities
Primary standard for spectral radiance and spectral irradiance is being improved. Spectral responsivity standard has been re-established in VIS and IR spectral range.

(c) photometric quantities
Standards for illuminance and total luminous flux have been improved. Standard for luminance has been re-established.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

LED and measurement equipment calibration□measurement equipments for optical communication□CCD measurement□spectral range expansion for reflectance and transmittance calibration□high level laser power and high level laser energy measurement technique and calibration method, spectral standard based on synchrotron radiation.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Material damage-threshold to laser beams.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?
Characterization of new light source and display, UV measurement and high power laser measurement.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

None

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.
No comments

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

No comments

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

1. Dai Cai-hong, Yu Jia-lin, Yin Chun-yong **Experiment analysis of correlated color temperature and distribution temperature of the source** *Optical Technique (Chinese)* Vol.29, No.3 May, 2003, p344-346
2. Dai Cai-hong, Yu Jia-lin **Determination high temperature of blackbody using monochromatic radiance ratio method** *Optical Technique (Chinese)* Vol.28, No.3 May, 2002, p250-252
3. Liu Jin-yuan, Xue feng-yi The UV and VUV spectral radiation standard lamp-**deuterium lamp** *Measurement technique (Chinese)* 2002.3 p19-21
4. Lin Yige, Ma Yu, Chen Xiaju **Discuss Spectral Diffuse Reflectance Measurement in the d/0 Geometry** *China Illuminating Engineering Journal (Chinese)* Vol.13, No.4, Dec. 2002, p1-4
5. Li Ping, **UPF Evaluation of textile materials**, *Modeern measurement and test (Chinese),* 2001.5
6. Yao He-Jun, Lu Zheng, Lin Yan-Dong, **Facility development of optical detector non-linearity measurement,** *Modeern measurement and test (Chinese),* 2001.9

14) Have you got any other information to place before the CCPR in advance of its next meeting?
None

NIST Gaithersburg and Boulder Responses to CCPR Questionnaire
For Preparation for the 17th CCPR Session

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs?

The requirements of the MRA has increased our emphasis on bilateral comparisons. Given the time lag between CCPR organized intercomparisons and the increased importance of demonstrated technical competencies, the bilateral activities are a more direct, more efficient means of accomplishing the comparisons. The requirements of the MRA, including submitting and reviewing CMCs, havetaken a considerable amount of staff time and has resulted in a change in priority in some of our programs.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?

It is probably too early to assess the advantages of the MRA in terms of its impact on trade and to judge its benefits to our customers, however there is potential for substantial benefit once all the activities are complete to compile the CMCs and obtain their recognition. We need to speed up the process of getting the CMCs approved and remove the arbitrary and conflicting obstacles to getting approval of the various regional metrology groups submissions. In the field of P&R we seem to be demanding a direct linkage to a KC for a readily accepted CMC. This is in direct violation of the JCRB advertised guidelines and procedures. We feel it is imperative for the various groups involved in setting policy for CMCs to coordinate and rationalize their participation.

3) Given the announcements on the restructuring of the BIPM and the attached **explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.**

The inability of the BIPM to participate in Key Comparisons, and assume the responsibility of the pilot laboratory when appropriate, will have a deleterious effect on the ability of the CCPR members to carry on a vigorous system of comparisons. The work previously done by the BIPM staff will not necessarily be assumed by the CCPR member laboratories as many of them, NIST included, do not have additional resources to apply to this endeavor. Consequently the breadth and frequency of the Key Comparisons will necessarily diminish. The course chosen by the BIPM to move in new directions in chemistry in an indirect support of the mole comes at the expense of the BIPM divesting itself of a capability in doing research and measurement advancement in one of the fundamental SI units, the candela. Whether the BIPM can make any contributions in a field that requires considerable laboratory presence, such as analytical chemistry, remains to be demonstrated. The issues involved in the typical problems of chemistry, such as trace gas concentrations, are basically ones of experimental technique and procedure and are not ones of fundamental physical or chemical standards for which the Treaty of the Meter was envisioned. Only time will tell whether this redirection of resources is a positive managerial decision that is beneficial to the World's metrology community.

4**) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.**

NIST Gaithersburg response :
A tremendous amount of effort goes into the organization and management of an intercomparison for the pilot laboratory and the outcome may be judged by some to not justify the expense of time and labor expended, particularly since the final report is no longer published in the traditional format. The expense involved makes it incumbent upon the CCPR to carefully chose its selection of KCs to ensure that scarce resources are wisely expended that and the result justifies their committment.

NIST Boulder response:
International intercomparisons are invaluable for evaluating measurement reproducibility within and across laboratories, for identifying inconsistencies, and for defining uniform measurement procedures. The data from these intercomparisons helps industry to place meaningful, qualified bounds on uncertainty estimates.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.
Since many of our CMCs have not been included in the database, our assessment of the value is not meaningful at this time. Again the effort that has been expended is extensive and yet the outcome is uncertain. Many of the rules of inclusion were not and have not been determined or seem to be in conflict with the JCRB guidelines. In particular, early on in the process we submitted all our CMCs and subsequently the CCPR decided to organize the submissions into three separate parts to be considered sequentially. Even now not all our round 1 submissions are currently included in the MRA database due to controversy over details of wavelength/uncertainty dependence: too much detail/not enough detail.

6) Summarize the progress in your laboratory in realizing top-level standards of:
Responses from NIST Gaithersburg :

(a) broad-band radiometric quantities:

New Reference Colorimeter :
We have constructed and are presently testing a new reference instrument for measuring the reflectance color of materials. This project was undertaken in response to industry and government demands for improved color measurements and standards, as articulated in the 6th and 7th Reports of the Council for Optical Radiation Measurements (CORM). Improved color standards are required to ensure better color matching of products manufactured at different sites. Because the color of a product often plays a major role in its acceptability, color measurements and standards are extremely important to industry.

Our new instrument performs measurements for all possible combinations of illumination and viewing angles, including the standard 0º/45º and 6º/diffuse geometries, allowing the complete characterization of the reflectance properties of an object. The popular 0/45 measurements are highly automated through a sample wheel with a capacity for 20 samples.

We did a complete uncertainty analysis, considering wavelength accuracy, stray-light rejection, reproducibility of sample positioning, and signal noise. A critical aspect of the analysis was the inclusion of the statistical correlation between signals at the same wavelength and between reflectance factors at different wavelengths.

(b) spectral radiometric quantities:

Spectral Irradiance and Radiance Responsivity Calibration with Uniform Sources (SIRCUS)
The facility has been developed and is already being used for fundamental scale realizations in radiometry and photometry as well as calibrations of practical radiometers at NIST. The facility is composed of a number of tunable lasers, beam stabilizers, wavemeters, and integrating spheres, producing purely monochromatic, Lambertian, uniform irradiance and radiance at sufficiently high levels. Irradiance and radiance responsivities are currently determined against trap detectors (with calibrated aperture) that are traceable to the High Accuracy Cryogenic Radiometer. We have three SIRCUS facilities. The UV-VIS-NIR SIRCUS is now operational covering from 350 nm to 1000 nm, and is to be expanded to cover the 200 nm to 2500 nm range. The currently estimated uncertainty is 0.15 % (k=2) for irradiance responsivity and 0.24 % (k=2) for radiance responsivity measurements. A dedicated Absolute Cryogenic Radiometer (ACR) is being introduced to provide the power and irradiance responsivity scales directly to SIRCUS to extended the wavelength range and reduce the uncertainties. Another SIRCUS for the infrared range is being developed to make power, irradiance, and radiance responsivity measurements between 2.0 μm and 20 μm. A Traveling SIRCUS has also been developed for use at remote locations to characterize instruments for remote sensing applications (see an article below).

Improved Modular Radiometer/Photometer System :
A new generation photo/radiometer system has been established to realize and propagate the high accuracy detector-based scales in the Optical Technology Division. The devices can measure radiant power, irradiance, radiance, luminous flux, illuminance, and luminance. The new radiometers are modular systems. The detectors can be cooled to improve the noise performance and the stability of the meters. Filter packages, positioned in front of the detectors, can be heated slightly above room temperature to ensure stable spectral transmission without condensation. The temperatures of both the detector and the filter are regulated by two independent analog control loops. Nitrided Si, Si, Ge, InGaAs, and extended InGaAs photodiodes are positioned behind the different filter and diffuser combinations to cover the spectral regions from the Ultraviolet to the Near Infrared. The input optics of the radiometers can be modified easily for measurements of photometric quantities. The photocurrent from the photodiodes is measured with a detachable electronic unit. The current-to-voltage converters of the electronic units were optimized for noise performance in both dc and ac signal measurement modes. Photocurrents between 0.01 fA and 10 mA can be measured. The typical relative standard uncertainties of radiometric and photometric measurements using the new standards are 0.1 % (k= 1).

Detector-Based Radiance and Radiance-Temperature Scales :
Converting to detector-based scales has reduced the uncertainties of the present, NIST source-based, spectral-radiance and radiance-temperature scales. These scales are tied to an absolute imaging pyrometer (AP1). We calibrated its absolute radiance responsivity at the SIRCUS facility, using a tunable, laser-illuminated integrating sphere as the source of spectral radiance. The spectral radiance is traceable to silicon trap detectors calibrated for absolute power responsivity against HACR and a set of apertures of known area to define the geometry.

Measurements performed with AP1 of the freezing point of a high-emissivity blackbody cavity in contact with molten gold reveal a noise-equivalent temperature of 2 mK (k = 2) at 1337 K. The total uncertainty of the measurements, about 120 mK (k = 2) at this temperature, is due to the combined uncertainties arising from the radiance-responsivity calibrations, the size-of-source effect, and the long-term stability of the pyrometer.

In concert with the AP1 development, we have performed radiance-temperature measurements of a 2950 K high-temperature blackbody (HTBB), comparing both conventional source-based and newer detector-based measurement methods. The source-based approach uses measured radiance relative to a gold-point, fixed-temperature blackbody to assign the temperature to the HTBB as prescribed by the International Temperature Scale of 1990. The detector-based approach uses a set of filter radiometers to assign a temperature to the HTBB. Their spectral-irradiance responsivities are traceable to the HACR optical-power scale through the

Division's Spectral Comparator Facility. The spectral-irradiance responsivities are converted to spectral-radiance responsivities by an appropriate choice of precision apertures and measurement geometries. The aperture areas required in the analysis are determined using an optical coordinate-measuring machine. The net result: we demonstrated a detector-based temperature uncertainty of 0.21 K (k = 2) at 3000 K, more than a factor of six better than the source-based approach.

SURF III as an Absolute Source of Spectral Irradiance :
An experiment was undertaken to verify that the absolute spectral irradiance from the NIST Synchrotron Ultraviolet Radiation Facility (SURF III) can be predicted using the Schwinger relativistic electrodynamical model for synchrotron radiation and knowledge of the electron-beam energy, current, and radius.

The study was performed on Beamline 3, recently developed for absolute, source-based, ultraviolet radiometry at SURF III. The measurements consisted of characterizing the angular spread of the radiation from SURF III in the direction perpendicular to the orbital plane of the electron beam. Because of the highly relativistic speed of the electron beam, the angular spread is narrowly confined to within a fraction of a degree of the orbital plane. Narrow-band filtered radiometers, with spectral responsivities measured to 0.1 % relative uncertainty (k = 2) at the SIRCUS facility, were used to directly measure the radiation emitted from a tangential source point of the ring, from the near ultraviolet to the infrared.

The experiment demonstrated agreement with theory to within 0.5 %. Such excellent agreement not only confirms the Schwinger theory, but it also connects the detector-based spectral-irradiance scale, based on SIRCUS and cryogenic radiometry, to the source-based scale of SURF III. The study further validates Beamline 3 as a broadband standard of spectral irradiance for the absolute calibration of optical instruments and for the calibration of deuterium and FEL incandescent lamps as secondary or transfer standards.

(c) photometric quantities:

Realization of the candela using SIRCUS
Re-realization of the candela utilizing SIRCUS is in progress. The modular Radiometer/Photometer system (see below) as well as several other standard photometers are being measured at SIRCUS and with the conventional Spectral Comparator Facility to evaluate the new scale. The uncertainties of the illuminance unit and the candela are expected to be reduced by a factor of two.
Tunable LED-based Integrating Sphere Source:
We have developed a prototype tunable LED-based integrating sphere souce for calibration of instruments (both spectrographs and filter radiometers) used for ocean color measurements. The integrating sphere is equipped with 40 channels of different LED's with spectral distributions ranging from 380 nm to 600 nm to mimic ocean color spectra. By varying the drive current of the individual LED's, the sphere spectral radiance can be tuned to match a particular target spectrum. The source can be used to calibrate the instruments directly, reducing calibration errors arising from stray light for example, or to examine measurement errors as the spectral distribution of the source is changed to develop spectral correction factors for these ocean color instruments. We are also developing another LED sphere source to cover the entrie visible region, intended for calibration and characterization of display colorimeters and spectroradiometers.

NIST Boulder Response:
Progress in realizing top-level standards:

- Reduced expanded uncertainty in excimer laser calibrations to 1 %

- Reduced expanded uncertainty of C-series calorimeter measurements to 0.5 %
- Completed documentation for Laser-Optimized Cryogenic Radiometer with expanded uncertainty of 0.02 %

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?
NIST Boulder Response:

1. Developed a high-NA optical trap detector for use as a transfer standard for fiber optic power measurements. The detector has a field-of-view of 30 degrees, and can use either silicon or germanium detectors, to provide spectral coverage from 450 nm to 1800 nm.

2. Developed a calibration service for 157 nm excimer laser power and energy measurements.

3. Developed measurements of detector nonlinearity for 193 nm excimer lasers and optical fiber power meters.

4. Developed a measurement for full vector frequency response (both magnitude and phase) of photoreceivers to 110 GHz.

5. Expanded the continuous tuning range (using a tunable laser system) for laser and optical fiber power measurement to wavelengths between 500 nm and 1050 nm.

6. Began development of single-photon sources for improve radiometry. We recently demonstrated photon-on-demand emission from an optically-pumped quantum dot.

7. Established a calibration service for relative intensity noise

8. Increased power of optical fiber power measurements to 500 mW. There are no new needs of users that are not being supported by current CCPR activities. On a tangent with the key comparisons, a uniform approach to handling the uncertainties reported by the labs would be helpful. This could take the form of an agreed-upon table of uncertainty components prior to the start of the comparison. At present, the manner in which uncertainties are reported is left up to the pilot laboratory.

9. Developed the following measurements and standards for fiber optics:
   - A new Standard Reference Material for non-mode-coupled polarization mode dispersion (PMD)
   - A Measurement Assurance Program for polarization dependent loss (PDL)
   - Two new Standard Reference Materials for wavelength calibration over the telecommunications L-band
   - Improved capability of relative group delay measurements to 150 fs resolution

10. Completed an intercomparison with Physikalisch-Technische Bundesanstalt (PTB) of optical fiber power measurement. Measurement results showed differences of less than 1.5 parts in 10^3, well within the combined uncertainty for both laboratories

11. Developed a measurement system for characterizing the spectral responsivity and spatial uniformity of optical fiber power meters.

NIST Gaithersburg Response

Validated Heat-Flux Sensor Responsivities Using a Spherical Blackbody

The Division has been researching new methods to accurately determine the radiative responsivities of heat-flux sensors, widely used in fire and aerodynamic tests of aerospace vehicles and components. Comparison of radiative heat-flux measurements between various laboratories using a variety of different techniques reveal that presently claimed responsivities vary by as much as 15 %. Studies at NIST indicate, however, that the sensor responsivities are stable and reproducible to better than 1 % over a period of several years. The calibration method developed by the Division uses an electrical substitution radiometer to determine the absolute heat flux at the sensor from a cylindrical heat-pipe blackbody (detector-based method) and has an expanded uncertainty of 2 % (k = 2). To validate this detector-based method, the Division has developed a totally independent source-based calibration procedure in which a sensor is plunged into a 0.23 m diameter high-temperature spherical blackbody, as shown in fig. 1, and the heat flux is directly calculated using the Stefan-Boltzmann equation. This approach also yields a responsivity with an expanded uncertainty of 2 % (k = 2). Sensors calibrated using the two approaches give responsivities that agree to within 2 % (k = 2), validating the two methods. The availability of accurate heat-flux sensor calibrations from NIST allows sensor users and manufacturers to better assess the performance of their calibration methods and offers validated calibration procedures for implementation by other laboratories.

Radiometric Calibration of the NIST Advanced Radiometer (NISTAR) and Earth Polychromatic Imaging Camera (EPIC) for the TRIANA Satellite

OTD has completed the radiometric calibration of two instruments, NISTAR (NIST Advanced Radiometer) and EPIC (Earth Polychromatic Imaging Camera), both planned for deployment on the Triana satellite. The Triana satellite, after launch by the Space Shuttle, is to be positioned in an orbit at the Lagrange-1 point to allow continuous monitoring of the sunlit Earth. NISTAR will measure the absolute irradiance of the Earth while EPIC will provide hourly, spatially resolved measurements of cloud properties, ozone concentration, and aerosol levels of the Earth's atmosphere.

NISTAR, originally designed by NIST, was calibrated at NIST using the capabilities of the Division's Spectral Irradiance and Radiance Calibrations with Uniform Sources (SIRCUS) facility. During the tests, NISTAR was illuminated to mimic its view of the Earth from space. The resulting relative uncertainties on the calibration are below 1 %. The NISTAR instrument has since been delivered to NASA's Goddard Space Flight Center and integrated onto the Triana satellite.

The bulk of the EPIC radiometric calibration was performed during thermal and vacuum testing of the instrument at Lockheed Martin in Palo Alto, California in December 2000, with additional, final measurements performed in October 2001 at the Goddard Space Flight Center. The intense, multi-day calibration effort required the unique radiometric expertise of NIST staff, specialized calibration sources and detectors, on-site evaluation of results, and modifications to the initial calibration plan when circumstances or scheduling changed. Preliminary results have already been made available to the mission science team.

Radiometric Calibration of the Marine Optical Buoy (MOBY)

The Division is providing radiometric calibration of the Marine Optical Buoy (MOBY) to ensure the accuracy of the measured down-welling irradiances and ocean-leaving radiances used to calibrate or validate ocean-color measurement satellite instruments, such as the Sea-Viewing Wide Field-of-View Sensor (SeaWifs) and the Moderate Resolution Imaging Spectroradiometer (MODIS). The Division is supporting the radiometric calibration of MOBY by both traveling to the deployment site in Hawaii to perform calibrations of the buoy and by developing standards and methodologies to directly calibrate and test a duplicate MOBY spectrograph at NIST. This spectrograph, denoted MOS for Marine Optical System, was characterized at NIST using SIRCUS, in response to concerns about stray or scattered light causing significant errors in the instrument readings, particularly at shorter wavelengths (see fig. 3). The success of the SIRCUS measurements led to the development of a "Traveling" SIRCUS to allow direct calibration of the MOBY instrument in Hawaii using the Division's laser-based monochromatic radiance sources. The improved calibration of MOBY is allowing the correction of the legacy ocean radiance and irradiance data, which is being made available to researchers dependent on these measurements. The project has also demonstrated the unique advantages of using SIRCUS for the calibration of remote sensing instruments.

Traveling SIRCUS

The Division is actively involved in providing radiometric calibration for remote sensing satellites. It is often desirable to be able to perform the calibrations at the customer's site, typically an aerospace company or a NASA or DoD facility, either because of the instruments large size or fragility, scheduling constraints, or special clean-room or environmental limitations. To be able to provide the highest accuracy spectroradiometric calibrations requires that we bring the capabilities of SIRCUS, i.e., broadly tunable single-frequency radiance and irradiance standards, to these sites. We are presently developing such capabilities in the visible and near infrared, which we are calling Traveling SIRCUS. Upon completion, Traveling SIRCUS will consist of Ti:Sapphire and dye lasers pumped by a solid-state diode-pumped laser, a small Ar-ion laser, a solid-state frequency doubler, and integrating spheres, providing a monochromatic source of continuous spectral radiance from the ultraviolet to the near-infrared, that is, from 350 nm to 980 nm. While at NIST, the system is used as a research tool to advance the capabilities of SIRCUS, as the present SIRCUS instruments are frequently unavailable due to the calibration workload. The initial deployment of Traveling SIRCUS was made recently at the MOBY site in Hawaii.

Calibration of Light-Pipe Radiation Thermometers for Applications in Rapid Thermal Processing (RTP)

To help improve temperature measurements in semiconductor RTP, the Division has undertaken extensive research on light-pipe radiation thermometers (LPRT's) and their calibration. The goal of the RTP program is to enable the semiconductor industry to achieve temperature measurements of better than 2 °C at 1000 °C, a goal stated in the Semiconductor Industry Association roadmap. Improved LPRT measurements are essential to achieving this goal, as they are the predominant temperature measurement instruments in RTP. The Division's research has led to a calibration protocol and a set of recommendations to ensure accurate temperature measurements with LPRT's.

Expanded uncertainties of 0.6 °C ($k = 2$) were achieved for the calibration of LPRT's for radiance temperature near 1000 °C. The radiance temperature standard was a well-characterized, high-emissivity, sodium-heat-pipe blackbody, as shown in fig. 4. To be useful in applications, LPRT's must retain their calibration over a long period of time to limit the down time of the RTP chamber. Short-term, 10 min variations in the sensor response were found to be less than 0.1 °C, while long-term, 1 yr variations in the sensor response were less than 1 °C. These measurements indicate that LPRT's are capable of making temperature measurements to within 1 °C. (C. Gibson, F. Lovas, and B. Tsai,)

Intrinsic Birefringence in CaF_2

Deep ultraviolet photolithography technology has turned to crystalline CaF2 for the next generation of refractive optical elements because of the poor transmission of glasses at 193 nm and 157 nm. Despite the cubic symmetry of CaF2, its crystalline nature introduces spatial-dispersion-induced birefringence, which results from the finite wave vector of the light. Measurements made in this Division and the Atomic Physics Division were supported with theoretical calculations performed in collaboration with the Electron and Optical Physics Division. We have successfully modeled it in CaF2, BaF2, and several semiconductor materials from first principles, obtaining good agreement with all measurements.

Our main results are presented in fig. 5. Our key findings are as follows. First, the birefringence in CaF2 is about ten times larger than specifications desired by the semiconductor industry. Second, the birefringence in CaF2 is opposite in sign from that in BaF2 and many other materials. Third, a mixed CaxBa1-xF2 crystal may exhibit zero birefringence at chosen wavelengths by tuning x.

High-level UV Irradiance Calibration

We have calibrated the irradiance responsivity of a diode array spectrophotometer designed to measure the irradiance at the exit port of an advanced xenon-lamp-illuminated integrating sphere source (BFRL). The 2 m diameter-integrating sphere was designed for accelerated UV aging studies of advanced materials over the spectral range from 290 nm to 400 nm, with irradiance levels at the sphere exit port calculated to be as high as the equivalent irradiance from 30 suns. A fiber-coupled diode array spectrophotometer, equipped with an integrating sphere fore optic, is used to calculate the irradiance at an exit port.

We used a collimated laser source to determine the spectral power responsivity of the spectrophotometer as several wavelengths over the 300 nm to 400 nm spectral region. We then determined the effective aperture area of the input fore optic, and averaged the response over the entrance aperture, to establish the irradiance responsivity. To obtain an estimate of the responsivity over the entire spectral range from 300 nm to 400 nm, we measured the output of a Xe arc lamp using a reference standard filter radiometer, and interpolated the radiance between filter radiometer tie points. This relative measurement was subsequently scaled at 334 nm to obtain a measure of the absolute spectral responsivity of the spectrophotometer. (S. Brown and E. Bryd, with J. Chin, Div. 862)

Improved Low Background Infrared Facility (LBIR) Broadband Blackbody Calibrations
The LBIR broadband blackbody calibrations can now be performed at 1 nW power levels with 1 % Type A (random contributions) uncertainty. This achievement is a direct consequence of improvements in background environment stability and the use of the new LBIR Absolute Cryogenic Radiometer (ACRii), and corresponds to a factor of 10 improvement in power measurement capability. A new refrigerator system with greater cooling capacity and better temperature stability is partially responsible for the improved background environment. The calibrations are also now being performed in the newer Spectral Calibration Chamber (SCC) with its more efficient cryoshrouds. These improvements have changed the background environment from 25 K with a relatively common 0.1 K drift in temperature in a 10 minute period, to a 17 K environment with drifts in temperature of less that 0.01 K over a 10 minute period. The electronics-limited 10 pW sensitivity of the ACRii can be fully used in the new stable environment. This can be compared to the use of the older ACR in the Broadband Calibration Chamber (BCC) where the noise floor was 100 pW at best. These improvements have made it possible to meet most of the recent calibration requirements for the blackbody sources from the aerospace contractors of the Ballistic Missile Defense Organization (BMDO).

LED Luminous Intensity and Luminous Flux Calibration

Calibration capabilities for light-emitting diodes (LEDs) have been established at NIST. A calibration system for Averaged LED Intensity (defined by CIE 127) has been developed utilizing the NIST photometry bench. The Averaged Intensity scale has been established and maintained on two reference photometers having CIE-defined geometry. A calibration capability for total luminous flux of LEDs has been established utilizing the NIST 2.5 m integrating sphere. The best geometry for mounting a test LED has been studied and a special LED holder was built for the sphere. Detailed uncertainty analyses have been made for these measurements. A calibration service (NIST Test No. 37130S) is now available for the total luminous flux as well as for Averaged LED Intensity for submitted LEDs with an uncertainty typically from 1 % to 3 % (k=2) depending on the characteristics of LEDs. Work is in progress to develop spectroradiometer system for spectral and color calibration of LEDs, and also to develop temperature-monitored standard LEDs for luminous flux and luminous intensity.

Bilateral Comparison with PTB on LED Photometric and Colorimetric Quantities
A bilateral intercomparison was conducted in April 2002 between PTB and NIST on LED luminous intensity (CIE Averaged Intensity), total luminous flux, and chromaticity coordinates. 12 temperature controlled LEDs (R/G/B/Y/W) built by PTB were used. The Averaged Luminous Intensity (CIE A, B geometry) agreed within 1 % for all colors. Luminous flux agreed within 3 % for all colors.

Retroreflectance Calibration Facility

A reference instrument for calibration of retroreflectance is being developed at NIST. This project is funded by National Cooperative Highway Research Program (NCHRP) to establish national calibration standards for retroreflectivity of traffic control materials, and thereby to reduce the current large variations in measurement of traffic signs and pavement markings. The reference instrument is a sophisticated goniophotometer with three rotating axes and three linear translation axes, and mounted on a 35 m long rail system. Installed at the end of the rail are high-intensity projection sources and a translatable detector system (now photometric only). The entire system is installed in a dark room tunnel in the basement of Metology building. The goniophotometer will have sufficient flexibility to accurately measure spectral and luminous quantities of both signs and markings over the full range of angles in compliance with all relevant documentary standards, with the best possible accuracy.

NIST-NPL CCPR Intercomparison of Mid-infrared Transmittance and Reflectance Scales
For the first time, an international intercomparison of infrared spectrophotometry scales at the National Measurement Institute (NMI) level has been performed. NIST and the National Physical Laboratory (NPL) of the UK have undertaken a comparison of scales for regular transmittance and reflectance in the mid-infrared part of the spectrum. The comparisons have been carried out as "Supplementary Comparisons" of the Consultative Committee for Photometry and Radiometry (CCPR) of the Bureau International des Poids et Mesures (BIPM). The transmittance comparison was performed using a Schott NG11 glass as the comparison artifact. Measurements were carried out at seven wavelengths between 2.5 µm and 5 µm where the gradient of the transmittance profile was flat. The reflectance comparison was performed using three different artifacts – a non-overcoated front-aluminized glass mirror, a NiCr coating on a glass substrate, and an uncoated plate of Schott BK7 optical glass – to cover a range of reflectance values. Measurements were carried out for near-normal incidence between 2.5 µm and 18 µm. In all cases there was agreement between the two national labs, within the combined expanded uncertainties.

Development of Monte-Carlo Integrating Sphere Reflectometer Model
The Division has developed a highly efficient code based on Monte Carlo methods and ray-tracing to study the performance of an integrating sphere designed for hemispherical-directional reflectance measurement. This code has been used to perform a comparative analysis of different sphere designs, with variation of critical sphere parameters including sphere wall reflectance and sample scattering characteristics. Integrating spheres have been used for nearly a century for reflectance measurements. However, due to the inherent difficulties of accurate uniform collection of all reflected or transmitted light from a diffuse sample, significant measurement errors and uncertainties are common. A significant contributor is the complexity of analytical approaches to sphere analysis that ultimately necessitates the use of approximations. Numerical modeling approaches do not require approximations, but the long computation times even with the fastest computer processors, limit the accuracy of the results.

Our code incorporates a number of significant time-saving features, that enable us to reduce statistical uncertainties to less than 0.1%, even for very low efficiency spheres. Numerical modeling methods offer the most promise for sphere analysis, design, and error reduction. For example, the effect of different design options including baffling arrangements on the measurement accuracy of the sphere was analyzed. The studies have resulted in a specific sphere design to be built for near-infrared reflectance and non-contact temperature measurements.

Colorimetric Characterization of Special-Effect Pigment Coatings
The Division, with NIST's Advanced Technology Program support, is developing methods for the quantitative characterization of special-effect pigment coatings, such as pearlescent coatings, important for the appearance of many commercial products, including automobiles, cosmetics, and various consumer goods. The complexity of these coatings increases the need for better appearance measurements for process and quality control.

Pearlescent coatings typically consist of thin metal-oxide-coated transparent mica platelets. Constructive and destructive interference of light from the front and back surface reflections of these platelets are responsible for the chroma, hue, and brightness variation with the angles of incidence and viewing.

To quantify the properties of the pearlescent coatings, a series of samples supplied by manufacturers were examined using the Division's Spectral Tri-function Automated Reference Reflectometer (STARR). STARR measured the reflectance of the samples for incident wavelengths from 380 nm to 780 nm in 10 nm increments and incident angles of 15°, 25°, 45°, 65°, and 75°. Viewing angels were chosen from –80° to 80° in 5° steps. For each pair of incident and reflected angles, colorimetric values of lightness, a, b, hue, and chroma were determined. The STARR-determined colorimetric quantities validated the qualitative expectations by exhibiting a strong dependence on the incident and reflected angles. Empirically, it is found that measurements at a subset of the reflectance angles, 15°, 35°, 45°, 70°, and 85°, for each incident angle, provide a complete characterization of the coatings.

Detector Damage/Depth Dependence
A new detector measurement capability has been added to the UV radiometric beamline at the Synchrotron Ultraviolet Radiation Facility (SURF III). The beamline is capable of calibrating photodetectors from 130 nm to 600 nm.

The new setup allows simultaneous measurement of the spectral reflectivity and the spectral power responsivity of the detector. With the measurement of both quantities, the important detector quantity of internal quantum efficiency, the response of the detector per total amount of the radiation absorbed by the detector, can be deduced. The internal quantum efficiency of a detector depends only on the internal mechanism of converting photons to electrons and the collection of electrons because the variation in radiation loss due to detector surface reflectivity is eliminated during the calculation of internal quantum efficiency. In the visible, the internal quantum efficiency of a working standard silicon photodiode is close to 100 % and was modeled to provide a detector calibration curve by extrapolating to all wavelengths from visible to near infrared. The new setup measures both reflectivity and power responsivity simultaneously to reduce the uncertainty in deriving the internal quantum efficiency caused by effects like positioning of the detector and contamination of the detector surface when measurements are performed separately. We have studied the internal quantum efficiency of a variety of photodetectors, especially UV detectors with potential application for the photolithographic industry. Our measurements of the internal quantum efficiency have provided us with insight into the photon detection mechanism. We were able to model the detector internal quantum efficiency and found clear evidence of interface trap states inside some of the detectors. We also found evidence that these trap states were formed when a detector is damaged by UV radiation. The capability of studying detector internal quantum efficiency has become an important tool for detector characterization.

High-Accuracy Cryogenic Radiometer II (HACR II)
A second-generation NIST cryogenic radiometer is under development to further reduce the uncertainty in our optical-power measurements. The expected factor-of-two reduction in the power-measurement uncertainty will affect many of the radiometric and photometric scales maintained in the Division and presently tied to the first-generation HACR.

The new instrument is designed to have a greater dynamic range, from 1 μW up to 70 mW in power, faster response time, lower noise figure, and improved modular construction. It will be installed in the Spectral Irradiance and radiance Calibrations with Uniform Sources (SIRCUS) facility, providing ready access to a variety of lasers. These lasers allow a broad range of wavelength and power levels to be selected for scale transfer to silicon trap detectors, further reducing the uncertainties in the measurement chain. Additionally, the modularity of the detector section permits new detector modules to be designed and built, optimized for specific wavelengths and power levels.

Standard Reference Material (SRM) 2017 for the Paint Industry
The Optical Technology Division has developed SRM 2017 to aid the many industries dependent on special-effect or gonioapparent paints to improve the appearance of their products. Examples of special-effect paints include the pearlescent and metal-flake coating found on automobiles, which change color or brightness with viewing angle. The continued appeal of these novel paints to consumers will ensure that they will attract an increasingly larger faction of the color pigment market, estimated to be about $3.5 billion dollars in 2005. The value that these coatings add to products is even greater, as yearly there is approximately $700 billion dollars worth of shipped goods for which overall appearance is critical to their sale. The successful use of these special-effect paints, particularly in automobile manufacturing, requires repeated measurements of the optical reflectance properties of the coatings as a function of angle to ensure that the paint application is performed correctly, is reproducible between manufacturing plants, is constant over time, and can be replicated during a repair. SRM 2017 is an opal-glass white reflectance standard, which was developed in response to industries demands for multi-angle reflectance standards to calibrate the spectrometer instruments used to measure the optical properties of special-effect paints. The reflectance of the opal-glass sample has been accurately measured for an illumination angle of 45° and viewing angles of 15°, 25°, 45°, 75°, and 110° for 10 nm wavelength increments between 360 nm and 780 nm in the visible spectrum. This standard will help ensure that the measured properties of the special-effect paints are independent of instrument manufacturer or locale. The standard was produced using the Spectral Tri-function Automated Reference Reflectometer (STARR facility).

NBS 910-1 through 910-8 The Self-Study Manual on Optical Radiation Measurements now available on CD
The *Self-Study Manual on Optical Radiation Measurements*, edited by Fred Nicodemus, consists of a series of eight documents from the period 1977 to 1985 that were published as NBS 910-1 through 8 by the Radiometric Physics Division, formerly the Optical Physics Division, of the National Bureau of Standard, presently the Optical Technology Division of the National Institute of Standards and Technology. Out of print for many years, but still a valuable and useful reference to the field of radiometry, this publication series is available electronically for the first time using this CD ROM. Presented in Portable Document Format (PDF), the entire series of eight volumes is now available on the web and on CD for viewing, searching, and printing. Through this CD you will be able to download the reader software, visit the Optical Technology Division's website, and use the self-study manuals to learn about the measurement of incoherent optical radiation, including definitions and terminology, measurement equations, relevant SI units, instrumentation, and sample applications.

Visit the Optical Technology Division's website http://physics.nist.gov/otd to download your copy or to obtain ordering information.

Short Courses in Photometry and Radiometry
The Optical Technology Division offers short courses in photometry and radiation thermometry, and spectroradiometry on an annual basis. Attendees include NIST staff, as well as representatives from other national metrology institutes, national laboratories, and industry.

The courses will consist of lectures and skill-building, problem-solving laboratory experiments.

A generic overview of the courses include the following:

- Practical laboratory experiences;
- Proper uncertainty analysis; and,
- Treatment of the measurement equation.

Additional information is found on the Division's Short Course web page http://physics.nist.gov/Divisions/Div844/shortcourseintro.html

Optical Scattering by Nanoparticles on Si Wafers
Light-scattering methods were developed to allow accurate measurement of the diameters of standard reference particles bound to silicon substrates. This was in response to the semiconductor industry's need for improved metrology of particles and other defects on silicon wafers. The identification and quantification of such defects are required to facilitate the transfer of wafers from the factory to the chip manufacturers, and to locate and diagnose problems in the chip fabrication line.

To calibrate inspection tools, and thus to assure agreement between the wafer and chip manufacturers, the industry intentionally deposits accurately-sized, polystyrene spheres onto reference wafers. Because the deposition process can lead to changes in the size distribution of the particles, techniques are required to accurately determine the diameters of the deposited particles.

To address this need, we did a combined theoretical and experimental investigation of the optical properties of subwavelength-diameter spheres on surfaces. The Bobbert-Vlieger theory of light scattering by a spherical particle on a flat substrate was extended to account for films on both the substrate and the particle, and then validated by measurements on deposited, polystyrene and copper nanospheres. The copper spheres provided a particularly demanding test of the theory due to the presence of a strong near-field interaction between the conducting spheres and the silicon substrate.

To assess the measurement uncertainty of the diameter of the particles, the effects of non-sphericity, size distribution, and doublet formation were investigated. The modal diameter of the 100 nm polystyrene sphere standard (SRM® 1963) was determined to be 99.7 nm with an uncertainty of 1.7 nm ($k = 2$), in excellent agreement with aerosol measurements. The technique is presently being incorporated into semiconductor industry standards.

Deep-Ultraviolet, Index of Refraction Measurements at SURF III
A new beamline (BL-5) was completed at the NIST Synchrotron Ultraviolet Radiation Facility (SURF III), equipped with a high-resolution, deep-ultraviolet, Fourier-transform spectrometer (DUV-FTS) to measure the index of refraction of materials, with high accuracy. In contrast to the traditional, prism-goniometer measurement of the refracted angle, the DUV-FTS analyzes the fringe pattern in the transmittance spectrum of an etalon made from the sample material.

Using independent measurements of the sample thickness and fringe order, we determined the index of refraction with uncertainties (approximately 10-5) similar to that of the classical prism method. The interferometer approach offers significant advantages over the prism method, including greater speed, continuous wavelength coverage, and the ability to measure thin samples such as absorbing fluids.
Plans are underway to extend the range to below 157 nm for measuring optical materials important to the deep-ultraviolet photolithography industry. Measurements are also planned on deionized water at 193 nm, which is under consideration for immersion photolithography.

Thermal-Infrared Transfer Radiometer Verifies Radiance Scales Used in Earth Remote Sensing
To establish the traceability of radiometric measurements performed by the remote-sensing community to NIST's radiometric scales, and to perform on-site calibration verifications of critical remote-sensing instruments, we have developed the transportable Thermal-Infrared Transfer Radiometer (TXR). Such traceability helps ensure that the measurements undertaken by this community are of the highest accuracy and can be compared to similar measurements performed by other countries or at other times.

The TXR was deployed at the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences, in collaboration with NASA-Goddard, to verify the radiance scales of several blackbody sources used by the sea-surface remote-sensing community to calibrate ship-based radiometers. These, in turn, validate satellite measurements of sea-surface temperature. The radiometer was then sent to ITT Industries in Ft. Wayne, Indiana, to measure the radiance of two calibration targets used to verify the calibration of the NOAA Geostationary Operational Environmental Satellite (GOES) imagers. A third deployment was made to Los Alamos National Laboratory, to measure the radiance of blackbody sources in a cryogenic vacuum chamber previously used to calibrate a space-flight instrument for the Department of Energy.

The success of these deployments has led to new efforts to improve the calibration of the TXR and to extend its operational range to temperatures below 288 K by performing the measurements in a low-infrared-background, liquid-N2-cooled, vacuum test chamber. To do these measurements, the NIST Medium-Background Infrared (MBIR) facility was used to calibrate the TXR against a high-accuracy cryogenic blackbody in conditions that simulate outer space. The facility allowed the extension of the TXR radiance scale down to 200 K and enabled the evaluation of measurement uncertainties due to room-temperature infrared background radiation and atmospheric infrared absorption and emission.

Wire-Contrast Measurement Standards

We developed a new facility to measure the contrast of ultraviolet-laser-written markings on electrical wires used in aerospace and military vehicles, in response to a request by the Navy for improved standards in this area. Although the ultraviolet-laser-written markings are immune to fading with age, the gray color of the writing reduces the visual contrast relative to black-ink markings. A high contrast level is desirable for these markings to ensure the correct identity of a wire during installation, repair, or maintenance. Wiring-contrast values of 60 % or higher are recommended by industry standards. However, the measured values for the same wire sample often vary by as much as 10 % to 20 %.

Our new reference instrument consists of a well-characterized luminance meter with a microscope to measure the luminance on a circular spot of 12 μm diameter or larger. The wire is illuminated by a fiber-optic source with a known spectral distribution. A three-axis translation stage under computer control automatically scans the wire surface. The computer also acquires and analyzes the data. The instrument characterization yields an expanded relative measurement uncertainty of better than 2 % for typical wire colors and sizes.

A formal calibration service is being established for both standard wires and contrast-measuring instruments.

Single-Photon-On-Demand Sources for Quantum Cryptography

The security of quantum cryptography and communication schemes depends on the use of single photons to carry information. Parametric down-conversion (PDC), which produces photons in correlated pairs, is the basis for one type of single-photon source. Unfortunately, present single-photon sources are generally incapable of producing single photons on demand with high probability, while simultaneously suppressing the probability of yielding two or more photons. This compromises the overall security of the communication. One reason PDC-based schemes have this problem is because they employ photon-counting detectors which cannot discriminate whether just one or a burst of photons was detected.

In response to the need for an improved, on-demand, single-photon source, we have proposed a multiplexed version of the PDC scheme that allows independently adjustable probabilities for producing one and more than one photon. The system operates by collecting multiple pairs of correlated photons from the ring of correlated photon pairs azimuthally distributed around the PDC pump-laser propagation axis. The scheme allows a single, conventional, photon-counting detector to better approximate a true "photon-number" detector, which in turn allows the overall system to better approximate a true single-photon source.

A recent experimental test of this concept with four channels was successful.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Present or new areas that are not supported by the CCPR: LEDs, Flashing Light, Total Spectral Radiant Flux, Spectral Irradiance Responsivity, Ambient IR spectral response, DUV detector response.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry?

In photometry, the development of total spectral radiant flux standards is at high priority, as increasing number of laboratories in industry are using integrating spheres with a spectroradiometer for luminous flux and color measurement. Significant variations of measurement results are reported among different systems using commercially-made standards. In radiometry, the effort that the various NMIs are expending on detector-based metrology utilizing well characterized filter detectors should be continued and expanded including work on filter detector-based radiance determination.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?
NIST Boulder response:

- Excimer laser (157 nm, 193 nm, 248 nm) power, energy, dose, and linearity key comparison
- Optical fiber power meter intercomparison

NIST Gaighersburg response

- NIST is developing total spectral radiant flux scale, and is interested in intercomparisons with any other national labs that have developed or are developing such standards (NPL and ?).

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

The current level of interaction through the efforts of representatives of the CCPR who also are active in the CIE seems appropriate. The WMO should be encouraged to participate in bilateral intercomparisons with CCPR members in order to ensure their radiometric scales are equivalent to the world's NMIs. There does not seem to be a compelling reason to make more elaborate relationships or expend additional resources in this regard.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?

These organizations like the CIE, ILAC and WHO have different tasks and purposes than the CIPM. Inasmuch as they need standards, they should be encouraged to use the NMIs in their home countries or wherever convenient in order to reference standards they may need. As mentioned above, the WMO should tie itself to internationally accepted standards through appropriate intercomparisons with CCPR members. A complex system of MOUs among disparate organizations will not be useful to either the organizations or the customer seeking their services. If some clear need of MOUs for better serving our customers could be established, then it might be possible to negotiate a particular relationship as indicated by the demand. We have not had requests for MOUs such as indicated here and hence at this time do not see the necessity for either business or technical reasons.

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14) Have you got any other information to place before the CCPR in advance of its next meeting? We need to resolve the disputes involved in the analysis of data from the Key Comparisons and we need to establish a well-understood and firm protocol for performing the Key Comparisons. NIST will raise these issues at the Key Comparison working group and with the whole assembly as determined by the discussions of these issues. NIST will also like to discuss the timetables for Key Comparisons and the impact that the diminished BIPM efforts in photometry and radiometry will mean for our Key Comparison agenda, both presently and for the future.

The SIM countries seem to have experienced difficulty in getting their P&R CMCs accepted by the JCRB. NIST would like to revisit this matter and hopefully decide on a policy that decreases the bureaucratic overhead in getting this important work done. We need to reconcile our activities with the guidelines of the JCRB.

National Metrology Institute of Japan (NMIJ)

NMIJ Response to Questionnaire for the 17th meeting of CCPR

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The CIPM MRA was one of the biggest factors that triggered the reorganization of our institute, NMIJ/AIST. After the reorganization, our activities not only in Photometry and Radiometry but also in other fields became more customer-oriented focusing on consolidation of calibration services rather than research-oriented. Also, participation in international comparisons, especially key comparisons became more important than before and therefore, resources of manpower and time are significantly used for performing such comparisons. Responding to another important requirement of the CIPM MRA, efforts to establish quality systems satisfying ISO/IEC 17025 were not negligible as well. As a review team member, time spent for intra- and inter-regional review is becoming a heavy load.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

Benefits: At the moment, we are not clearly aware of the benefits of the MRA. In principle, our customers especially in the industries are having benefits in their trade of imports and exports by utilizing such an authorized quantitative relationship among NMI standards in the world.
Disadvantages: Procedures to be registered in the Appendix C, principally reviewing, are time-consuming and difficult to rigorously perform. It seems that actual criteria has not been completely unified across RMOs. It will be necessary to resolve such a problem in order to guarantee the reliability of the MRA.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

The closure of the Photometry and Radiometry activities at the BIPM was surprising for us considering the loss of their high research activities especially on cryogenic radiometer based radiometry that we have highly evaluated. However, we understand the hard decision in the situation stated if the BIPM continues to support CCPR activities. Since we have not been routinely provided services by the BIPM, there will be no direct negative affect on our national activities by its closure. However, in the long run, it will be a big loss regionally and internationally, for instance, because chances to collaborate on filter-radiometry for realizing new high temperature scale and to perform bilateral comparisons of cryogenic radiometer based spectral responsivity, in which it is difficult to find an alternative institute to do the services, will be lost.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

We highly esteem the CCPR intercomparison activities not only because of the academic interest but also because of the important influence on the world-wide trades etc.. One of the merits is clearly that the intercomparisons give us chances to see our standardization activities objectively and enable one to compare one country's standard with another. A shortcoming of the current processes is that we tend to be overwhelmed by the strong needs for many kinds of intercomparisons to satisfy the requirements for the MRA.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

See 2).

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities
None to add.

(b) spectral radiometric quantities
Re-establishment of spectral diffuse reflectance standard:
NMIJ has successfully established a spectral diffuse reflectance scale in the visible wavelength region based on a new integrating sphere-based method (modified Sharp-Little method). At present, NMIJ is undertaking the comparison measurement for the CCPR-K5 (It will be completed by about the end of July.). In addition, NMIJ has started a new calibration service on the spectral diffuse reflectance for Japanese industries since April, 2003.

Extension of calibration service on spectral responsivity to the region below 250 nm:
We are performing a program to extend calibration service on spectral responsivity in the wavelength region below 250 nm, tentatively down to 200 nm.

Re-establishment of spectral irradiance standard:
We are in the process to re-establish a spectral irradiance standard based on a high temperature black body aiming to reduce the uncertainties.

Study on photoemission current contribution to the photocurrent generated in semiconductor photodiodes:
We revealed that photoemission current contribution to the photocurrent generated in semiconductor photodiodes can reach in the order of 10-20% in the rear side grounding configuration in the VUV region (Ref. 2).

(c) photometric quantities
None to add.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

Precise measurements of photoabsorption cross-sections in the soft X-ray region:
Photoabsorption cross-sections of rare gas atoms have been precisely measured in the sub-keV energy region, about 50 - 1100 eV, using a multi-electrode ion chamber.

Development of laser power standards from 200 mW to 10 W in visible and near infrared wavelengths.

Development of laser power standards up to 1 kW of CO_2 laser.

Development of optical attenuation standard for fiber optics up to 90dB.

Quality system establishment:
NMIJ has developed quality systems in the fields of luminous intensity, total luminous flux and spectral irradiance. The peer review according to ASNITE/NMI for the accreditation under ISO17025 has taken place at NMIJ from March 18 to March 20, 2003.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Standards in application fields:
One example of such needs is a need for standard LEDs. Although we understand its strong needs, we reserve to suggest the CCPR to take the initiative since we consider that the CCPR should work on only fundamental quantities.

Organization to secure lamps suitable for standards:
Although uncertainties of detector-based standards are becoming smaller than those of source-based standards in many cases, needs for standard lamps still exist. However, it is becoming difficult to obtain stable lamps suitable for standards because of the shrink of the market for that purpose. Therefore, the CCPR could excute leadership to organize a long-term stable method to obtain such standard lamps for the member NMIs.

Standards for laser and fiber optics related parameters:
Lasers and fiber optics are important fields in opto-electronics fields and a lot of instruments are used in industries. Their standards are not dealt in CIPM activities until now except a few items of laser power standards. In future these standards will be more important and it is hopeful to incorporate these fields.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

See 8).

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

None at the moment.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

Concerning the current interaction between the CCPR and the CIE, there actually exist overlapping fields, at least, of terminology. For instance, in the definition of candela, although no information is given for optical frequencies of other than 540 THz on the BIPM side, the use of CIE-defined V(λ) function is implicitly authorized according to my understanding. In addition, talking about uncertainty of a certain quantity, one should note that the quantity is uniquely defined; otherwise, uncertainty depends on its definition. However, there are quantities that are not explicitly defined on the CCPR side (such as distribution temperature). Therefore, in many cases, definitions in the CIE vocabulary are actually used or implicitly assumed. It would be better to formalize the relationship between the CCPR and the CIE and to explicitly declare the use of such terminology.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

We agree to the idea if the relationship is constructive and beneficial for both organizations. Since activities in CCPR and CIE are closely relevant, both activities could become more efficient, for instance, by citing and/or authorizing the partner's official documents.

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15. N. Saito and I. H. Suzuki, “Precise photoabsorption cross-sections of Ne and Xe”, Nucl.Instrum.Meth. Phys.Res. **A467/468**, 1577-1580 (2001).
16. H. Onuki and P. Elleaume ed., “Undulators, wigglers and their applications”, (Taylor & Francis, London, 2003)

14) Have you got any other information to place before the CCPR in advance of its next meeting?

None at the moment.

Responded by Terubumi Saito
May 2, 2003

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Response to questionnaire by NMi-VSL

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs?

The MRA has resulted in a significant increase of workload to bring the existing quality manual to ISO-17025 requirements. Of course this has a temporal character as maintenance on acknowledged entries consumes less time. However as it is foreseen that our activities (CMC entries) will grow considerable the next four years the workload related to quality manuals and associated validation activities will grow. This could negatively affect the progress in development of calibration facilities if not properly accounted for.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?

The calibration activities at NMi-VSL are at a proper documented level ensuring quality to customers, also in an international context. Depending on the philosophy the quality manual can also be used for internal education purposes and transparent documentation of calibration activities. Furthermore audits at NMi-VSL by technical experts (colleagues) from other metrology institutes were found to be very fruitful. A major benefit is transparency in traceability of calibration services to the customer; his choice for traceability from either a national or international standard is now quantifiable.

*3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.*

At present several institutes are traceable to the maintained luminous flux and luminous intensity standards at the BIPM. Several non-trivial problems need to be addressed when the PhoRa activities are stopped, for instance, keeping track of the candela and lumen, linking previous customers to the KCRV through a single NMI. Finding and tackling consequences of the BIPM restructuring needs time to preserve quality in traceability. Latter is very valuable, also in the context of the MRA set by the CIPM, and needs attention before restructuring takes place.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

Intercomparisons are important to make local primary realizations traceable internationally and support the CMC claims. At the end of 2003 primary realization related to spectral emission properties of sources at NMi-VSL will be effective in the visible part of the spectrum and expanding over time. As a result NMi-VSL would like to get linked to existing KCRVs in that particular area.

Although the workload increases due to the increasing number of CCPR intercomparisons one might wonder whether the update of the KCRV over time is sufficient to support international traceability. An illustrative example is the announced closure of photometry and radiometry activities at BIPM; her role in monitoring the evolution of the world mean candela and lumen realization cannot be covered with present schemes for CCPR intercomparisons KCRVs maintenance.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

A benefit of our inclusion of entries in the database is transparency in traceability of calibration services to the customer; his choice for traceability from either a national or international standard is quantifiable. Currently NMi-VSL has only 6 entries in the database that need a significant update and more entries are expected. A negative side effect of the mentioned benefit is the fact that the database must be updated regularly to reflect the actual status of the calibration service.

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities

No specific activities to report

(b) spectral radiometric quantities

- The realization of a set of filter radiometers for spectral irradiance measurements over the interval 400 nm to 900 nm with 50 nm steps facility,
- The realization of a spectroradiometer facility for spectral irradiance measurements over the interval 400 nm to 900 nm,
- Improvement of existing calibration facility laser power, 2%, to a level of 0.5%.

(c) photometric quantities

- Realization of candela employing filter radiometers (Illuminant A) and a set of illuminance meters to a level of 1.5%,
- Improvement of illuminance and luminance calibration facility to levels of 1.5% and 2.7% respectively.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?

A project is started to improve transfer standards for spectral responsivity realization in the infrared from 2 μm to 20 μm. At present uncertainties at the 1% to 3% level are obtained by direct comparison against a cryogenic radiometer.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

There is a need for intercomparisons supporting traceability for calibration of broadband UV meters and consistency in UV-ozone spectral irradiance measurements.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?
A particular field of interest is the development of standards, protocols for broadband UV meter calibration (UVA,UVB and UVC) and UV-ozone measurements.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?
At this moment transfer detectors are being developed to improve the spectral responsivity scale realization in the 2 µm to 20 µm region. The detectors are calibrated directly against the cryogenic radiometer. Collaborative work on either development along this line or direct comparison of scale realization is sought.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.
No comment

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?
No comment

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

Since the last CCPR meeting of April 2001 one paper relevant to radiometer has been published:

E. W. M. van der Ham, H. C. D. Bos, and C. A. Schrama, Primary realization of a spectral irradiance scale employing monochromator-based cryogenic radiometry between 200 nm and 20 mm," Metrologia **40** (2003) S177-S180.

14) Have you got any other information to place before the CCPR in advance of its next meeting?

NMi-VSL does not have other information in advance to the CCPR meeting.

Delft, June 2003

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

NML CSIRO Australia reply to questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?
    a. *The heavy redirection of activities towards development of quality systems, intercomparisons, to the detriment of longer term research.*

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?
    a. *The large number of derived units and measured quantities, which are also often spectral or cover a large dynamic range (ie. uncertainties and techniques are wavelength and intensity range dependent), will lead to very complex and unwieldy CMC tables. I would like to see some agreement towards simplification and reduction of CMC tables.*

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.
    a. *It is unfortunate, as it will diminish BIPM's ability to contribute technically in the organization and analysis of key comparisons.*

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.
    a. *CCPR comparisons play a fundamental role for our laboratory. Firstly, they independently check our metrological performance, complementarily with our independent external ISO17025 quality system audits. Secondly, they provide a clear mechanism for us to prioritize and allocate resources for out standards development and research activities.*

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.
    a. *A large amount of bureaucratic effort goes into this process and the returns from the MRA-CMC process for our laboratory are presently negligible or marginal at best. This may change if Australian industry and calibration laboratories take advantage of offshore service providers, but presently no detectable changes have been observed.*
    b. *Side benefits of this process has been the pressure to review and revise our uncertainty estimations, and the opportunity to closely examine the procedures and equipment used in other laboratories, and thereby improve our own systems.*

6) Summarize the progress in your laboratory in realizing top-level standards of

a. broad-band radiometric quantities: *research is underway in the calibration of narrow band and broad band filter radiometers for the measurement of the thermodynamic temperature of near-blackbody thermal sources.*

b. spectral radiometric quantities: *We have, for some years now, been re-establishing a local spectral irradiance scale, based on a blackbody radiator and a number of narrow band filter radiometers. This work is now nearing completion. In the last year we have also used our recently re-commissioned cryogenic radiometer to calibrate suites of traps, Si diodes and InGaAs diodes using an significantly larger number of laser lines.*

c. photometric quantities*: We have begun incorporation of correlation effects into our calibration services for photometric quantities, but there is presently no experimental research.*

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

a. We are presently setting up facilities for the calibration of sensors used for high power and pulsed laser power and energy calibrations.

b. The implementation of quality systems: We have now had two successful formal external accreditation audits, the first to ISO-25 and the second to ISO-17025. This has resulted in us undertaking an ongoing project to systematically characterize the magnitudes of our uncertainty sources in a more formal manner.

c. We are incorporating the effects of correlation in uncertainties into our calibration services.

d. We have re-commisioned our RADIOX cryogenic radiometer, re-characterising all aspects of its use and associated measurement uncertainties. We have also significantly expanded our suite of laser sources to UV and NIR, and include more lines, which now includes Kr and Ar ion lasers with vis-UV mirror suites, HeCd laser, the usual He-Ne lasers, and >6 diode laser sources. Work is commencing on system automation for this facility.

e. Work is underway on a joint project with the NML-CSIRO thermometry group to develop a thermodynamic temperature scale, using calibrated filter radiometers and apertures.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Laser power and energy is not presently handled by the CCPR, even though this is a more logical group for its discussion. Significantly different techniques are used for high power laser systems, and I think the CCPR should investigate coordinating a comparison and an agreed list of the dominant uncertainty terms to ensure measurement certificates are comparable.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

The existing research base seems satisfactory to present and anticipated user community needs.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?

a. Aperture measurement at below the 0.01% level

b. Radiance/irradiance transfer techniques

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

   a. **Accurate calibration of UV pyroheliometers, and their traceability to SI units.**

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

   a. *only if there are specific identifiable outcomes expected, or specific identifiable problems to be solved.*

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

GARDNER, J.L., "Correlations in primary spectral standards" Metrologia 40 S167-S171 (2003).

GARDNER, J.L.,"Uncertainties in interpolated spectral data" J. Res. Natl. Inst. Stand. Technol. 108, 69-78 (2003).

Wilkinson, FJ, "Calibration of ultraviolet radiometers", TIPP-1473, Mar 2002

Wilkinson, FJ, "The NML1990 scale of relative spectral irradiance for the wavelength range 250-2400 nm", TIPP-1559, Sept 2002

Wilkinson, FJ, "Spectral transmission measurements of a plane fused silica window at NML", TIPP-1631, Jan 2003

Wilkinson, FJ, "NML working standards of spectral responsivity – Re-evaluation following draft report on CCPR K2.b key comparison", TIPP-1514, April 2003

14) Have you got any other information to place before the CCPR in advance of its next meeting?

No.

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17^{th} Meeting (17 - 19 June 2003)

Questionnaire: Replies from NPL (UK)

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

Prior to the MRA NPL had already undergone full formal quality assessment both for its measurement services, accredited by UKAS and the remainder of its activities to ISO 9000. This meant that we were well prepared for much of the processes associated with the MRA.

The increased number of comparisons and review activities has required significant commitment of resources which would otherwise have been deployed on research and development.

The MRA has led to greater interaction between all NMIs rather than just those who are members of CCPR.

It has led to increased visibility of, and confidence in the services provided by other NMIs. However, to achieve this has required the significant, but clearly important, additional task of reviewing the CMC of other NMI for Appendix C of the MRA.

The MRA has also led to debate on how to improve the consistency of presentation and treatment of comparison data, both within a CC and between CCs.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

The overriding benefit is the increased clarity and visibility of the degree of equivalence between measurement services offered by different NMIs. This, when fully appreciated by the user community, will significantly improve our customers' ability to trade across borders and will support regulation. The increased rigour, consistency and clarity of peer reviewed uncertainty estimation and presentation together with the establishment of a "Key Comparison Reference Value" as part of this process is also a significant advance. When fully implemented this will provide clarity around the differences that sometimes exist between NMI national standards, a situation that NMI have often ignored in the past.

One potential problem is the different approach taken by different RMO and between metrological fields, for the review of CMCs. If this is not addressed it could ultimately undermine confidence in the MRA.

The other major challenge for the MRA is the significant level of resource required to underpin the activity. Some means of reducing this effort whilst providing sufficient information for a reliable review of CMC data, would be welcome.

3) Given the announcements on the restructuring of the BIPM and the attached explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

NPL recognizes the difficult choices faced by the CIPM to manage BIPM costs within the available budget. We are disappointed by the decision to end work on photometry and radiometry BIPM. We have greatly valued the contributions made by BIPM over the years in both research and through the piloting of comparisons in this area. However, we recognize that the field of radiometry and photometry has made rapid progress in recent years, particularly since the advent of improved solid-state detectors and cryogenic radiometry, and this has led to significant increased effort at NMIs. Our judgement is that there is now probably adequate resources deployed across the worlds NMIs, for them to maintain appropriate advancement in this field and to support future comparison needs.

An unfortunate consequence of the closure will be the loss of the calibration services currently offered by BIPM. This is likely to be of concern to NMIs currently dependent on such services. NPL is willing and has the capacity to provide for these NMIs needs, if an appropriate mechanism can be found to finance the activity.

In an international context, the loss of an independent expert view on issues such as degrees of equivalence between NMIs is also of concern. BIPM was responsiblity for, and has successfully maintained, a world mean for SI photometric quantities. The maintenance of this world mean has ensured that the stability of the SI photometric quantities have been monitored over time, independent of any particular NMI realizations. CCPR may wish to consider how this capability might be continued into the future.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

NPL sees comparison activities as essential to its research programmes. Without independent assessment of its work by international comparisons, particularly the establishment and maintenance of primary scales, it is difficult to fully evaluate possible systematic errors. However, the processes are very time consuming and costly, particularly for the pilot lab.

Such comparisons are the only means of validating primary scales and establishing degrees of equivalence between NMIs. In this way they also provide valuable data to support the review of CMC claims of NMIs.

Some aspects of running comparisons need further refinement. For example: analysis and presentation of results is too subjective and varied, and there is still insufficient peer review of uncertainty budgets provided by NMIs with Key Comparison results.

The high kudos associated with key comparisons has encouraged the establishment of new primary scales. This was not the original intention of the MRA, which provides for NMI with national standards traceable to primary standards realized elsewhere. This has led to very large numbers of

NMI participating in CC Key Comparisons. At present the large number of participants in CC Key Comparisons is too onerous on pilot laboratories and leads to the comparisons taking too long. Clear guidance is required on who should participate in comparisons at CC and at regional level.

One solution would be to limit participation in the CCPR key comparison to a much smaller sub-set of members (maybe 5 or 6). These participants would then provide linkage to the regions allowing the process to progress much more quickly and cost effectively. It is also important to ensure that there is good coordination between the CCPR and RMO comparisons, particularly in terms of timing with some NMIs feeling obliged to participate in the CCPR comparison because of uncertainty in the timing of the regional follow-on comparisons. Also the status of RMO Key Comparisons needs to be enhanced.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

To date, NPL has not seen significant value from having its entries in the CMC database. However, we feel that as the database becomes more widely known and used by customers, its value will increase significantly.

The CMC database provides a convenient summary for our customers to compare the services offered by NPL with those of other NMIs. This is particularly important for those trading across international borders and regulatory bodies, where traceability to SI is important and can be provided with equal convenience at any of a number of NMIs.

The database has been used by NPL, and our funding agency, to review our capabilities against other NMI, and thus better assess priorities for improvement or withdrawal.

Another important achievement of the implementation of the CMC database was the establishment of a common vocabulary to discuss services provided by NMIs.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

i) **Absolute Radiation Detector (ARD).** The ARD is the NPL crygoenic radiometer designed to measure total radiation from a black body in order to measure the Stefan-Boltzmann constant and thermodynamic temperature. In measuring the Stefan-Boltzmann constant it confirms the uncertainty of the cryogenic radiometer and provides a formal link to fundamental constants for radiometric and photometric quantities. It has previously been reported that there was an error within the ARD instrument causing an offset. The source of this error is now thought to be due to an incomplete absorption of radiation outside of the geometric beam. This error arose from limitation of the models used for the initial design, which were also present in earlier work [1]. The consequence for ARD is that the radiation trap must be significantly larger (50% increase) to perform adequately. This redesign has been completed and a new radiation trap and surrounding radiation/vacuum cans is under construction. First measurements are anticipated early in 2004. The new radiation trap will be coated with a more conventional Nextel black paint coating which will aid in performance prediction. In addition, experimental studies are underway to characterize the interaction of radiation (at a few specific λ) from the black body with the radiation trap to compare and confirm the performance of the new model.

ii) **Black body radiance sources.** A new smaller version of the “Christmas tree” black body [2] used with ARD has been developed as a technology demonstrator for the European Space Agency (ESA). The project called TIFRI (Technology Innovations For Radiometer Instruments) involves not only the design of the black body but also an investigation of temperature sensors and an electronic control package suitable for space use. The project has been carried out in conjunction with industry under support of ESA. The final “flight capable” black body is half the mass and uses half the power of an equivalent conventionally designed version, built for the soon to be launched HIRDLES instrument.

The AMBER (Absolute Measurement of Black body Emitted Radiation facility [3]) is a radiometrically calibrated filter radiometer operating in the 3 to 5 μm and 9 to 10 μm region. It will be used to determine the spectral radiance of this new black body source and thus provide traceability to SI through radiometric rather than thermal quantities.

iii) **Cryogenic Solar Absolute Radiometer (CSAR).** NPL continues to pursue the flight of a cryogenic radiometer in space to measure Total Solar Irradiance. A new proposal called TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies) was recently submitted and reviewed by ESA. This new proposal incorporated the concept of ARMS as reported in the minutes of the 16th CCPR meeting but extended the concept into a new dimension which will be reported later in this report.

iv) **Colour Temperature.** The NPL colour temperature scale is derived by calculation from the spectral irradiance scale. The major contributions to the uncertainty in the colour temperature scale are uncertainty in the spectral irradiance scale and uncertainty over the effect of correlations within the spectral data. A study is underway to better understand these correlations and it is anticipated that this, coupled with improvements in the uncertainty of the spectral irradiance scale itself, will ultimately lead to a reduction in the uncertainty of the colour temperature scale.

(b) spectral radiometric quantities

i) Spectral Responsivity.

Primary scales. No further work has been carried out on the establishment of primary spectral responsivity scales. The uncertainty of the scales being disseminated is currently adequate to meet customer demands. The results of the CCPR K2 will determine the need for any further work.

Current effort is concentrated on upgrading and improving our primary dissemination facilities in time for the move to our new building. This work also includes a constant review of transfer standards and their performance. In particular, NPL has noted and reported problems associated with many commercial cryogenically cooled IR detectors. The presence of ice (as opposed to water) can result in variable abosorption features close to regions of interest to the radiometric community [4].

NPL has continued the fruitful collaboration with NIST on pyroelectric detectors used to establish primary relative scales of spectral responsivity. The incorporation of foam under the detector element has reduced the susceptibility to microphonic pickup. The recent K2 comparisons have shown that the performance of such detectors is more than adequate to extend spectral responsivity scales to regions beyond the visible.

Cryogenic radiometers. NPL has now taken delivery of a new cryogenic radiometer cooled to <4K using a mechanical cooling engine. The new radiometer is currently being used to perform a comparison, in vacuum, with solar radiometers of the World Radiation Centre, Davos. Following this, it will be commissioned to measure low photon fluxes at power levels of ~ 1 μW with an estimated noise floor of 10 pW.

It should be noted that in the last year NPL took over full responsibility from Oxford Instruments (OI) for the manufacture and maintenance of cryogenic radiometers. The relatively low volume of sales made it impractical for OI to maintain sufficient expertise. Following, this change NPL recently successfully completed construction and testing of the second radiometer manufactured entirely at NPL.

National Laser Radiometry Facility (NLRF). The NLRF of NPL has recently been upgraded, with two of its old Argon Ion pump lasers being replaced by more convenient solid state lasers. Since its inception 15 yrs ago only minor modifications have been made to its operation and the methods established for spectral responsivity, spectral radiance and irradiance calibrations. However, as the commercial supply of laser stabilization equipment becomes more unreliable and the demand for measurements in more difficult spectral regions becomes greater, we have started work to improve its flexibility and reliability. This has involved the redesign of the laser stabiliser with the aim of achieving improved long-term intensity stability <0.001 % over several hours. The facility currently provides full continuous spectral coverage (CW) over the range 210 nm to 5 μm, supplemented with a tuneable CO2 laser in the 9 to 11 μm region. However, it is relatively difficult to use tuneable CW radiation for calibration of, for example, filter radiometers, in regions outside of the visible and near IR. NPL has thus continued its investigation of the use of quasi-CW lasers in the form of mode-locked Ti-sapphire and its harmonics. This has concentrated on potential non-linearity effects due to high average powers associated with the mode-locked system. Such problems have not materialized for either Silicon or GaAsP photodiodes. The use of this system has other advantages when used for spectrophotometric like measurements e.g. for calibrating filter radiometers,since the effectively reduced coherence between successive pulses removes the need for the filters to be wedged.

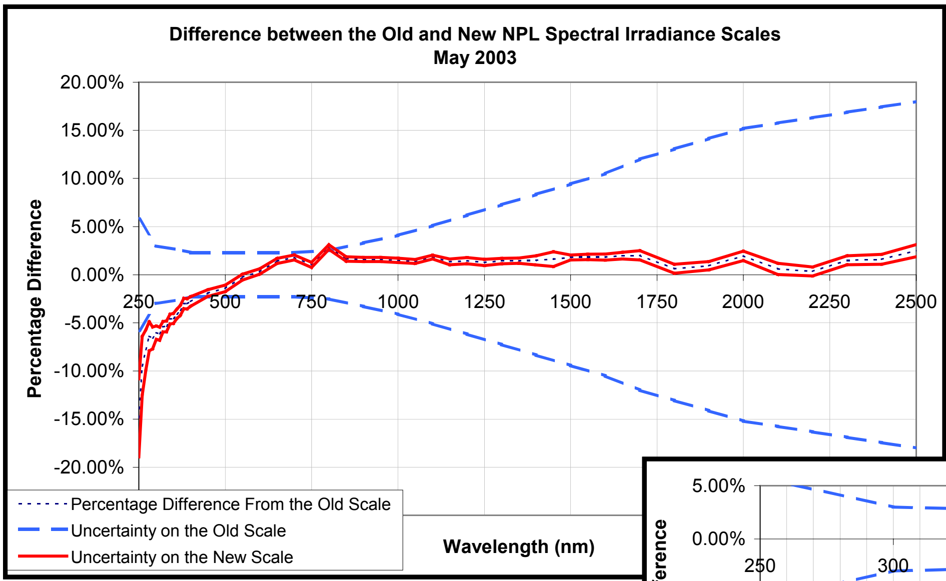
ii) Spectral Irradiance and radiance

Primary scale. The new NPL scale of spectral irradiance from 250 to 2500 nm is now being disseminated to customers. The new scale has been established using the Ultra High temperature Black Body (UHTBB) calibrated by reference to a group of filter radiometers. The filter radiometers themselves calibrated traceable to the cryogenic radiometer using tuneable laser radiation of the NLRF. The new scale has been show to be stable within its uncertainty over an 18 month period and will be the scale compared within the ongoing CCPR K1-a comparison. The new scale exhibits some differences from the scale previously disseminated by NPL. These differences are within uncertainties, except for some parts of the UV, where the new scale deviates significantly.

The new scale together with its associated uncertainty is compared to our previous scale in figure 1. It should be noted that the old NPL scale below 350 nm was based on a relative scale held on Deuterium lamps calibrated in radiance mode against a synchrotron radiation source, normalized to the absolute value at 350 nm. This is probably the cause of the differences in this spectral region, which are related more to an offset in level than a change in spectral shape. Work to extend the new scale below 250 nm will follow the completion of the CCPR K1a. The new UV scale requires a modification to the SRIPS (Spectral Radiance and Irradiance Primary Scales) facility to carry out this work (currently used for the comparison), but should be completed in time for K1b.

In addition to establishing a new scale, NPL has also constructed a new dissemination facility, based on the SRIPS facility. The new facility will be able to calibrate up to 4 lamps at a time and should be capable of taking full benefit of the improved uncertainty of the new scale in the services provided.

NPL is also currently working on the establishment of a new spectral radiance scale in the IR spectral region from 2.5 to 14 µm. This work will also involve the development of a new large area black body to act as a transfer standard for the principle customers of this work .



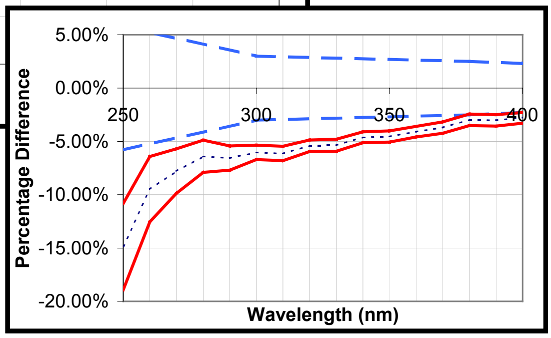


Figure 1. Comparison of new NPL spectral irradiance scale with that previously disseminated. (Uncertainty at 95% confidence level)

Transfer standards. The original Detector Stabilised Lamp (DSL) of NPL reported in previous minutes has been largely discontinued. This decision was based on the relatively high cost of the system dominated by the needs of the 1 kW FEL type lamp. However, recognizing that the need still exists for a compact stable transfer standard source, the technology has been simplified and a more compact version developed based on a 250 W lamp of similar colour temperature. This new system has also removed the sophistication of full computer control in favour of a more simple self-contained process but maintaining flexibility for the more critical user to obtain access to monitor information and make corrections to spectral data between recalibrations. The new system is supplied with an integrated power supply and costs little more than NPLs existing standards.

Figure 2. New NPL detector stabilised source.

The detector stabilization technologies developed for the DSL have also been incorporated within new lamp illuminated integrating sphere sources. These Transfers Standard Absolute Radiance Sources (TSARS) were designed to have high spatial uniformity of radiance within a relatively large exit port. Their principle application is targeted at the remote sensing community whose demand for high accuracy spectral radiance measurements are second to none. Versions of the TSARS have been used to calibrate the Geostationary Earth Radiation Budget (GERB) instrument on board Meteosat Second generation, where the requirement was for an uncertainty of < 1% over the spectral region 350 to 5000 nm.

Comparisons. NPL expects to complete all of its measurements for participants taking part in CCPR K1-a by June 2003. The comparison has involved more than 370 separate calibrations (involving realignment) on ~69 individual lamps, each in 5 separate wavelength regions. Although later than planned, it is hoped that a Draft A can be produced before the end of the year.

The results of the CCT/CCPR comparison of filter radiometer spectral response are now being collated and will be presented to the CCPR 17th meeting in a separate document. However, in summary it can be said that the filter radiometers circulated by NPL have all remained extremely stable (<0.1 % change in their effective integrated response) over a two year period, based on repeat measurements at NPL using its NLRF.

iii) Spectral Total Flux.
NPL goniophotometer has now replaced the 4.8 m sphere for spectral total flux measurements on large sources and is now considered the primary instrument, responsible for establishing the scale from 300 to 800 nm. The lower wavelength of 300 nm represents an extension from 350 nm and is nearing completion. The use of a goniophotometer also enables measurements of spectral radiant intensity distribution to be carried out on lamps and luminaires and this new service will shortly be made available to customers on a routine basis.

iv) Laser Power and Energy
NPL has recently extended its calibration capability in laser power to 100 W at 1550 nm to meet the needs of the telecoms industry.

(c) photometric quantities

Research into photometric base scales is concentrating on the mesopic range. NPL is working on an EU project (called "MOVE") in collaboration with a number of other research institutes. The aim of the project is to establish new spectral luminous efficiency functions for the mesopic region, based on a task performance-based approach. The particular task selected is driving, although many of the elements of this (reaction time, object recognition etc.) will be applicable to other tasks. NPL's particular role is to provide a link between the experimental set-ups used and the photopic scale, as well as to carry out much of the data modeling. The results and recommendations from this project will be fed into the relevant CIE Techcnical Committees, to assist with the establishment of new International standards.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

i) Pulsed sources
A new project has been started to establish traceability for the measurement of spectral and photometric properties of pulsed sources. For the purpose of this project the minimum pulse length

is defined to be 50 μs. The project seeks to provide traceability for not only time averaged characteristics but also intra-pulse variation. At present a measurement facility based on a customized CCD array based spectrometer is being established.

ii) Calibration of LEDs

Work is currently progressing to establish facilities to provide traceability for LEDs based on CIE agreed definitions for the measurement geometry. Services for spectral quantities as well as photometric values are being established. The scope of the work also includes LED clusters and arrays and research into optimum geometries, viewing angles and other measurement conditions is underway. The work is being coordinated with a CIE Technical Committee on this subject, and will support future international measurement recommendations.

iii) IR Spectrophotometry

NPL currently provides a wide range of IR spectrophotometric services: wavelength (wavenumber), regular transmittance and reflectance, and diffuse reflectance, many of which are for the Quality Assurance of commercial spectrophotometer instruments used in a variety of manufacturing processes. These services have been based on grating spectrometers, which are not only time consuming to use but are also obsolete. Most of the commercial IR spectrophotometers sold today are based on Fourier Transform instruments. NPL has thus begun a programme to replace its grating instruments with FT based devices.

The first stage of this process has now been completed with polystyrene wavenumber standards now being generated by an FT instrument. This same instrument is expected to provide regular and diffuse reflectance measurements by the end of the year.

A second FT spectrometer is being evaluated as an "absolute" instrument to allow primary realization of scales.

iv) Visible spectrophotometry

NPL has completed its measurements for CCPR K6 spectral regular transmittance and is in the process of calibrating diffuse reflectance standards for CCPR K7. During this latter comparison some asymmetry was noted in the goniometric reflectance properties of the spectralon samples being used as internal references. Since the NPL diffuse reflectance scale is based on goniometric based measurements it was essential that such reference standards were replaced before completing the comparison.

Work has also been carried out to develop protocols and software to allow the calibration of certain types of spectrophotometer via the internet. The service allows the remote user to connect to the NPL server which then takes control of the instrument and guides the operator through a series of calibration steps, (reference standards) before finally issuing certified results. It is anticipated that such a service can be used to more quickly and cheaply perform QA and performance assessments minimizing the need for physical attendance by an engineer or auditor.

v) Correlated photons

NPL continues to have a research project in this area and has recently completed the automation of the detector positioning of the facility. This should make the system easier to optimize and will allow improved characterization of some of the potential loss mechanisms associated with path absorption and detector non-uniformity.

In the near future, the system will be used to used to carry out a comparison of detector quantum efficiency measurements with a target uncertainty of ~ 0.5% (limited by our conventional measurements) and also IR spectral radiance with an uncertainty < 1%, comparable with conventional methods.

vi) Fibre optics

All of NPLs fibre optic calibration services have now been extended to cover the spectral range up to 1650 nm and services are available for Polarisation Dependant Loss, Polarisation Mode Dispersion, Polarisation Extinction Ratio and Polarisation Dependant Gain.

vii) Displays

In addition to providing services for luminous intensity and spectral radiance work is underway to evaluate human factor issues such as “readability”.

viii) Earth Observation

During this period NPL provided specialist calibration support for a number of Earth Observation instruments. Two of which required facilities beyond our normal scope.

GERB (Geostationary Earth Radiation Budget). The first of a series of imaging Earth radiation budget instruments was launched on board Meteosat Second Generation (MSG) in July 2002, a European geostationary weather satellite. The instrument measures spatially resolved radiation emitted and reflected from the Earth. The instrument design goal was for an uncertainty < 1% solar reflected and 0.5 % for thermal emitted (demanding for terrestrial applications). NPL provided calibrations of all optical sub-systems and also designed and calibrated large aperture radiance sources for solar reflected (TSARS) and thermal emitted radiation (black body radiators).

CHRIS (Compact High Resolution Imaging Spectrometer). Currently flying on board the ESA Proba spacecraft (launched October 2001), CHRIS is a hyper-spectral imager operating in the silicon band. NPL used lasers from its NLRF to generate a large (200 mm diameter) beam of highly collimated radiation to evaluate out-of-band stay light. This novel method gave much higher resolution than conventional methods. It also used its Ultra-High Temperature Black Body (primary standard source) directly with CHRIS to provide a spectral radiance and irradiance calibration of the instrument. The Black Body is a very good simulator for solar radiation and enables errors due to apparent size of source and angular deviation to be minimized.

TRUTHS (Traceable Radiometry Underpinning Terrestrial- and Helio- Studies). In January 2002 NPL led an international team in a proposal to ESA to fly a satellite to establish a set of primary reference standards, Sun, Moon and Earth targets, to improve the traceability to SI of Earth Observation measurements. The TRUTHS mission in effect proposed the establishment of a free-flying radiometric calibration laboratory in space. The core concept being the flight of a cryogenic radiometer, CSAR, which acted as a reference to establish calibrations of filter radiometers in-orbit, which in turn provided calibrations of spectral radiance. This unique in-flight calibration concept effectively removes the dominant source of uncertainty in existing instruments, (change from ground pre-flight calibration to in-orbit operations).[5]

The proposal was not successful at this time but continues to be promoted and we hope will be re-considered at a future date.

Tracebility for EO measurements. NPL in conjunction with NIST continue to promote to the international EO community the need for improved traceability to SI. The message is increasingly being heard as future missions seek higher accuracy and/or become subject to greater scrutiny as the move to establish "commercial" operational services takes hold.

ix) Appearance

Facilities to make rapid goniometric multi-spectral measurements of surface reflectance, together with the use of specialist digital colour cameras and processing software, are nearing operational status. These facilities and the techniques required to make use of them are being developed in conjunction with a consortium of industrial partners. The objectives of this work are to establish and define measurement conditions which can fully describe the "appearance" of a surface or volume in a quantitative manner, and which can be linked to national measurement scales.

x) Eutectics/temperature

Collaborative work with VNIIOFI and the temperature group of NPL to investigate the radiometric properties of metal/carbon Eutectics has been initiated. Studies have included measurement of repeatability of individual crucibles and also to identify any differences between design of crucible and host black body furnace.

The work to-date has proven to be highly encouraging with the Eutectics offering the prospect of highly stable reference sources with colour temperatures comparable to or higher than those of incandescent lamps.

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8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

Our customer needs are broadly served by existing CCPR activities. We see no particular need to change the scope or coverage significantly. However, we would encourage greater collaboration on research projects both within the CCPR and, where appropriate, with other CCs, in work which may have long-term general benefits to the SI e.g. work on the new metal carbon Eutectics with CCT and the valuable work of the UV working group.

To encourage greater collaboration it may be helpful to identify major facilities at NMIs, which could be used for collaborative R&D projects, e.g. synchrotron facilities or laser radiometry facilities such as at NLRF at NPL and SIRCUS at NIST.

The calibration and validation needs of the remote sensing community and those studying climate change are becoming increasingly demanding. Whilst the specialist nature of the needs of this customer and the relatively small number do not necessarily demand a significant change in scope for the CCPR, there may be benefit in some small comparison activities amongst a few NMIs being initiated under the auspices of CCPR, to promote the us of capability at NMI to this community.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Improved low cost, high accuracy, generic transfers standards remains the highest priority for R&D in the the Photometry and Radiometry area. In particular, filter radiometers (in the general sense) are a major requirement, both as transfer standards to customers and also between primary scales e.g. spectral responsivity and irradiance or photometry etc.

Collaborative work with the radiation thermometry community of CCT in the development and application of the new metal carbon Eutectic is likely to become a high priority.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

The following are topics we feel are appropriate for collaboration:

Metal Carbon Eutectics
Correlated photons
Improved IR detector transfer standards
Measurement of appearance

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

The level and effectiveness of the interaction between organisations is varied. For example, many of the CIE Technical Committees, particularly those within the Divisions concerned with measurement, have a high level of membership from NMIs and it is therefore relatively easy for these Divisions to maintain contact with the CCPR, preventing overlap. The CIE, with its strong industrial links, provides an infrastructure to develop standardization and discuss methodologies at an industrially relevant level, leaving the CCPR to deal with underpinning principles and primary scales. Nevertheless, there would be benefit from improving the level of awareness of the CCPR within those Divisions of the CIE which are less directly involved with measurement, to ensure that appropriate coordination and transfer of knowledge takes place between all of the CIE Technical Committees and the CCPR - the CIE should be encouraged to consider how to achieve this. Interaction with other bodies such as WMO is much less effective with very limited interaction between the communities. This has in the past, and in some cases continues to create an independent structure which can potentially lead to the establishment of reference standards unrelated to SI and/or comparison procedures which lack the rigour of those being encouraged by the MRA. Increased interaction between the committees of the WMO with the NMIs would bring great benefit to both communities.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

We feel that, whilst there is a need to maintain and in some cases improve the communication between the two organizations, we see no particular need for this to be formalized through a MoU.

The WMO, and WHO are very different organizations to that of the CIE. Although all are international organizations which can have a standardization role, the first two are established through international statutes in a similar manner to the CIPM, funded directly by governments. Whereas the CIE is funded by subscriptions from members and is dominated (rightly) by the industrial community. Clearly the overlap of activities with CIE means that a close working relationship should be maintained and encouraged. Historically there will always be a strong link because of the adoption of the CIE $V(\lambda)$ curve but otherwise there is no particular reason why the relationship with CIE needs to be any different than any other standards organization e.g. IEC, ISO etc.

However, there may be a need to ensure that the roles and scope of activity of each organization is more clearly defined and a greater emphasis placed on communication between the two organisations. In particular the role of CIPM (CCPR) in defining SI and derived quantities and the role of CIE in providing standardization of test/calibration methods and as voice of industry.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

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14) Have you got any other information to place before the CCPR in advance of its next meeting?

No.

NRC Response to CCPR Questionnaire for 17th CCPR Session (17 - 19 June 2003)

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The implementation of the CIPM MRA has resulted in a considerable increase in workload in the Photometry and Radiometry (PAR) Group of the Institute for National Measurement Standards (INMS) at NRC. This increased workload has been in the following main activities:

- Key comparisons : in order to provide the necessary database (Appendix B)which is the backbone of the MRA, many new international comparisons (Key Comparisons) were initiated at the CCPR meeting in 1997. PAR is participating in most of these. This has required (and is continuing to require) considerable manpower and funds. To-date, these Key Comparisons are only about 50% complete.
- Supplementary intercomparisons (e.g. bilateral intercomparisons) : PAR is participating in several intercomparisons to supplement the key comparisons. A major motivation for doing this is to underpin some of the services that are being listed by NRC in Appendix C of the MRA.
- CMC's : the services which are covered by the MRA are listed in the so-called Appendix C of the MRA. In order to have these CMC's accepted for Appendix C, they must be reviewed and vetted by all other NMI's ; in particular, the uncertainties quoted must be backed by intercomparison results. NRC has spent considerable time preparing its own CMC submissions, modifying them in accordance with reviewer comments, and also reviewing all the CMC's of other NMI's.
- Implementation of a Quality System: one of the requirements of the MRA is that the participating laboratories implement a Quality System. Due in large part to this MRA requirement, INMS has decided to implement a quality system complying with ISO 17025, with external assessment. In preparation for this, PAR has spent considerable time developing, modifying, and documenting various procedures, as well as the preparation of various documents, including new calibration report formats; in particular, these reports now provide a more detailed analysis of uncertainties.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?

No comment

3) Given the announcements on the restructuring of the BIPM and the attached explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

It is not expected that the closure of BIPM photometry and radiometry (PAR) activities will have a significant impact at the national or regional level. However, the loss will be felt at the international level, especially with respect to CCPR activities. Over the last ten years, the BIPM has been the pilot laboratory for many international comparisons. Their role as a "neutral", independent and internationally-recognized authority is unique and irreplaceable. This neutral role is particularly important at the present time, in the context of the MRA. The BIPM PAR group has also developed expertise which contributed, via their publications and participation in conferences, to advancements in the field of PAR. The closure of the BIPM PAR laboratory will be a great loss to the international PAR community.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

From the NRC PAR group perspective, the international comparisons organized by CCPR are the most important CCPR activity. The NRC PAR group has participated in almost every intercomparison organized by CCPR over the past 20 years. Participation in international comparisons is essential in order to establish and maintain an international credibility in the quality of the standards developed and maintained at NRC and in the calibration services provided by NRC. This activity is also important for increasing scientific knowledge of factors that contribute to measurement uncertainty.

On the negative side, the protocols and data analysis procedures of CCPR comparisons are becoming more and more complicated. As a result, there is a loss of transparency in the procedures used and carrying out intercomparisons has become much more time consuming, especially for pilot laboratories. A possible consequence of this more arduous process is that fewer labs will be willing to act as pilot laboratory, or even to participate in future intercomparisons. It also seems to us that the approach used in the past was less formal and more conciliatory, based on experienced judgment, and where the ultimate goal of achieving international harmonization of standards was more apparent.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

The primary value of inclusion of NRC's CMCs in the MRA database has been in providing an internationally-recognized point of reference for clients who request information on: NRC traceability, certification/accreditation/registration, official recognition of its measurement services, or level of agreement with other NMIs. The number of these inquiries has increased in the past few years largely due to the requirements of ISO registration and laboratory accreditation. Since CMC's entered in the MRA database have been peer-reviewed and approved, these measurement services gain a greater worldwide visibility and acceptance. However, the existence of the BIPM key comparison Appendix B database, and the fact that NRC regularly participates in CCPR key comparisons, rather than the inclusion of NRC's CMCs in Appendix C, have been the more valuable references for the purpose of addressing these questions.

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities
(b) spectral radiometric quantities

Spectral responsivity

In preparation for the CCPR-K2c intercomparison, we are in the process of realizing a new spectral responsivity scale in the UV range 200 nm to 400 nm. Several types of transfer radiometers are being used; these will be calibrated directly using our cryogenic radiometer facility. Since the last CCPR, and in preparation for K2c, we have acquired Hamamatsu S5227's which were mounted in single-detector heads: these were fully characterized, and calibrated directly using the cryogenic radiometer in the range 250 nm to 400 nm at 10 nm intervals. Recently, we have received from PTB a number of PtSi detectors, also in preparation for K2c. Three of these were selected and mounted, and they will be calibrated in the range 200 nm to 400 nm. The first phase of this calibration, the relative calibration of the PtSi radiometers in the range 200 nm to 300 nm using thermopiles, has been completed. The calibration of the radiometers in the range 250 nm to 400 nm using the cryogenic radiometer is in progress.

Spectral irradiance

In preparation for our participation in CCPR K1a and K1b, we have been working to extend our present spectral irradiance scale (300 nm to 1600 nm) further into the IR to 2500 nm and into the UV down to 200 nm. In particular, we have purchased a solar blind photomultiplier for the UV and the deuterium lamps to be used for the CCPR K1b comparison. We have also upgraded our facility to use chopped radiation detection techniques for the IR. We plan to use calibrated sources previously obtained from NIST as the lamp standards for the UV (below 300 nm) and the IR (beyond 1600 nm). The first phase of the K1a comparison has been completed ; we have calibrated both the FEL-type and the Polaron-type of tungsten lamps and returned the lamps to the pilot lab (NPL).

Spectrophotometry

The photoluminescent effect was investigated in various opal glasses used as reflectance standards. The motivation for this study was to quantify the colorimetric error due to this effect when these materials are used to calibrate colour measuring instruments, such as spectrophotometers. The measurements were performed on the NRC Reference Spectrofluorimeter and showed that the photoluminescent effect was weakest in Russian opal glass MS14 and strongest in the Japanese opal glass, Everwhite. These research results were presented at Oxford IV and will be published in a special proceedings issue of *S.P.I.E.*

(c) photometric quantities

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

NIST-NRC bilateral intercomparison of spectral responsivity calibrations

The motivation for this comparison was to test the level of agreement between NIST and NRC for routine calibrations in the range 250 nm to 1100 nm using Si diodes, and in the range 700 nm to 1800 nm using InGaAs and Ge detectors. The results indicate that agreement between NIST and NRC is well within their combined uncertainties throughout the spectral ranges tested and for the three types of detectors used. In particular, this intercomparison supports the CMC's listed by NIST and NRC in Appendix C of the MRA. The results of this intercomparison were presented at the NEWRAD2002 conference and have been published in the conference proceedings issue of *Metrologia*

NRC-NPL bilateral intercomparison of mid-infrared regular transmittance measurements

This comparison involved an NPL standard glass artifact, NG11 that was measured in the range from 2000 to 4000 cm^{-1}. The differences between NRC and NPL were within the combined uncertainties throughout the spectral range. These results were presented at the Oxford IV Conference at Davidson College, NC and will be published in a special proceedings volume of *S.P.I.E.*

NORAMET/ SIM UV/Visible Spectrophotometry Wavelength Standard Interlaboratory Comparison

The motivation of this comparison was to evaluate the suitability of holmium oxide solution as an intrinsic wavelength standard. This reference material was measured by five participating labs, including three NMIs (NRC, NIST, CENAM) under routine calibration conditions. The results showed that the wavelength measurements were in agreement to better than 0.2 nm (at a 95% confidence level) for spectral slit widths ranging from 0.1 nm to 3.0 nm. The results of this comparison were published in **Analytical Chemistry.**

NRC-NIST Bilateral Comparison of Specular Gloss Measurements

This comparison involved both high and medium-gloss standards measured at standard geometries of 20°, 60° and 85° geometries. The results of this comparison showed good agreement for the measurement of highly polished black glass standards, well within the combined uncertainties of the two labs (0.3% respectively at a 95% confidence level). These results will be published in *Journal of Coatings Technology.*.

NRC-NIST Inter-laboratory Measurement Comparison of Visual Display Gamut Assessment Standard

The goal of this comparison is to design a standard illumination source with optical filters to serve as a target for the assessment of state-of-the-art display measurement systems. This source (GAMUT assessment standard) has been developed by the NIST Electronics and Electrical Engineering lab. The results of the comparison with NRC provided valuable information on design improvements and the suitability of this type of source as a transfer standard for laboratory self-certification.

New Visual Display Calibration Services
New calibration and consultation services have been established for the colour characterization of video displays (CRT, FPD, etc.). The following services are now routinely available: measurement of tristimulus values including absolute luminance of the RGB primaries of the display, measurement and mathematical modelling of the relationship between the digital data and radiometric data in accordance with CIE recommendations, and 2D diffuse ambient contrast measurements.

NRC Quality System – Improvements to Routine Calibration Measurements
As part of the implementation of a quality system at NRC, and in preparation for a formal external assessment of our calibration services, considerable work has been carried out since the last CCPR to modify or develop procedures and the associated documentation for our photometric, radiometric and spectrophotometric calibration services. For spectral responsivity calibrations, a new calibration report format was prepared which now includes detailed uncertainty budgets for various measurement scenarios. This also required extensive auxiliary measurements and calculations to quantify more accurately certain uncertainty components. The PAR Group successfully completed an internal audit of its quality system documentation in January 2003.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives? In the light of this information please suggest desirable changes in the future working program of the CCPR.

- With the completion of CCPR K2a, K2b, and K2c comparisons, the spectral responsivity scales of NMIs will have been intercompared throughout the spectral range 200 nm to1600 nm, using PtSi, Si, and InGaAs detectors. No spectral responsivity intercomparison has ever been carried out for the range 1500nm-2500nm. It would be a good idea for CCPR to organize an intercomparison in this spectral range, using as artifacts either extended range InGaAs detectors, or liquid nitrogen cooled InSb detectors. Although it may be premature to implement this intercomparison now, a working group could be formed to study feasibility and report back to CCPR.
- The CCPR has never organized an intercomparison of broadband UV meters (UVA, UVB, UVC). In view of the increasing interest worldwide in UV measurements, and the large discrepancies observed in many laboratories between measurements carried out using different UV meters, it may be time for CCPR to get involved in this type of measurement. Again, it may be premature to organize an intercomparison now, but a working group could be formed to study the feasibility of such an intercomparison.
- The CCPR has never organized an intercomparison of colorimetric measurements, such as CIE x,y,Y, L*a*b* values of surface non-fluorescent or fluorescent colours. This comparison data would be valuable in underpinning CMC claims for these quantities.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Although both the UV (<400nm) and the IR (>1600nm) are spectral domains where improvements in radiometric measurements are needed, the problems encountered in the UV need to be resolved more urgently in view of the increasing worldwide demands and concerns regarding this spectral range. There is a need for better detectors: more stability, better UV selectivity, erythemal matching, etc.. Although many new types of detectors are being developed (GaN, SiC, PtSi, etc..) , the technology is not mature and much work remains to be done. In particular, there is a need for improved band-type UV meters (UVA, UVB,UVC) and also improved calibration procedures for these artifacts.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

Collaboration with other NMIs in the development of a new spectral irradiance scale in the range 200 –2500 nm, using the method based on the use of a high-temperature black body source and a cryogenic radiometer facility (subject to NRC receiving internal funding and additional manpower to set up a blackbody facility).

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

The interaction between CCPR and CIE appears to be quite good. This is facilitated by the fact that several members of CCPR are also active members of CIE, and there are regular CIE liaison reports on relevant activities at CCPR meetings. A similar close relationship between CCPR and WMO does not appear to be as necessary. However, open lines of communication currently exist with WMO, as evidenced by the presence of the director of the World Radiation Center (WRC), a member of the WMO, at the last CCPR meeting. Other links also exist, for example through the NEWRAD conferences, where WRC and CCPR members are not only participants, but also members of the scientific committee. We have no information regarding actual or potential overlap in working programmes or duplication of efforts between the CCPR and the WMO. However, regarding the CIE, although the potential for duplication of effort exists, it does not appear to have been a problem. For example, intercomparisons organized by the CIE appear to have been complementary or different from the ones organized by CCPR. The same observation can be made about the documentation activities of the two organizations. This avoidance of duplication may result from the fact that several CIE members and officers are also CCPR delegates.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

No comment.

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14) Have you got any other information to place before the CCPR in advance of its next meeting?

No.

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire
Answers from OMH Hungary

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

1./ Hungary is a small and poor country compared to other CCPR members. Most of our calibration is for Hungary and our prices are lower compared to other CCPR members. Therefore the CIPM MRA between NMIs had a week effect on our work. We got some calibration work from abroad, but this is a small percentage.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

2./ I think that through MRA the unnecessary double calibrations are avoid. I think it needs more confidence from a lot of nations in MRA.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

3./ I think CCPR was an excellent organisation in the field of photometry and radiometry. Its real advantage was that it was suited for technical discussion as well and the intercomparison measurements gave a good overview about the measurement accuracy. The regional organisations like PHORA in EUROMET is rather ineffective due to the rather large technical differences among the members. These differences in CCPR were much smaller.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

4./ The CCPR intercomparisons gave for us the proof of the validity of or uncertainty budget. I do not think there is any more important thing in our calibration. This gave us a link to the other part of the world.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

5./ We do not have any new entry.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities
(b) spectral radiometric quantities
(c) photometric quantities

6./ a./ We developed a method for detector based irradiance measurements in the spectral range of 380-900 nm. Its accuracy needs further investigations.. We calibrate UV Meters at 365 nm.
b./No new developments.
c./No new developments.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

7./..We have developed a method for wavelength calibration. It has only industrial importance.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

8./ Our limits are not due to the CCPR activity range…..but financial.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

9./ In our country the calibrations in the field of telecommunication is not solved…..This is personal and financial problem again in Hungary. I do not think we may suggest anything.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

10./..Not now.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

11./ I think CIE had and still has a great importance in some special industrial measurements like gloss, CRT characterisation, colour measurements, etc. Their recommendations are up to date too.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

12./ I am not informed well enough.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

13./ Andor Gy: Gonioreflectometer-based gloss standard calibration
Metrologia 40 (2003) S97-S100

14) Have you got any other information to place before the CCPR in advance of its next meeting?

14./ No information.

Physikalisch-Technische Bundesanstalt

Braunschweig und Berlin

Reply to CCPR Questionnaire
for Period April 2001 to April 2003

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

More international comparisons (CCPR and RMO KCs) have to be carried out; a lot of work was and is needed for establishing and maintaining the CMC database.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

Major benefits are the extended international contacts and stimulated co-operation, especially in the field of uncertainty evaluation and quality assessment.
Major disadvantage is the time-consuming effort for the entries in the CMC database, which is unbalanced with respect to a possible benefit.
The claimed uncertainties of the entries in the CMC database are often difficult or almost impossible to validate. It may be better and more realistic to dispense with details about uncertainties apart from those entries based on KCs and SCs.

3) Given the announcements on the restructuring of the BIPM and the attached explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

The decision to stop photometry and radiometry activities at the BIPM, just when strongly recognised reports like “Harnessing Light” (in the US) and “Optical Technologies” (in Germany) are presented to the public, may be noticed as “political” action. It will not affect national or regional metrology but may reduce international reputation of the BIPM. Chemistry is of course important, but what type of activities related to “Chemical units” will be done at the BIPM?.

While different NMIs will surely take on and continue r&d activities of the BIPM, it has to be discussed and decided who can and will calibrate photometric and radiometric standards done so far at the BIPM and who will bear the costs in future.
As the BIPM activities are not associated with the KCs CCPR-K5 and CCPR-K6, the field of spectrometry and similarly of optical telecommunication as well as other fields of applied radiometry and photometry are not affected.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

Main merits: documentation of competence, validation of measurement facilities and quality management system.

Shortcomings: in several cases heavy workload and high costs including e.g. meetings to find the "best" method for the determination of KCRVs and EUROMET projects (RMO KCs) to disseminate the CCPR KCRVs, long duration of intercomparisons where several intercomparisons are not completed, no financial support for intercomparisons available (financing them by e.g. European programs failed in the past because of little interest by industry).

A clear difference between a "best national realisation" of a unit (focusing on traceability) and the "CCPR KCRV" (focusing on international equivalence) seams to be unbalanced today, both should be taken of equal importance. Otherwise the available money for fundamental realisations of units will be reduced.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

The CMC database may be useful for those, who are new in a field and try to find calibration laboratories. However, PTB is definitely not yet affected; there was no request by customers based on our entries in the MRA database.

6) Summarize the progress in your laboratory in realizing top-level standards of:

(a) broad-band radiometric quantities

(b) spectral radiometric quantities

Short-wavelength radiometry using synchrotron radiation

After shutdown of the electron storage ring BESSY I in 1999, PTB's measuring facilities for radiometry using synchrotron radiation at short wavelengths from the UV to the x-ray region have successfully been reestablished and extended at PTB's new synchrotron radiation laboratory at BESSY II.

In the field of detector-based radiometry, the spectral responsivity of semiconductor photodiodes was already reported to be uniformly traceable to cryogenic radiometers in the spectral region from 0,7 eV to 10 keV (Reply to CCPR Questionnaire for Period April 1999 to March 2001). In the region of photon energies from 10 keV to 60 keV, it was now possible to trace the spectral responsivity of semiconductor diodes back to the free-air ionisation chamber as a primary standard, this chamber being operated at BESSY II with monochromatised radiation of a superconducting 7 tesla wavelength shifter. Thus, the scale of the spectral responsivity of the PTB now covers six decades of the photon energy. In the range between 10 keV and 60 keV, the work is now concentrated on using a cryogenic radiometer and a free-air ionisation chamber in parallel with a view to discovering uncertainties of the primary standards which may not have been identified up to now.

(c) photometric quantities

The new EUROMET Major Investment "Universal Robot-Based Goniophotometer" (under construction; accessible by the end of 2004) will be uploaded shortly to the EUROMET web site (Reg. no 10025).
TULIP facility (Tunable Laser In Photometry) for the calibration of filter radiometers (in photometry and colorimetry and for the radiometric measurement of blackbody temperatures) is being developed and established.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

General remark: Moving into a new building in 2003 and 2004, many activities are well under way to establish and reestablish improved measurement facilities and standards in photometry, radiometry and reflectometry. In order to allow overlapping use of old and new facilities and to complete key comparisons that are under way, the old building will be used until the end of 2004.

Spectral irradiance
For the CCPR key comparison K1.b where the PTB is acting as the pilot lab, various activities were started and meanwhile successfully completed:
A new transfer standard lamp system with a deuterium lamp in a suitable housing that can be combined with a SiC reference photodiode has been developed and successfully tested.
A special facility has been completed where three deuterium lamps simultaneously can be pre-aged, their ageing process can be observed (integral method) and spectrally characterised, too.
A UV-optimised facility for the calibration of lamps within the spectral range of 200 nm up to 400 nm is operational.
The measurements for the CCPR key comparison K1.a within the wavelength range of 250 nm up to 2500 nm have been completed and the set of three 1000W FEL lamps were returned to the pilot lab (NPL).

Photometry
DSR facility (Differential Spectral Responsivity) for the calibration of reference solar cells and large-area filter radiometers in photometry has bee improved (reduction of uncertainty; extension of wavelength range from 220 nm to 1900 nm; establishment of an automatic and economical calibration procedure).
Calibration techniques for LEDs including LED clusters and development of LED standard sources are being developed; a bilateral comparison with NIST based on new LED standards for luminous intensity, flux and chromaticiy has been completed (report in preparation).
Photometric calibration and characterisation of displays has been started and will be continued after moving into the new building.

Laser radiometry
New facilities for high power laser radiometry at 193 nm and 157 nm have been completed. The 157 nm facility allows measurements in vacuum as well as in protective gas atmosphere. A new type of thermal cone detector optimised for high energy pulses and with an electrical substitution heater included is in preparation.
The "Facility for high-power laser radiometry" has been registered in the EUROMET database (Reg. no 10020).

Radiometry for the optical telecommunication
For the optimised calibration transfer in the infrared spectral range from the cryogenic radiometer to other facilities, two types of trap detectors were constructed and spectrally completely characterised: InGaAs and Ge trap detectors built of large-area commercially available photodiodes were investigated in terms of spectral responsivity (radiant power) or quantum efficiency, spectral temperature coefficient and non-linearity.
More and more customers of the telecommunication community are requesting fibre-bound calibrations instead of free-beam calibrations of detectors. Thus, new facilities were constructed and tested for the fibre-based calibration in terms of responsivity and non-linearity.

Radiometry and spectrometry related to synchrotron radiation
In close cooperation with different partners, the measurement capabilities for the calibration of photodetectors have been extended to the detection of strongly pulsed VUV radiation such as F_2-laser radiation at 157 nm and free-electron-laser radiation below 100 nm.

A microwave-heated electron-cyclotron resonance plasma source has been developed as a stable transfer source standard in the VUV.

A new reflectometer was put into use in October 2002. With this device the PTB is the only institution worldwide to be in a position to characterise mirrors up to 55 cm in diameter and 50 kg in weight with small uncertainties. At present, the reflectometer is mainly used for measurements in support of the development of extreme UV semiconductor lithography, especially for 13 nm at-wavelength characterisation of multilayer mirrors, mask blanks and masks in cooperation with industry. Measurements of this kind can now be done at the required standard uncertainty level of a few 10^{-3}, as shown by the agreement reached in an international EUV reflectivity comparison with four other US and Japanese institutions. In particular, the comparison supported the small relative uncertainty of 0.14 % claimed by both the CXRO (Center for X-Ray Optics, USA) and the PTB.

In cooperation with the German Federal Institute for Materials Research and Testing (BAM), progress has been made in the radiometric traceability of fluorometry. The measured signal in a fluorescence experiment is determined by sample-related quantities (e.g. fluorescence yield) and instrument-related quantities. In order to allow for a correction of the wavelength-dependent instrumental effects on emission and excitation fluorescence spectra, a set of reference materials are developed at the BAM, the radiometric traceability to the primary radiometric standards of spectral radiance and spectral responsivity being provided by the PTB.

Improved calibration of the spectral responsivity of filter radiometers in the near infrared
The spectral comparator facility for the calibration of filter radiometers used for radiometric measurements of thermodynamic temperatures has been substantially improved by implementing a prism pre-disperser, a polarisation prism, and a highly accurate temperature control of the detectors (within 50 mK throughout the complete calibration chain). Together with the implementation of two additional near-IR lasers at the radiation thermometry cryogenic radiometer, this now allows the calibration of the spectral responsivity of Si- and InGaAs-based filter radiometers in the near-infrared wavelength range up to 1800 nm. Based on this progress, thermodynamic temperatures down to the temperature of freezing tin (419 °C) have been measured with standard uncertainties of 44 mK at the tin point and of 16 mK at 457 °C. These measurements contribute to detect a possible systematic deviation of the International Temperature Scale of 1990 from thermodynamic temperature in the high-temperature range.

A new instrumentation for the fast measurement of aperture areas has been implemented. Using a reference aperture of 5 mm in diameter, the unknown areas of apertures with diameters ranging from 50 µm up to 5 mm are determined by measuring the signal ratio of a trap detector alternately equipped with the reference and the unknown aperture. Typical relative standard uncertainties range from 0.2 % (5 mm) to 0.5 % (50 µm).

Applying calibrated filter radiometers, thermodynamic temperatures of the phase transitions of metal-carbon eutectics have been measured in the irradiance mode at the PTB in cooperation with the VNIIOFI.

Spectrometry

In 2001, NIST, NPL and PTB performed a trilateral intercomparison measuring the radiance factor for bi-directional geometry. Results were presented at NEWRAD 2002 conference.

Measurement facilities were improved for the IR wavelength range for regular transmittance and reflectance, especially efforts are made to improve spectral transmittance measurement for low transmittance ($\tau(\lambda)< 10^{-6}$) in the NIR (900 nm to 1,5 µm). Participation in a wavelength intercomparison on absorption minima of Holmium-Oxide filters organised by NIST.

A new gonioreflectometer (bi-directional geometry) to be installed in the new building is being developed; the 2 facilities (sphere reflectometers) for the determination of the absolute spectral diffuse reflectance in the VIS and IR are being improved including better automation and characterisation of the spheres.

Service of the testing of eye-protection filters will markedly be reduced within the next 3 years.

The ultra-high peak power of femtosecond laser pulses is utilised in studies of the non-linear optical properties of matter.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

For a growing number of applications, demands of customers for radiometric support at short wavelengths increase; examples are materials research and testing (fluorescence analysis), astrophysics (VUV and x-ray astronomy), radiation protection (dosimetry), and semiconductor photolithography (at 157 nm and 13 nm). This increasing demand should adequately be taken into account by the CCPR. Corresponding CMC entries may be admitted in the future.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

Measurement of Luminance and comparison of related unit.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

Goniophotometry for the conversion of near-field measurement results to far-field characteristics.
Intercomparison between PTB (Germany), NIST (USA), and AIST (Japan) concerning spectral responsivity of semiconductor photodiodes in the VUV.

Investigation of the equivalence of spectral irradiance and spectral radiant intensity of deuterium lamps in the UV and VUV (PTB Berlin and Braunschweig, NIST)

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

CCPR deals with units and principles, while CIE handles applied metrology, measurement procedures and standardisation. A closer co-operation regarding strictly the borderline between their different fields of competence would be helpful for CIPM with respect to the closure of the Photometry and Radiometry activities at the BIPM and could give more weight to CIE definitions.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

A MOU between CIPM and CIE may be useful if agreed in considering the borderline mentioned earlier: units and applied metrology.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

2000

L. Werner, J. Fischer, U. Johannsen, J. Hartmann: *"Accurate determination of the spectral responsivity of silicon trap detectors between 238 nm and 1015 nm using a laser-based cryogenic radiometer",* Metrologia **37**, 279-284 (2000)

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14) Have you got any other information to place before the CCPR in advance of its next meeting?

No comment

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire

Reply from SMU

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

The activities of photometry and radiometry laboratories in accordance with the CIPM MRA have been oriented on the problems connected with the quality system according to ISO 17025 even if the work on the involving this system in SMU has began in1997. Moreover we have concentrated the work on the problems of uncertainties expression especially by spectroradiometric measurements.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

By introducing of key comparison and supplementary comparison categories MRA provides the base for creation of quantified Metrological world's system. The CIPM MRA should include some control mechanism for checking this system within period between two key comparison with the possibilities assess the stability this system and predict its trend. This administrative – technical task is and should be in the competency of BIPM.

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

We don't know all details for this decision but from view of the general impact we can note that it will be represent some significant complication especially for NMI's which have not realised all units on primary level and they get them from BIPM laboratories. To stop it will be resulting in break of following the trends (SMU and former CSMU got the luminous flux value from BIPM continually last forty years). The new system probably will be established on the results of selected regional NMI's and there is the question of co-ordination their activities and comparability.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

Laboratory of photometry and radiometry of SMU took part in five key comparison measurements in last five years. The results of these measurements allowed us to identify the errors in measurements procedures, to correct models for their processing and determine trend and to refine tasks by creating of radiometric and photometric scales.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

This inclusion give us the imaging about our laboratory status in world's metrological system.

6) Summarise the progress in your laboratory in realising top-level standards of:
(a) broad-band radiometric quantities
(b) spectral radiometric quantities
(c) photometric quantities

(a) In accordance with the request from industry on emissivity measurement the laboratory renews its activities in this area. The measurements are realised by means of quasi non-selective pyroelectric triglycinsulphate detectors and for next year is planned developing new equipment for this purposes.

(b) In account of our results in key comparison CCPR K2.b we have completed the set of primary radiometers with the new "TRAP" radiometer. The primary testing of it indicate that by means of this radiometer we can cover the spectral range from 300 nm to 920 nm. We are preparing the others two "TRAP" spectroradiometers. We have organised the comparison measurements of spectral responzivity scales between SMU Bratislava and CMI Praha

(c) We have paid attention to calibration and verification of illuminance meters. National standard for verification of this instruments was introduced.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?
Progress is connected with primary standards and some special areas (see points 6 and 8)

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.
In the last years demands for calibrations of instruments used in the telecommunication is increasing. Besides of power meters calibration is required calibration of sources (lasers and LED's), optical spectral analysators and measurements of linearity on nominal wavelength 850 nm, 1310 nm and 1550 nm.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?
Metrology for optical telecommunication.

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?
We appreciate receiving information dealing with realisation of radiant flux and irradiation scale in spectral range from 200 nm to 400 nm using optical radiometers.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organisations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.
We have not enough relevant information to assess this problem.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?
No comments.

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

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(In Czech) Metrologie, Praha, No.1, vol.11, 2002, p. 18-21

14) Have you got any other information to place before the CCPR in advance of its next meeting?
We have any other information relevant to CCPR meeting.

Bratislava 04.06.2003

Dr. Peter Nemeček, PhD.

Reply to Questionair for the 17th Session of CCPR (17 - 19 June 2003)

From SPRING Singapore

1) **In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs?**

   Meeting the criteria set by the MRA has become our main objective for all our activities, including various efforts to improve our quality system, review & improve calibration techniques, procedures, formalise uncertainty evaluation and traceability statement. It also encouraged us to more actively participate in key comparisons and metrology conferences & meetings at regional and international levels.

2) **What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved?**

   Major benefits: Our quality system and calibration service has been improved through the implementation of the MRA. Confidence of our customers on our service has also been enhanced.

   Disadvantages: those areas for which we have not been able to provide supporting evidence may face difficulties to get recognition in the next few years. Key comparisons are expensive and not always available for participation – leading to difficulties especially for relatively new NMIs.

3) **Given the announcements on the restructuring of the BIPM and the** attached **explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.**

   Potential problems or consequences of this decision could be:

   - Future initiatives and key comparisons may be affected due to the lack of a neutral coordinator;
   - Increased cost for some NMIs as some free calibration services are no longer available from BIPM e.g. luminous intensity and flux;
   - Increased cost for some NMIs as some larger or more advanced NMIs could impose charges on request for bilateral comparisons from smaller or less advanced NMIs.
   - Future role of CCPR will also be weakened gradually and eventually CIE may take over.

4) **Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements**.

There is no doubt that the CCPR KCs are very valuable to us as we need them to check the performance of our standards, calibration techniques and procedures to support our CMC claims. However, the long period often required for such comparisons has become the biggest hurdle for us and may also affect the progress in setting up the CMC database.

For example, K6 for spectral regular transmittance started more than 3 years ago (from the date of artifacts being dispatched). Although this comparison is relatively simple as its artifacts (neutral density filters) are easy to deliver and maintain, the final results still have not come out (we submitted our results in Sep 2000). K2c on spectral responsivity is even worse – it has not even started after 3 years preparation. With such speed, there is no way a lab without previous records of international comparisons can provide in time the required supporting evidence for many of its CMC claims.

Our suggestion is to encourage NMIs carrying out more regional or bilateral comparisons. The latter, especially, can be much faster to complete. However, one lab for such comparisons must be a linking lab to the CIPM KCs and it may not be willing to do such comparisons as it may see them as a burden with nothing to gain. A formal mechanism should therefore be designed to address this issue aiming to benefit all parties involved in such comparisons.

5) **Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.**

No assessment has been done yet.

6) **Summarize the progress in your laboratory in realizing top-level standards of:**

a) broad-band radiometric quantities

Nil.

b) spectral radiometric quantities

- **Establishment of spectral responsivity scale** (250nm – 1600nm) through a group of detectors calibrated by a mechanically pumped cryogenic radiometer using intensity-stabilised lasers (HeNe and Kr^+) with a double-monochromator based calibration facility. A bilateral comparison on trap detectors at 350.7, 356.4, 476.2, 568.2, 632.8, 647.1 and 799.3 nm with NPL is in final stage;

- **Improvement of spectral irradiance scale** (250 – 1600 nm) through a newly developed double-monochromator based calibration facility with extended wavelength range and better uncertainty. An international comparison is needed to verify the accuracy of our scale;

c) photometric quantities

- **Realisation of Candela** through a set of trap-photometers traceable to our cryogenic radiometer. Three trap photometers were designed, fabricated and calibrated. Initial results show an agreement with our previous scale (based on BIPM candela of world means through a set of lamps) within ±0.1%. Estimated expended uncertainty of the new scale is 0.58% (2σ) mainly limited by the uncertainty of measurement on aperture area. A new international comparison is required to confirm the accurary of our new scale;

7) **What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?**

- Development of a reference standard for fibre optical power measurement traceable to our cryogenic radiometer;
- Development of a calibration facility for optical spectrum analyzer;
- Study on methodology of characterisation and calibration of broadband UV radiometers (related to CIE TC2-47);
- Coordinating an APMP comparison on the irradiance responsivity of UVA detectors (started in July 2002, expected completion in October 2005), (Eight participates including NML/Australia, NMIJ/Japan, NML/South Africa, CMS/Chinese Taiwan, KRISS/R. O. Korea, NIM/P. R. China, MSL/New Zealand and SPRING/Singapore)(in progress);
- A Near-normal Spectral Regular Reflectance scale has been established recently using a V-W absolute reflectance accessory on a double-beam spectrometer together with six numbers of narrowband, multilayer dielectric coated HR Laser mirrors for wavelengths of 325 nm, 501 nm, 830 nm, 1064 nm, 1300 nm, and 1550 nm. The expended uncertainty (k=2) is +/- 0.6% (relative) over the wavelength range of 250 nm to 2500 nm for the measurement of highly reflective samples (reflectance ≥ 10%).

8) **What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives? In the light of this information please suggest desirable changes in the future working program of the CCPR.**

- Calibration of LED related parameters;
- Calibration of fibre optic related parameters;
- Broadband UV radiometer calibration (200 -400 nm);
- High power laser power meter calibration (>500 mW);
- Pulse laser energy meter calibration

9) **What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry?**

- Study general methodology of uncertainty evaluation on measurement/calibration of broadband radiometric and spectrophometric quantities (color related).

10) **Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration?**

- High power laser power meter calibration
- Pulse laser energy meter calibration

11) **Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological**

Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

No comment

12) **Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?**

Yes.

13) **Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?**

G Xu and X Huang, Calibration of broadband UV radiometers - methodology and uncertainty evaluation, Metrologia 40 (2003) S21-S24

14) **Have you got any other information to place before the CCPR in advance of its next meeting?**

Nil

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire

Replies of Ulusal Metrology Enstitüsü (UME, Turkey) to the CCPR Questionnaire

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs ?

CIPM-MRA relation is important for us and it is the activity that directed our studies mostly. Looking in general structure of MRA is based on key comparisons, quality system, arrangements and persuasion of CMC tables. Looking in terms of time, these mentioned activities affect the timing for laboratory's research studies, economical power, and availability of use of equipment. In addition, research studies in the laboratory, studies on uncertainty analyzes, preparation of CMS's at the regional/international levels and increasing of national calibration needs, especially in the photometry and radiometry were affected.

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

The advantages of MRA will become clear as the public understands more about its usage. MRA acted as a driving force for interlaboratory comparison arrangements and on its results.
For disadvantages see 1).

MRA can be improved by clarifying some gray areas.

3) Given the announcements on the restructuring of the BIPM and the attached **explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.**

Decision of closing the BIPM Photometry and Radiometry activities can be described as a difficult decision. Addressed to the past evaluation as a pilot laboratory BIPM successfully carried on many international comparisons. For the future evaluation, closing of this section will affect a lot of the needs for calibration services, research studies, the institutions that may plan to take treceability. Closure will have major impact when and if major laboratories have disagreements on measurement results, and a deadlock is generated.

Nationally, our laboratory will not be affected in photometry, since our treaceability is through PTB standard lamps.

Regionally, within Euromet, there are laboratories with proper facilities and are able to meet treceability requirements in the region.

But internationally, in case of significant discrepancy in comparison results, role of BIPM as a referee may be effective.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

CCPR comparisons are conveying an important position for the laboratory works to be accepted in the international fields. With the classification of key and supplementary comparisons we have learned which one and in which priority they can be done.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

Constituted CMC database in order to make a choice among the NMI's is important for the institutions that want to take treceability. The national and international acceptances of our studies with CMS tables when compared with the other NMI's, seem dependent of the laboratory position and level of work

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities

(b) spectral radiometric quantities

- UME purchased a liquid helium cooled cryogenic radiometer (Radiox) and uses it as a primary standard. Using stabilized Ar+, He-Ne and Nd:YAG laser sources the optical power measured absolutely. As a transfer standards laboratory researchers produced silicon based (Hamamatsu S1337) reflection type trap detectors and their responsivities were measured at the limited laser wavelengths between 457nm and 1064 nm. Then in order to realize the responsivity scale from 250 nm to 1100 nm with the measurements performed with double monochromator (Bentham) interpolation and extrapolations of measured responsivities were modeled. In addition in the realization of responsivity scale electrically calibrated pyroelectric radiometer (RS-5900) was also used. With those studies UME optics laboratory participated Euromet No:587 (Euromet Key Comparison on Spectral Responsivity in the 300-1000nm interval (Euromet PR-K2.b) comparison, which will be start at the end of 2003.

- In order to measure the spectral irradiance values of light sources in the 350-900 nm wavelength range six filter radiometers were constructed. To use in these radiometers, various filters having narrow band but different wavelengths interval were purchased, characterized and added to the radiometer. The interval and maximum wavelength values for these filters were measured using Bentham Monochromator based set up. Constructed filter radiometers formed from a reflected type trap detector based on the arrangements of three silicon photodiodes in such a configuration that to remove the polarization sensitivity. Responsivities of these radiometers were realized with the responsivity scale based on cryogenic radiometer. To keep the temperature of filter and the aperture (0.5 cm^2) at the entrance of radiometer at 0.05°C stability a temperature control circuit was also added to the filter radiometer. Also

linear translation stages with computer control were applied to irradiance measurement set-up.

- The double monochromator set up formed for the spectral reflectance and regular transmittance measurements was renewed with the purchased new optical accessories and gratings and the wavelength interval were enlarged between 250 nm to 16000 nm. In this measurement set-up we participated to Euromet Comparison, which was measurements of V(λ) filter transmittance (EUROMET Project No: 353)

- The area of optical aperture used in front of the filter radiometers and radiometric applications were measured with developed scanning method (He-Ne laser, integrating sphere and X-Y motorised translation stages system). This measuring system is useful up to apertures of 12-mm diameter.

- Treceability in optical power measurements on fibre optics was obtained by using two NPL traceable InGaAs detectors.

(c) photometric quantities

- SI base unit luminous intensity (cd) and its derivatives luminous flux (lm), illuminance (lux) and luminance (cd/m^2) are realised and maintained.
- This year we have joined to the Euromet Comparison (No: 444) on Luminance-meter measurements
- Studies subject to measure the photometric features of LED's have started.
- The studies subject to the new realization of candela based on filter radiometer continues.

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?

- **The radiometer, which is based on InGaAs photodiode cooled with liquid nitrogen, is constructed by laboratory researchers for measuring total spectral loss of single mode optical fibres and calibrates the loss axis of OTDR. The characterization studies of the radiometer still continue.**
- **Two UV broad band radiometers (Si, Hamamatsu 1337-11) are constructed and characterized by laboratory researches.**
- **UME will possibly move completely into the new research complex at the end of 2003. It is planned that the new measurement systems and facilities will be incorporated in the new optics laboratories. Procedures for intended systems and facilities in the new optic laboratories are:**
  - Establishing (home made) of a spherical goniophotometer with 5 m inner diameter for absolute realization of luminous flux
  - Retroreflectance measurement system for characterizing of properties of retroreflective materials

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

- Comparison of LED parameters and color measurements

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?

With our existing cryogenic radiometer at Ar+ and He-Ne laser wavelengths we are planning to participate to the intercomparison with other NMI's.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programs and actual or potential duplication of efforts.

It is observed that the relationships between CCPR-CIE are better and speedier as compared with the relationships between CCPR-WMO. One of the most important reasons according to my point of view is the CCPR members play quite effective role in CIE activities. Moreover, the introduction of basic measurement units, and the contraction of measurements systems and procedures are the most important activities of CIE. In addition to these the timing of expert symposium and that technical committee conventions are arranged by CIE in coordination with us are more suitable situation for us

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way?

No comment

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

F.Samadov, M.Durak, A.K.Türkoğlu "*Measurement of 0/45 diffuse reflectance of reflection standards by using a spectophotometer*" Proc. of CIE International Lighting Congress Istanbul, Turkey, v.**2**, 433-437 (2001)

A.K.Türkoğlu, F.Samadov, M.Durak, U.Kucuk "*Construction of a reference photometer head for the realization of candela*" Proc. of CIE International Lighting Congress Istanbul, Turkey, v.**2**, 379-386 (2001)

M.Durak, F.Samadov, A.K.Türkoğlu "*Spectral characterization of silicon photodiodes*" Proc. of CIE International Lighting Congress Istanbul, Turkey, **v**.2, 388-393 (2001)

M.Durak, F.Samadov, A.K.Türkoğlu "*Spatial non-uniformity measurements of large area silicon photodiodes*" Turkish Journal of Physics 26 No:5 375-379 (2002)

F.Samadov, M.Durak, A.K.Türkoğlu "*Photometric characterizations of light emitting photodiodes*" Proc. of the 2nd Balkan Conference on lighting, Istanbul, Turkey, 150-155 (2002)

M.Durak, A.K.Türkoğlu, F.Samadov "*Construction of a reference filter radiometer for the spectral irradiance measurements*" The 5th Pacific Conference on Lasers and Electro-Optics Taiwan (accepted).

14) Have you got any other information to place before the CCPR in advance of its next meeting?

None.

Comité Consultatif de Photométrie et Radiométrie (CCPR)
17th Meeting (17 - 19 June 2003)

Questionnaire & Answers from VNIIOFI

1) In what way have your activities in Photometry and Radiometry been affected by the CIPM MRA between NMIs?

2) What do you see as the major benefits and disadvantages of the current MRA for the field of Photometry and Radiometry and in what respects could the MRA be improved ?

3) Given the announcements on the restructuring of the BIPM and the **attached** explanation for them by the Director of the BIPM, give your assessment of the impact of the closure of the Photometry and Radiometry activities at the BIPM for this area of metrology internationally, regionally and nationally. Also try to put the restructuring and its impact into the context of the wider priorities of current international metrology.

4) Supply an assessment of the value of the CCPR intercomparison activities for your laboratory, highlight the main merits and shortcomings of the current processes and make suggestions for improvements.

5) Supply an assessment of the value of the inclusion of your laboratory's CMCs in Photometry and Radiometry in the MRA database.

6) Summarize the progress in your laboratory in realizing top-level standards of:
(a) broad-band radiometric quantities

(b) spectral radiometric quantities

2000. (1) Measurements of repeatability of Ir-C and Re-C metal-carbon phase transition temperatures of the cells manufactured at NMIJ (Japan); The measurements were performed utilizing the VNIIOFI-made high-temperature windowless BB3200pg blackbody as a furnace. Reproducibility obtained was better than 30 mK;
(2) Joint experiment (VNIIOFI-NPL-PTB) at VNIIOFI on measurement of temperature of Ir-C and Re-C cells provided by NMIJ using filter radiometers provided by participants. Re-C freeze/melt: 2748.15K / 2748.48K; Ir-C freeze/melt: 2564.61K / 2564.31K. Measurement uncertainty was 0.5 K.

2001. Design and manufacturing of a "small" (4-mm aperture) and "large" (10-mm aperture) high-temperature blackbody cells operating, correspondingly, in Spectral-Radiance (SR) Spectral-Irradiance (SI) modes, containing high-temperature Re-C eutectics. Measurements of Re-C fixed point temperature reproducibility, results were presented at NEWRAD'2002.

2002. (1) Development and investigation of fixed-point TiC-C system (SI-mode cell), average melting/freezing temperature 3034K. BB3500 furnace, TSP-2 and new TSP-4 precision pyrometers (VNIIOFI) were used.
(2) Joint investigations (VNIIOFI-NPL) at NPL of Re-C (SR-mode) fixed-point systems manufactured at VNIIOFI. The VNIIOFI-designed BB3500 furnace and NPL-owned filter radiometers were used.
(3) Development and Investigation of fixed-point ZrC-C system (SI-mode cell) average melting/freezing temperature 3154 K.

2003. (1) Joint investigations (VNIIOFI-NPL) at VNIIOFI of Re-C, TiC-C and ZrC-C (all cells with 10-mm aperture) fixed-point systems manufactured at VNIIOFI. The VNIIOFI-designed BB3500 furnace, TSP-2, TSP-4 (VNIIOFI) and NPL-designed filter radiometer were used. Reproducibility and influence of non-unifirmity of furnace were investigated.
(2) Joint experiment (PTB-VNIIOFI-NPL) at VNIIOFI on measurement of TiC-C and ZrC-C fixed-point thermodynamic temperatures using (for the first time) filter radiometers operating in Irradiance mode. VNIIOFI-designed fixed-point cells with 10-mm cavity diameter, PTB-designed set of filter radiometers, 3 and 5-mm apertures were used.
(3) Development and investigation of fixed-point HfC-C system (SR-mode cell), average melting/freezing temperature 3458 K. BB3500 furnace, TSP-2 and new TSP-4 precision pyrometers (VNIIOFI) were used.
(4) Joint investigations (VNIIOFI-PTB) at PTB, Berlin of Re-C, TiC-C, and ZrC-C (all 6 paired cells with 10-mm aperture) fixed-point systems manufactured at VNIIOFI. BB3200pg (PTB-owned) as a furnace, 5-mm

apertures, and PTB-designed set of filter radiometers (676 nm and 800 nm wavelengths) were used to measure both radiance (by LP-3 pyrometer) and irradiance.

(c) photometric quantities
2001-nowadays:
A facility for realization of the LUMEN has been developed at VNIIOFI within the framework of joint research project involving NIST (USA), NPL (UK), and PTB (Germany). The facility uses a high-temperature blackbody BB3500 as an external source of reference flux (instead of commonly utilized photometric lamp), transfer standard pyrometer TSP-2, and precision apertures, as a means of introducing a known flux into a 2-m diameter integrating sphere; this can then be used to calibrate a lamp in the sphere using the absolute integrating sphere method. The project takes into account the best methods and procedures available for thermodynamic temperature measurement of blackbodies; for absolute calibration of the integrating sphere with optimisation of its geometry; and for scanning the integrating sphere surface in order to determine the spatial nonuniformity correction associated with the external beam geometry and the spatial characteristics of photometric lamps.
The first (radiometric and photometric) stages of the project were devoted to:
(1) investigation of methods for thermodynamic temperature measurement of high temperature black body (HTBB) by means of pyrometers / filter radiometers within the 1600…3300K range. International comparisons within 1380K-3200K temperature range were carried out in 2000 in VNIIOFI; The results of comparisons demonstrated that discrepancy of measurements did not exceed 0.5K-1K. This allows to reproduce the lumen unity at the summarized uncertainty of less than 0.1%.
(2) development in VNIIOFI of measurement facility for realization of the lumen using HTBB and an absolute integrating sphere (IS) with configuration proposed by NIST. Perfection of methods of IS spatial and spectral characteristics' (zonal responsivity) measurements. The analysis of preliminary geometry of optical layout of measurement system for reproduction of the lumen was carried out by the NIST and VNIIOFI, on the basis of that the new geometry of experiment was offered.
The 3-rd (current) stage of the Project is devoted to intercomparisons of luminous flux on the base of VNIIOFI facility with participation of NPL, PTB and VNIIOFI. Unique measurement facility presented at NEWRAD'2002 conference has deserved deep approval of leading specialists of world photometric society. It is intended to compare the lumen and the candela realized at VNIIOFI with the units realized at NIST, NPL, and PTB.

The following works are carrying out nowadays:

(1) development and investigation of high-temperature metal carbide-carbon eutectic fixed-point δ(MoC)-C system (2856 K).

(2) investigations of possibility of usage of fixed-point source (δ(MoC)-C system) for lumen, candela realization and other photometric applications as ultra-reproducible "source A" (2856 K).

7) What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR ?
Development of next generation multipurpose blackbody BB3500MP intended to serve as a furnace for high-temperature large-area eutectic-based fixed-point cells. BB3500MP features: 60 mm inner diameter of radiating cavity; max. temperature 3500 K; improved temperature uniformity. BB housing is planned to be made from solid piece (free of welds).
Development of new eutectic-based high-temperature fixed- point blackbody cell (destined for placement in BB3500MP as a furnace) with 20 mm cavity for Irradiance-mode applications.
Development of new "compact-size" high-temperature BB3400 («PyroG») blackbody based on design of the famous BB3500 model but featuring ID 19-mm of pyrographite cavity and has at least 2 times less power consumption as compared with its « full-size » prototype. The «PyroG» is intended to serve as a budget-price source for precision measurements in radiometry, photometry, radiation thermometry and pyrometry.

8) What are present, new or emerging needs of users of your services that are not being supported sufficiently by current CCPR activities or initiatives ? In the light of this information please suggest desirable changes in the future working program of the CCPR.

9) What priorities do you suggest for new research and development programmes at NMIs in the area of Photometry and Radiometry ?
(1) Obtaining reproducibility of the fixed points at the level of 30 mK;

(2) Measurements of thermodynamic temperature of the fixed points by different methods to meet 150-300 mK uncertainty (0.05-0.1% in terms of radiance in visible);
(3) For radiometry and photometry we should utilize LARGE AREA high temperature fixed point blackbodies;
(4) Realization of Temperature, Radiometric and Photometric Scales basing on high-temperature eutectic fixed points: Lumen and Candela - on MoC-C (2856 K); spectral radiometry - on TiC-C (3034 K); UV radiometry – on ZrC-C (3154 K) and HfC-C (3458 K). Fixed points' thermodynamic temperatures will be determined in radiance and irradiance modes based on NMIs' international cooperation. Relative measurement uncertainty could be raised to around 0.01-0.03% with absolute uncertainty around 0.1-0.3%.
(5) Investigation of possibility of TRANSFER STANDARD design based on high-temperature eutectic fixed points for performing intercomparisons;
(6) Investigation of possible applications of high-temperature eutectic fixed points (in astrophysics, environment monitoring, etc.).

10) Are there any research projects where you might be looking for collaborators from other NMIs or are there studies that might be suitable for collaboration ?
Development of wide-aperture cells based on metal-carbon eutectics suitable for carrying out irradiance-mode measurements.
Participation in intercomparisons of eutectic fixed point cells.
Usage eutectic fixed point cells for temperature intercomparisons.

11) Make an assessment of the effectiveness of the current interaction between the CCPR and other international organizations in the field of Photometry and Radiometry, like the International Commission on Illumination (CIE) and the World Meteorological Organization (WMO) and also comment on actual or potential overlap in their working programmes and actual or potential duplication of efforts.

12) Taking cognizance of recently concluded or planned MOUs between the CIPM and the International Laboratory Accreditation Cooperation (ILAC), the World Health Organization (WHO) and the WMO, do you think that the relationship between the Metre Convention Organs and the CIE should be formalized through a CIPM - CIE MOU in a similar way ?

13) Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (April 2001)?

1. V.Sapritsky, B.Khlevnoy, M.Samoylov and Y.Yamada "Ir-C and Re-C fixed-point blackbodies' spectral radiance reproducibility at 650 nm". Proc. of TEMPMEKO'01, 2001, pp.513-518.
2. B.Khlevnoy, V.Khromchenko, M.Samoylov, V.Sapritsky, N.Harrison, P.Sperfeld, J.Fischer "Determination of the temperatures of metal-carbon eutectic fixed-points by different detectors from VNIIOFI, NPL and PTB". Proc. of TEMPMEKO'2001, 2001, pp.845-850.
3. B.Khlevnoy, E.Woolliams, N.Harrison, N.Fox, S.Ogarev, V.Khromchenko, V.Sapritsky "Metrological characterisation of Re-C high temperature fixed point cell". Poster presented at NEWRAD'2002, Gaithersburg, MD.
4. B.B.Khlevnoy, N.J.Harrison, L.J.Rogers, D.F.Pollard, N.P.Fox, P.Sperfeld, J.Fischer, R.Friedrich, J.Metzdorf, J.Seidel, M.L.Samoylov, R.I.Stolyarevskaya, V.B.Khromchenko, S.A.Ogarev and V.I.Sapritsky "Intercomparison of radiation temperature measurements over the temperature range from 1600K to 3300K" Metrologia, 40 (2003), No 1, S39–S44.
5. V.I.Sapritsky, V.S.Ivanov, R.I.Stolyarevskaya, S.A.Ogarev, B.B.Khlevnoy, V.B.Khromchenko, A.V.Belousov, N.A.Parfentyev, M.L.Samoylov, T.M.Goodman, Y.Ohno, G.Sauter "Project to realize the lumen unit with the participation of NPL, PTB, NIST, and VNIIOFI". Presented at NEWRAD'2002, Gaithersburg, MD.
6. V.S.Ivanov, V.I.Sapritsky, S.A.Ogarev, N.A.Parfentyev, M.L.Samoylov, B.B.Khlevnoy, T.M.Goodman, V.B.Khromchenko, Y.Ohno, G.Sauter R.I.Stolyarevskaya, "International project to realize the lumen". Light & Engineering, 10 (2002), No.3, pp.9-21.
7. M.L.Samoylov, S.A.Ogarev, B.B.Khlevnoy, V.B.Khromchenko, S.N.Mekhontsev, and V.I.Sapritsky "High Accuracy Radiation TSP-type Thermometers for Radiometric Scale Realization in the Temperature Range from 600 to 3200°C". Proc. of 8th Symposium on Temperature, Chicago, IL, 21-24 October 2002, paper ID #170.
8. V.I.Sapritsky, B.B.Khlevnoy, V.B.Khromchenko, S.A.Ogarev, S.P.Morozova, B.E.Lisiansky, M.L.Samoylov, V.I.Shapoval, and K.A.Sudarev "Blackbody Sources for the Range 100 K to 3500 K for Precision Measurements in Radiometry and Radiation Thermometry" Proc. of 8th Symposium on Temperature, Chicago, IL, 21-24 October 2002, paper ID #153.

9. V.I.Sapritsky, B.B.Khlevnoy, V.B.Khromchenko, S.A.Ogarev, M.L.Samoylov, and Yu.A.Pikalev "High Temperature Fixed-Point Blackbodies Based on Metal-Carbon Eutectics for Precision Measurements in Radiometry, Photometry and Radiation Thermometry". Proc. of 8th Symposium on Temperature, Chicago, IL, 21-24 October 2002, paper ID #152.
10. Sapritsky V.I., Ogarev S.A., Khlevnoy B.B., Samoylov M.L., Khromchenko V.B., and Morozova S.P., "Dissemination of Ultra-Precise Measurements in Radiometry and Remote Sensing within 100…3500K Temperature Range on the Base of Blackbody Sources developed in VNIIOFI", in Proc. of SPIE Vol. 4818 "IR Spaceborne remote sensing X" (10-11 July 2002, Seattle, WA, USA), edited by M.Strojnik, B.Andresen, (SPIE, Bellingham, WA, 2002), pp.127-136.
11. V.I.Sapritsky, S.A.Ogarev, B.B.Khlevnoy "Dissemination of developed in VNIIOFI high temperature fixed points based on metal-carbon eutectics for space applications of ultra-precise radiometry and spectral radiation thermometry measurements". Published at 34th Scientific Assembly of the Committee on Space Research (COSPAR'2002), Houston, TX, October 10-19, 2002, session D2.3-E3.3. Solar Variability and Climate Change. Abstract A-03035.
12. V.I.Sapristky, S.A.Ogarev, B.B.Khlevnoy, M.L.Samoylov, V.B.Khromchenko "Development of metal–carbon high-temperature fixed-point blackbodies for precision photometry and radiometry". Metrologia, 40 (2003), No.1, S128-S131.
13. V.I.Sapritsky, B.B.Khlevnoy, S.A.Ogarev, M.K.Sakharov, M.L.Samoylov, Y.A.Pikalev "Investigation of ZrC-C and HfC-C Eutectic-Based High-Temperature Fixed-Point Blackbodies". Metrologia, submitted for publication (2003).
14. S.A.Ogarev, V.I.Sapritsky, B.B.Khlevnoy, M.L.Samoylov, M.K.Sakharov, Yu.A.Pikalev "Fixed-point blackbodies above 2700K based on metal-carbon eutectics for radiometry, photometry and radiation thermometry". Accepted for presentation at APHYS'2003 Conference, Badajoz, Spain, October 14-18, 2003.

14) Have you got any other information to place before the CCPR in advance of its next meeting?
Would like to distribute the presentation "Fixed-point blackbodies above 2500 C^0 based on metal-carbon eutectics for radiometry, photometry and radiation thermometry" by the authors V.I.Sapritsky, B.B.Khlevnoy, S.A.Ogarev, M.L.Samoylov, V.B.Khromchenko.