Consultative Committee for Photometry and Radiometry (CCPR)

25th Meeting (on-line 10-11 May 2022)

CCPR member report on activities in radiometry and photometry since the last CCPR meeting (2019)

Reply from: LNE / LNE-CNAM

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1. Summarize the recent progress in your laboratory with respect to measurement standards, research projects, and metrology services to fulfill the demands of customers in:

   (a) broad-band radiometric quantities:

   No particular activity

   (b) spectral radiometric quantities:

   LNE-Cnam has changed its traceability chain for the realization of primary spectral irradiance scale. Now, the spectral irradiance is determined by measuring the temperature of the High Temperature BlackBody (HTBB) with a filter radiometer calibrated against our radiant flux reference. Thanks to this new measurement setup, our spectral irradiance reference is now traceable to radiometric reference, that is our cryogenic radiometer. This traceability scheme differs from the one used in our former setup, which was mainly based on the ITS-90 temperature reference. Thanks to this work, we have extended our measurement capability to cover the spectral range from 250 nm to 2500 nm. We have simplified the process by reducing the number of benches (3 in 1) and the number of operations, and we have designed a compact measuring setup through the use of a rotating integrative sphere. This allows us to reduce by at least a factor two our measurement uncertainties over almost the entire spectral range.

   (c) photometric quantities:

   No particular activity

   (d) other area(s) relevant to CCPR:

   A new goniospectrophotometer has been developed that can measure the BRDF in micron scale. With a measurement surface of 50 µm in diameter, this instrument produces traceable BRDF measurements. It is possible to use any angular arrangement of measurement that belongs to the hemisphere. This device is designed to aid in the advancement of the BRDF metrological scale from centimetre to micrometre size. Such traceable BRDF measurements are needed to validate physical-based rendering

models used in virtual prototyping and to further our understanding of the look of natural materials such as wool, wood, and leather

2. What work in PR has been/will be terminated in your laboratory, if any, in the past /future few years? Please explain the reasons and provide the name of the institution if it has been/will be substituted by a DI or accredited laboratory.

   High irradiance UVC radiometer calibration set-up. We build-up a UVC luminaire based on low pressure Hg lamps with amalgam that can provide irradiance up to 150 W/m² at 254 nm for UVC radiometer calibration.

   Radiometric properties of SiPM detectors. We study the radiometric properties of SiPM detectors that are used for instance in Lidar. The responsivity of such detector is comparable to photomultiplier tube responsivity but with extended spectral range in the near IR up to 1000 nm. The characterization includes: spectral responsivity, linearity, noise.

   Air-borne camera for light pollution evaluation. LNE is developing a camera that will be put on an air plane to measure the luminance and colour temperature of the light emitted towards the sky directly by the light sources or reflected by road structures or buildings. Images of large area of landscapes will be generated and each data point will be georeferenced. This work will contribute to the standard into development at CIE TC 2-95 “Measurement of obtrusive light and sky low”.

   Extension of radiometric and spectrophotometric references in UV-C. LNE-CNAM is working to extend it’s CMCs and decrease its uncertainties on the 3 following quantities :

   Spectral sensitivity : extension of the calibration spectral range from 280 nm to 200 nm
   Regular transmittance : extension of the calibration spectral range from 250 nm to 200 nm
   Spectral irradiance : extensiotn of the calibration spectral range from 250 nm to 200 nm.

3. Summarize the Capacity Building and Knowledge Transfer activities undertaken by your institute in photometry and radiometry (courses, training, …):

   LNE-CNAM is involved in the Euramet JRP SmartPhoRa. The idea of the project is, for "expert NMIs" to tutor "ermerging NMIs" within EURAMET and COOMET on different hot topics like LED based photometry, metrology of Appearance, metrology for photovoltaic panels, etc... LNE-CNAM is enrolled in this project as "Expert NMI" on metrology of appearance and is providing training on Gloss metrology.

4. Summarize the research projects currently performed within a collaboration with one or more NMIs or DI (name of the project, participants):

   LNE is currently involved in two European projects financed by EURAMET
   Project RevStdLED (Revision and extension of standards for test methods for LED lamps, luminaires and modules).
   Pilot: PTB

14 partners
The overall goal of the project is to deliver metrics and procedures as well as guidance on metrology issues, and to make existing CIE and CEN test standards for LED-based light sources applicable to testing laboratories as a whole. The specific objectives are:

- To develop a strategy for the evaluation, validation and traceability of spatially and angularly resolved luminance and luminous intensity distributions of LED-based lamps, luminaires, and modules.
- To develop guidelines on the estimation and uncertainty of i) the spectral mismatch of integral (filtered) measurements for sources emitting coloured light, and ii) integral quantities derived from spectral measurements.
- To propose a harmonised metric to compare luminous intensity distributions, including the definition of the associated tolerance intervals and uncertainties, with a focus on test methods that require the declaration of measurement uncertainties.
- To contribute to the revision of CIE S 025:2015 / EN 13032-4 through CIE Division 2, CEN/TC 169 and IEC TC 34.

LNE is leader of the WP5 “Impact” that is dealing with knowledge transfer to stakeholders including standardizing bodies, and training. LNE is also involved in the following technical workpackages:
WP1: Traceable measurements using ILMDs. LNE is characterizing an ILMD in linearity (luminance measurement)
WP2: Spectral correlations in photometric quantities. LNE with the project partner is evaluating the uncertainty of measurement of illuminance using a filtered detector that is calibrated in spectral responsivity. The uncertainty evaluation takes into account the correlation of spectral data.
WP4: Comparison of spatial distributions. LNE is helping KIT to organize a round robin comparison on intensity distribution of a reference luminaire.

Project MetroPV (Metrology for emerging PV applications).
Pilot: PTB
11 partners
The aim of this project is to provide the necessary metrological infrastructure, techniques and guidance to accelerate time-to-market for emerging photovoltaic (PV) technologies, which have the potential to significantly reduce the cost of photovoltaic energy, the most important future energy source.
LNE is involved in to the following activities:

- Determining the measurement uncertainties associated with IEC test procedures. LNE will evaluate the uncertainty of the I-V curve measurements performed by CERTISOLIS that is a subsidiary of LNE. The measurements are performed according to IEC standards. Temperature coefficients of the module will be measured and the uncertainty will be determined taking into account the temperature uniformity evaluated using a IR camera.
- Characterization and classification of emerging energy harvesting PV devices for indoor use and the Internet of Things . LNE is developing a bench that includes a LED source that can provide illuminance as high as 2000 lux to evaluate the

performance of PV modules used indoor for IoT devices. The characterization will focus on response linearity, angular dependence, spectral responsivity.

LNE-CNAM is currently involved in two European projects financed by EURAMET

Project BxDiff (New Quantities for the measurement of appearance)

Pilot : LNE-CNAM

18 partners

The overall goal of this project is to advance primary metrology in spectrophotometry in order to progress in the optical characterization of materials and to provide new indexes that help to measure the visual appearance of manufactured objects. In practice, this project has 4 main objectives :

- To address advanced metrological issues, i.e. speckle and polarisation, related to the measurement of the BRDF
- To establish a full metrological traceability of the BRDF from very small objects (micrometre scale) to regular objects (centimetre scale).
- To develop primary reference facilities and reference samples (artefacts) for the measurement and dissemination of the BTDF as a traceable quantity
- To develop primary reference facilities and reference samples (artefacts) for the measurement and dissemination of the bidirectional scattering surface reflectance distribution function (BSSRDF) as a traceable quantity

LNE-CNAM coordinates this project. It is involved in

- the works done to better understand the effect of speckle in BRDF measurement at high angular resolution and/or at narrow spectral bandwidth.
- the works on multiscale traceability of BRDF from micrometer to centimeter scales that is important for virtual prototyping, but also for 3D Printers.
- the setup of a BSSRDF primary measurement facility.
- LNE-CNAM is also involved in all the comparisons done in this project (BRDF, BTDF, BSSRDF, transmittance haze).

Project ChipsCALe (Self-calibrating photodiodes for the radiometric linkage to fundamental constants)

Pilot : JV

11 partners

The overall objective of ChipsCALe is to develop new experimental techniques for optical power measurements over a wide spectral and dynamic range by the production of an “NMI-on-a-chip” detector developed as a self- calibrating silicon photodiode. In particular, ChipsCALe will

- develop improved and validated 3D charge-transfer models to predict the PQED internal quantum deficiency.
- develop the best possible PQED photodiodes for cryogenic operation by using the improved 3D models and evaluation of passivation layer materials, passivation strategies and charge increasing techniques.
- develop instrumentation and packaging enabling self-calibration of photodiodes. The photodiodes should be operated in both photocurrent and electrical

substitution mode with sufficient sensitivity and equivalence between optical and electrical heating over a temperature range from 20 K to 300 K.
- Provide traceability of the self-calibrating photodiodes to the revised SI by measuring the fundamental constant ratio e/h for wavelengths from 400 nm to 850 nm over a dynamic range from 10 nW to 10 mW.

LNE-CNAM is involved in the selection and characterization of candidate thermometers that will be used on the self-calibrated PQED. CNAM is also involved in the characterization of the sensitivity of the PQED at cryogenic temperature according to the bias voltage.

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

   No

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

   No

7. Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (September 2019):

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   OBEIN G., 2019, "Le goniospectrophotomètre : principe, performances et limitations", in Simonot L. et Boulenguez P., *Quand la matière diffuse la lumière*, Presses des Mines, 2019, pp. 71-90

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OBEIN G., 2019, “The candela, the most human of the SI base units”, International School of Physics "Enrico Fermi" - Varenna, Italy, 6 July 2019

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SAHA D., GEVAUX L., CANCES T., RICHARD A., OBEIN G., 2021, ““Development of a µBRDF goniospectrophotometer for BRDF measurement on tiny surfaces”, *Proceedings of CIE Midterm meeting 2021, Kuala Lumpur (Malaysia), Sept 2021*

VALIN M. H., ROUGIÉ B., VISSIERE A., OBEIN G., VALIN T., 2021, "New spectral irradiance traceability scale at LNE-CNAM", Proceedings of NewRad 2021

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