Consultative Committee for Photometry and Radiometry (CCPR)
23rd Meeting (22 - 23 September 2016)

Questionnaire on activities in radiometry and photometry

Reply from: LNE

Delegate: FILTZ Jean-Rémy

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

   (a) broad-band radiometric quantities

Absolute calibration of reference photometers and filter radiometers are regularly performed to apply in radiometry and photometry references. These devices are made with trap detectors, color glass filters and diaphragms placed in temperature stabilized housings. Thermodynamic temperature measurements with these calibrated filter radiometers have been explored. The work is still in progress.

   (b) spectral radiometric quantities

Detector responsivity reference

The basis of the traceability for French radiometry and photometry is the cryogenic radiometer. There is a limited number of laser lines available to be used for calibrating transfer standards against the cryogenic radiometer. Consequently, the interpolation at any wavelengths of the transfer standards responsivity is performed by an additional process on a dedicated optical bench. It is a monochromator based setup using the transfer standard detector calibrated at laser lines and a non selective thermal detector as a reference for the other wavelengths.

After the improvements on this bench increasing the available flux and its stability the uncertainties of the detector responsivity calibration should be reduced.

The non selectivity of the thermal detector (cavity made by blackened pyroelectric detector) is a key point of the process. It is evaluated by comparing the relative responsivity measured at laser lines wavelengths by using both the cryogenic reference radiometer and the non selective detector. The variations over the range 450 nm to 850 nm have a 0.1% standard deviation. Given these variations are mainly due to type A uncertainty of thermal detector measurements, the spectral variations of the non selective detector are supposed to be lower than 0.1%

To explain and confirm this result the absorption coefficient of the thermal detector has been measured at wavelengths 453 nm and 633 nm). The coefficient has both low (2.10^{-4}) and constant values at these two wavelengths. This result shows that the uncertainty can be limited by the spectral selectivity of the thermal detector but at a level lower than the above evaluation.

Beyond this important point, other components of the uncertainties have been investigated.

The spectral bandwidth of the beam has a weak effect as long as the responsivity has a smooth spectral response (from 300 nm to 900 nm for our silicon detector transfer references). The spatial homogeneity of the responsivity over the surface is a small component for the transfer detector whose responsivity is very homogeneous and the homogeneity of the thermal detector(used only in relative values) over its surface is not depending on the wavelength.

The global uncertainty is mainly limited by the type A uncertainty of the thermal detector. It is estimated at 1.5 10^{-3} at 1 sigma level over the spectral range 300 nm to 900 nm.

Radiance and irradiance reference

To address the need of making high precision measurements in the ultraviolet for industry, health, climate change, earth observation, ... LNE-Cnam/LCM has the objective of developing a standard source of spectral radiance and irradiance with an uncertainty lower than 1% at 200 nm and a spectral coverage in the ultraviolet, visible (0.2% uncertainty) and infrared up to 2500 nm.

A black body exceeding the 3000 K temperature is used as a standard source whose irradiance, radiance and temperature is measured with a calibrated filter radiometer traceable to the national spectral responsivity reference, our cryogenic radiometer. The geometric extent is determined with the output diaphragm of the furnace and the input diaphragm of the radiometer. The corrections associated with the homogeneity and the emissivity of the black body have to be exactly determined.

The blackbody based on a commercial device has been deeply changed. It is now fully completed. The filter radiometer has been developed previously and it is regularly recalibrated.

A pyrometer has been developed more recently for characterizing the blackbody radiance and temperature homogeneity in both transverse and longitudinal directions. The requirements are a 1 mm diameter target size at a focusing distance from 0.9 m to 1.2 m and a low size of source effect. The geometric requirements have been obtained and the source corrections have been evaluated at 1 10^{-3} with the different sources we have to compare. The stability of its calibration is better than 1 10^{-3} over a 9 months period. As stated above this pyrometer will be the characterization instrument of the blackbody but it will be the link with thermodynamic temperature measurements developed in pyrometry laboratory, in order to have an homogeneous reference.

Spectrophotometry reference

The spectrophotometric bench has a long history. LNE-Cnam,(formerly INM-Cnam) has been the pilot for the first CCPR K6 and EURAMET K6 and has participated to the CCPR K6-2(2010). As LNE-Cnam will be a link laboratory for the next Euramet K6 comparison, the facility as been improved on three points

- Reduction of the uncertainty in the blue spectral region
- Better control of the filter temperature
- Increase of the capabilities of measurement (number of filters and automatisation of the process).

For reducing the **uncertainty in the blue region** the Xe arc source has been changed for a laser driven Xe source (LDLS) as it has been already experienced in our responsivity measurements setup and in some other National Metrology Institutes recently. With this source the flux is increased by a factor 8 and its fluctuations divided by a factor 2. To validate this change an NG5 filter has been measured at 4 wavelengths between 380 nm and 500 nm. The transmittance remains equal in 1 sigma interval with the two different Xe sources (arc and LDLS) ; As expected the uncertainty has been divided by a factor 2.

The stabilization of the **temperature of the filters** has been obtained by a simple stable temperature air flux provided in the filter chamber. This air flux is itself temperature stabilized by circulating in a classical stabilized water bath. The temperature of the filters is

now stable in a 0.1°C range. This result allows having no temperature influence on the filter transmittance even for high density filters.
Finally the linear filter holder has been changed for a **filter wheel** allowing the calibration of 6 filters at a time. This last mechanical change associated with a new software makes the filter transmittance measurement fully automatic. The time between two actions of the operator is now 22 hours rather than 6 hours previously. The efficiency of the bench is roughly multiplied by 3. All these three improvements are very important in the frame of the ongoing Euramet K6 comparison.

(c) photometric quantities

Luminous Intensity reference:

The 4 reference photometers have been fully calibrated : The detectors against our cryogenic radiometer reference and the filters on our spectrophotometric reference bench.
The reference batch of luminous intensity lamps has been recalibrated using our set of reference photometers.
LNE-Cnam has participated in the CCPR-K3 ongoing comparison and in a bilateral comparison of luminous intensity with KIM-LIPI (Indonesia).

Luminous flux reference

LNE-Cnam has participated in a bilateral comparison of luminous flux with KIM-LIPI (Indonesia).

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

LNE participates to several European projects in the framework of the EMRP program (European Metrology Research program):

Project Si B57: NEWSTAR, "New primary standards and traceability for radiometry"

To demonstrate the capability of the Predictable Quantum Efficiency Detector (PQED) to be a high level reference standard at room temperature is a major objective of the NEWSTAR project. The aim of Work Package 3 is to implement room temperature primary standards based on PQEDs as spectral responsivity standards for applications at the 100 ppm uncertainty level.
LNE has participated in Work packages 3 (2014) 4 and 5 in 2015 and 2016
The aim of work package 4 is to implement room temperature primary standards (RT-PQED) in applications of photometry and filter radiometry including radiation thermometry with a 100 ppm uncertainty level.
The work of this task is to equip and characterize newly developed PQEDs based on the photodiodes delivered by WP3. D1.2.5. Given that the uncertainty target of the photometer calibration is 100 ppm, the uncertainty in the characterization should be less than 100 ppm. These characterizations are mainly concerned with the calibration of the aperture delivered by CNAM, the evaluation of the diffraction effects and the measurement of the inter reflection and scattering effects.
The correction factor due to diffracted light (analytical and numerical computation) inside the radiometer itself has been found close to unity (0.9999). The main part of the diffraction

correction is due to the calibration bench itself. We have provided a table of diffraction correction, depending on configuration parameters of the photometric calibration bench.
The diffusion effect have been roughly estimated and remains at a few 10^{-6} level far above the targeted uncertainty
The 7 mm diameter precise aperture has been calibrated with a 2.10^{-4} relative uncertainty.
The calibration of a photometer against this reference is in progress at PTB. The calibration bench uses a diffuse laser source at variable wavelength (TULIP) for irradiating the PQED based reference and the photometer under test

Meteoc2

The goal of the project is to obtain global data for essential Climate Variables determination from observation of the terrestrial, atmospheric and solar radiation.
The aim of Work package 1.3 is to develop a fully operational prototype of the TRUTHS (traceable radiometer) in-flight calibration method from the primary standard cryogenic radiometer (CSAR) on TRUTHS to the Earth Imager, via a Multi-channel Filter Transfer Radiometer using a quasi-monochromatic laser-diode source.
Cnam-LNE, supported by NPL and CSIC will design, build and test the prototype monochromatic source system Low Power Laser Diode (LPLD) source which:

- Will operate at five wavelengths from 350 nm to 2300 nm
- Have stable flux (0.1 %) and wavelength (0.1 nm) over a 1 minute period.
- Will be spectrally known or calculable to 0.1 nm over the 5 year life of the mission
- Result in less than 0.1 % speckle
- Have a power output of 0.5 mW to 10 mW.

The laser suite has been first more accurately defined in order to reach the requirements in a practical manner. The financial limitation of the project lead to restrictive characteristics of some lasers. The requirement of the laser technology to be compatible with space conditions has been a second limitation.
LNE-Cnam has acquired 3 lasers at 355 nm, 520 nm and 785 nm. Our Spanish partner CSIC has acquired lasers at 1550 nm and 2004 nm.
Additionally LNE-Cnam has provided a specially designed laser switch to allow the conjunction of all the lasers on a single pass.
NPL has prepared a vacuum chamber for testing all the system in vacuum conditions as close as possible to the spatial running.
The characterization of the whole system is in progress.

xDReflect

The project xDReflect aims to improve primary metrology in the field of optical characterization of surfaces, in order to provide new measurement protocols and new standard artefacts that will permit industry to control the visual appearance of the surfaces they produce. In this field, the relevant quantity is the Bidirectional Reflectance Distribution Function (BRDF), measured with a goniospectrophotometer.
LNE-Cnam is coordinator of xDReflect and leader of WP2 on Gloss. During the last 2 years, the laboratory :

- Developed of a gloss scale made of 40 items, in collaboration with St Gobain Research

- Characterized the BRDF and the roughness of the gloss scale using respectively its absolute goniospectrophotometer and it optical roughmeter.
- Developed and characterized a conoscopic based detection that achieves an angular resolution for the BRDF measurement of 0.018°. This is the lowest resolution ever reached and an essential tool to progress in the field of gloss measurement.
- Set up a light booth for visual evaluation of gloss under different shapes of illumination and realized the first comparison of psychophysical scales on gloss sensation with KULeuven
- Implemented a BRDF model based on a microfacets approach, to better fit BRDF data in the specular region.
- Chaired the international committee of the 4th CIE expert symposium on colour and visual appearance (150 attendees) and the CIE Tutorial on the measurement of appearance (87 attendees)

xDReflect ended on August 31th, 2016.

Solid State lighting

In order to validate performance claims and stimulate user confidence, as well as facilitate efficient development of SSL products, dedicated metrology is needed. Conventional optical metrology was based on incandescent light sources, but during the EMRP JRP ENG05 'Lighting', basic metrology for first-generation SSL products was developed. Now, a new generation of SSL products, based on novel technologies (notably OLEDs and OLED arrays, nano-structured and phosphor-free LEDs, and high-power LED structures), is appearing. Therefore, the research in metrology needs to keep pace with these technical developments and dedicated traceable measurement solutions are needed to sustain the innovation and user uptake of novel SSL products. A second area where metrology is urgently needed is in the area of lifetime estimation; as lifetime predictions can reach tens of thousands of hours. This forms a major benefit and underpins the economic viability of SSL products, which require higher initial investment, but methods to assess the reliability of these claims are lacking.

LNE is involved in all work packages and leads the WP3 dedicated to safety and user visual comfort.

WP1: Transfer Standards for test laboratories

Development of photometrical transfer standards

LNE designs a new SSL based set of reference standards for the photometric and colorimetric quantities with varying source geometries but equivalent light distribution, electrical and spectral behaviour. LNE constructs five sets of three reference standards with different geometrical features. One reference set is characterised using a new goniophotometer and integrating spheres at LNE. A measurement report will be prepared including uncertainty budget and traceability chain.

Validation of test transfer standards by comparison

A comparison is carried out with novel and established SSL-products, chosen such that the spread of device feature of novel LED and OLED based lamps and luminaires on the market is covered.

WP2: Traceable measurement methods

Optical measurement of pulsed SSLs

LNE investigates the stability and use of time modulated LED sources developed by LNE and investigates the use of the standards from WP1, and different types of commercial dimmed SSL products for determining the performance of various types of classical measuring instruments with respect to temporal modulation.

Advanced metrology for OLED technology

LNE uses a 1 m integrating sphere with masks to fit the flat LED/OLED-panel under test to the rectangular opening of the sphere, for the study of 2π sphere geometry measurements. The spectral and spatial corrections needed for large-area OLEDs will be investigated using a special angular scanner positioned in different locations of the DUT plane.

WP3: Safety and comfort aspects

Flicker health concern

LNE sets up a classical detection chain (photodetector, amplifier and digitiser) with optimised components for flat bandwidth and low distortion of temporal stimuli. LNE creates reference of time modulated light sources from well- controlled LED and an opto-mechanical modulator. LNE realizes controlled and characterised flickering lighting environments of different modulation (PWM, AC, CW) and performs subjective experiments with them. LNE processes the results and provides a report on the methodology and results of short-term life experiment for the assessment of the effects of flicker of lightings.

Comfort, well-being and lighting quality

LNE develops an optical head measuring accurately, with respect to eye optics and face geometry, the luminous flux reaching the cornea/retina and will fit the head with an optical output dedicated to a fibre spectrometer to measure the relative spectral distribution.

LNE develops a new metric for improving the principles of the illuminance/gauge metric based on image processing of artefacts (faces, objects), taken by an Image Luminance Measurement Device (ILMD). A subjective experiment with human subjects will be conducted to compare metric predictions (existing and proposed) and subjective perception.

WP4: Reliability, lifetime and ageing

Reliability and lifetime studies of SSL

LNE contributes to define a protocol for natural ageing tests of SSL devices (LED, OLED). LNE carries out tests on device degradation (OLED) according to that protocol.

Determination of ageing mechanisms of novel SSL devices

LNE investigates the effect of environmental influences such as temperature and humidity on OLEDs, GaN on Si chip, COB (chip on board) and COF (chip on flex). A paper is written on the results and submitted to a peer review journal.

Photoclass

The EMRP ENG55 Photoclass project "Towards an energy-based parameter for photovoltaic classification" led by PTB (German metrology institute) aims at, defining a new metric for PV module performance evaluation based on energy production, and improving measurement uncertainty. This project is aimed at addressing the following scientific and technical objectives within four technical work-packages (WP):

- Development of a metric (energy based) for PV efficiency and the associated uncertainty budget. This is based on standardized environmental data-sets for Europe and beyond. (WP1)
- Development of new reference devices for an accurate SI traceable calibration process from the cell to the solar park. (WP2)
- Development of robust and improved characterization methods with an accuracy sufficient for the parameters necessary for the new metric (e.g. spectrally resolved angular dependency of the responsivity, low light performance, and temperature dependency). Validation of the spectrally and angularly resolved measurements of solar devices by comparison with integral measurements. (WP3)
- Reduction of the measurement uncertainty for the measurement of absolute irradiance of the natural and simulated Sun irradiation, spectrally and angularly resolved. The upper limit of the measured wavelength will be extended from 1050 nm to 2000 nm. (WP4)

LNE is involved mainly in WP3 and WP4. It is the leader of WP4.

In WP3 LNE contributes to two tasks:

- Task 3.2. The aim of this task is to investigate the impact of different irradiance levels on the PV devices manufactured with different technologies, designs and sizes. LNE uses a sun flash simulator from CERTISOLIS (LNE subsidiary) with a 2x2 m^2 illumination area and a set of neutral density filters to evaluate the linearity of at least 6 mini-modules, 6 modules and 6 reference devices for different integral irradiance. The integral irradiance level will be monitored using a calibrated reference cell. The irradiance range from 100 W/m² to 1200 W/m² with a 100 W/m² step is achieved by selecting the proper filter and by adjusting the power of the Sun simulator.
- Task 3.3. The aim of this task is to determine the temperature coefficients of PV devices in relation to the technologies used, and their design and size. The major challenge is how to ensure and control a uniform thermal distribution in the solar device. LNE is developing a climate chamber to allow the characterization of mini-modules in the temperature range 0°C to 65 °C. Heating or cooling is realized through the use of three thermoelectric coolers.

In WP4 LNE contributes to two tasks:

- Task 4.2. The aim of this task is to determine the traceability of the measurement of the spectral irradiance of pulsed solar simulators with pulse duration of few 10 ms. To measure the spectral irradiance of pulsed solar simulators array spectroradiometers are

the best candidate, because rotating grating spectroradiometers are not capable of acquiring the entire spectrum during the short pulse duration. The work performed is:

- Characterization of a UV-VIS-IR array spectroradiometer operating in the 300 nm-2000 nm spectral range which has been designed for pulsed solar simulator measurement. We pay attention to linearity and stray light characterization.
- Development of a calibration procedure taking into account the pulse mode operation of the sources to be measured.
- Evaluation of the uncertainty of the pulsed solar simulator spectral irradiance measurement using Monte Carlo (MC) techniques.

- Task 4.3. The aim of this task is to evaluate a new type of solar simulator that uses a set of LEDs (Light Emitting Diodes) to generate different AMx sun spectra. This would be an interesting tool for indoor PV module performance evaluation in the framework of the proposed new metric. Indeed to evaluate energy production it is necessary to measure the performance of the PV module under different source spectral distributions corresponding to the different sun elevations. The work to be performed is:
  - Characterization of LED sun simulator in CW and pulse modes : spectral emission, temporal stability, spatial uniformity
  - Measurement of PV module performance using LED sun simulator by comparison to classical indoor and outdoor measurements
  - Evaluation of the impact of this technology on spectral mismatch factor and uncertainty

SMART GRIDS

The Radiometry-Photometry group of LNE collaborates with the Electricity group to characterize the Verdet constant of optical fiber in order to develop a Fiber optic current sensors (FOCS) based on Faraday effect. The Verdet constant is determined by measuring the rotation of a linearly polarized laser beam propagating through the fiber that is placed in a constant magnetic field.
Preliminary results are obtained on a single-mode spun optical fiber at a wavelength of 632.8 nm. A Verdet constant of 3.97 rad/T.m with a standard deviation of 0.38 rad/Tm is measured. This value is in agreement with other values published in the literature at the same wavelength.

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

LNE is implementing array spectroradiometer calibration facility including stray light characterization based on LSF (Line Spread Function) measurement. The monochromatic light for stray light characterization is generated by a monochromator for qualitative measurements and selected laser lines for quantitative measurements. Software for stray light correction will be delivered to users.

4. 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.

-

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

Development of a measurement line for the characterization of material's translucency, based on the measurement of the BSSRDF Bidirectional Sub-Surface Reflectance Distribution Function

Developpment of work to better understand the multi scales traceability of BRDF quantity from the µBRDF to teledetection

Characterisation of the appearance of metals and non-isotropic samples.

6. 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 or coordination between NMIs?

LNE collaborates with others NMIs through the EMRP-EMPIR European projects.

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

-

8. Bibliography of radiometry and photometry papers of your laboratory since the last CCPR (September 2014)?

Peer review papers 2014

A-F. Obaton, Y. Sanogo, C. Yardin, J. Lautru, C. Lyathaud, J. Dubard and N. Fischer, "Association of vertically coupled polymer micro-resonator and phase-sensitive optical low coherence interferometer for label-free biosensing applications", Metrologia, vol. 51, February 2014

Conference 2014

Dubard, R. Etienne, T. Valin, "Uncertainty evaluation of solar UV irradiance measurement using array spectroradiometer", proceedings NEWRAD 2014, Helsinky, June 2014.

J. Dubard, T. Valin, "Reduced stray light array spectroradiometer fitted with band-pass filters", UVNET workshop, Davos, July 2014

J. Dubard, R. Etienne, "Monte Carlo technique applied to the uncertainty evaluation of spectral irradiance measurement using array spectroradiometer", UVNET workshop, Davos, July 2014

J. Dubard, R. Etienne, T. Valin, "Uncertainty evaluation of spectrally resolved source output measurement using array spectroradiometer", CIE Expert Symposium on Measurement Uncertainties

Coutin Jeanne-Marie, Rougié B, 'Measurement of the absorbance of the new cryogenic radiometer cavity from the ultraviolet to the near infrared range', proceedings NEWRAD 2014, Helsinky, June 2014.

Rougié B "Spectral radiance and irradiance UV reference based on a high temperature blackbody" Proceedings NEWRAD 2014, Helsinky, June 2014

Maija Ojanen, Stéphan Briaudeau, Mohamed Sadli, Bernard Rougié, and Frédéric Bourson,"Intensity stabilized monochromatic radiance source for thermodynamic temperature determinations Proceedings NEWRAD 2014, Helsinky, June 2014.

Andreas Höpe, Annette Koo, Carsten Forthmann, Francisco M. Verdú, Farshid Manoocheri,Frédéric B. Leloup, Gaël Obein, Gerd Wübbeler, Guillaume Ged, Joaquín Campos, Kai-Olaf Hauer,Li Yang, Marek Šmíd1, Mikhail Langovoy, Paola Iacomussi, Priit Jaanson, and Stefan Källberg , 'xD-Reflect - "Multidimensional Reflectometry for Industry a research project of the European Metrology Research Program (EMRP)" Proceedings NEWRAD 2014, Helsinky, June 2014

Guillaume Ged, Jérémie Teisseire, Emmanuel Garre, Marc E. Himbert, and Gaël Obein, Development of a controlled metrological gloss scale', Proceedings NEWRAD 2014, Helsinky, June 2014

Peer review papers 2015

Cooksey C., Obein G., Georgiev G., Durell C., Scharpf D., McKee G., L'Heureux M., 2015, Creation and Validation of Spectralon BRDF Targets & Standards, Proceedings of SPIE Vol 9639-49, 12p.

Ged G., Flys O., Silvestri Z., Källberg S., Tayeb-Chandoul F., Le Breton R., Himbert M., Obein G., 2015, Characterizations of specular peaks from a metrological gloss scale, Proceedings of 28th CIE Session, Manchester, UK, 344 - 354

H Baumgartner, D Renoux , P Karha , T Poikonen , T Pulli andE Ikonen, Natural and accelerated ageing of LED lamps, Lighting Res. Technol. 2015; 0: 1–13

L. Egli, J. Gröbner, G. Hülsen, L. Bachmann, M. Blumthaler, J. Dubard, M. Khazova, R. Kift, K. Hoogendijk, A. Serrano, A. Smedley, and J.-M. Vilaplana, Quality assessment of solar UV irradiance measured with array spectroradiometers, , Atmos. Meas. Tech. Discuss., 8, 1–36, 2015

Le Breton R., Ged G., Obein G., 2015, Out of plane BRDF measurement at LNE-Cnam using "ConDOR" our primary goniospectrophotometer, Proceedings of 28th CIE Session, Manchester, UK, 1401 – 1407

Obein G., Audenaert J., Ged G., Leloup F., 2015, Metrological issues related to BRDF measurements around the specular direction in the particular case of glossy surfaces', Measuring, Modeling, and Reproducing Material Appearance, Proceedings of SPIE Vol. 9398, 8 February, San Francisco, USA

B.Rougié, J.M Coutin : Références radiométriques pour les mesures de rayonnement optique, Techniques de l'ingénieur, R 6 412-2, 2015

M. Coutin, B. Rougié : Caractérisation et validation d'un nouveau radiomètre cryogénique au LCM, Revue Française de Métrologie, accepté

O Flys, S Källberg, G Ged, Z Silvestri and B-G Rosén, "Characterization of surface topography of a newly developed metrological gloss scale", Surface Topography: Metrology and Properties, Volume 3, Number 4 F.Sept 2015

Leloup, J. Audenaert, G. Obein, G. Ged, P. Hanselaere, "Repeatability and reproducibility of specular gloss meters in theory and practice", J Coat Technol Res (2016)

Conferences 2015

G. Obein, "Progress of xDReflect xDReflect", EURAMET TC-PR annual meeting, 28-29 January 2015, Delft (Neitherland)

G. Obein, "ConDOR, un équipement de recherche pour l'étude de l'apparence des surfaces modernes", Séminaire Opticsvalley - LNE : CND et caractérisation optique des matériaux : les atouts de la spectroscopie, 19 Juin 2015

G. Obein, "ConDOR, équipement de référence pour la mesure de BRDF", Journée Photonique et Contrôle Qualité des Surfaces et Interfaces, Pole ORA, St Etienne, 14 Octobre 2015

Olivier ENOUF, Jimmy DUBARD Exposition des travailleurs aux sources de lumière artificielle : normes de sécurité applicables, , actes du colloque INRS, Paris, octobre 2015

B. ROUGIE, La métrologie des rayonnements pour la sécurité : de l'instrument à la confiance, actes du colloque INRS, Paris, octobre 2015

J. Dubard, T. Valin, S. Bouhtiyya PhotoClass: a new metrology for opto-electric performance of Photovoltaic modules, , actes du Congrès International de Métrologie, Paris, 21-24 Sept 2015

Jean-Rémy FILTZ, Jimmy Dubard, Caroline To Van Trang, Olivier Enouf, Dominique Renoux Lighting : Panorama of the capacities and Impact of Metrology on the development and the improvement of LED technology, , actes du Congrès International de Métrologie, Paris, 21-24 Sept 2015

B.Rougié, J.M Coutin, D. Renoux, actes du congrès de Métrologie 2015 : Un nouvel étalon de référence pour la sensibilité spectrale de détecteur, "peu couteux" et de très faible incertitude, 17ème Congrès International de Métrologie, Paris, France, 21-24 Sept 2015

G. Obein, round table : The world of soft metrology CIM 2015 17ème Congrès International de Métrologie, Paris, France, 21-24 Sept 2015

Others, popular conference 2015

Conference CIE-France, 20 Mai 2015 : De la candela aux ambiance lumineuses",

Jeanne Marie Coutin, Le radiomètre cryogénique, référence primaire pour la mesure des rayonnements optiques

Bernard Rougié, Les détecteurs PQED, nouvelle génération de radiomètres haut de gamme

Gael Obein, Définition et mise en pratique de la candela, du lumen et du lux.

Jimmy Dubard, La redéfinition du Système international et de la candela

G. Obein, "Lumière et éclairage", Conférence d'une heure donnée dans le cadre du Plan Académique de Formation (PAF) des enseignants du 2n d degré sur le thème "La Lumière, éveil des sciences et des sens", 20 Janvier 2016.

G. Obein, "Lumière et éclairage", Intervention d'1h dans le Collège Jean Moulin à Verrières-Le-Buisson, dans le "club des petits physiciens", pour parler de la lumière et de sa mesure.

Peer review papers 2016

J. Dubard, J. Voyer, J. Hameury, F. Buteau, “Characterization of spectrophotometer; guide for industry”, Revue Française de Métrologie, Vol. 1, N° 41, 2016.