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

Questionnaire on activities in radiometry and photometry

Reply from: CMS/ITRI

Delegate: Kuei-Neng Wu

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

   (a) broad-band radiometric quantities

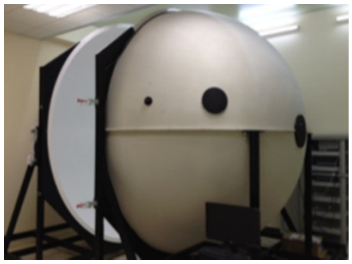
   None.

   (b) spectral radiometric quantities and (c) photometric quantities

   Establishment of absolute luminous flux measurement system using 3.0 m integrating sphere.

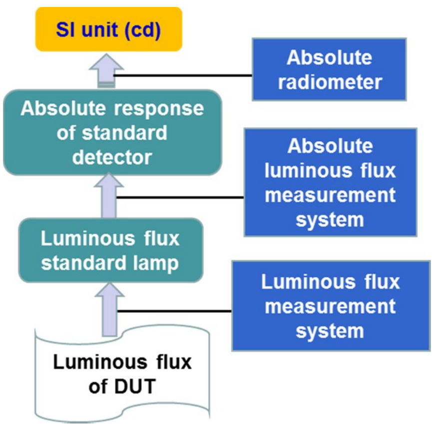
   New integrating sphere system is setting up. The measurement range of the standard lamps total luminous flux system is extending from 1 lm to 20000 lm. The relative expanded uncertainty is 1.0 % with a coverage factor. k = 1.98 corresponding to a level of confidence approximately 95 %.

   The realization for total spectral radiant flux (TSRF) by integrating sphere system is under constructing.



   - Wavelength range: 200 nm ~ 2000 nm
   - Luminous flux range: 1 lm ~ 2000 lm
   - Measurement geometry: 2π and 4 π
   - Spectrometer and photometer combined
   - Uncertainty: under estimating

   The traceability of integrating sphere system is by absolute response of standard detector. There are three Spectroradiometers in the system to extend wavelength range.

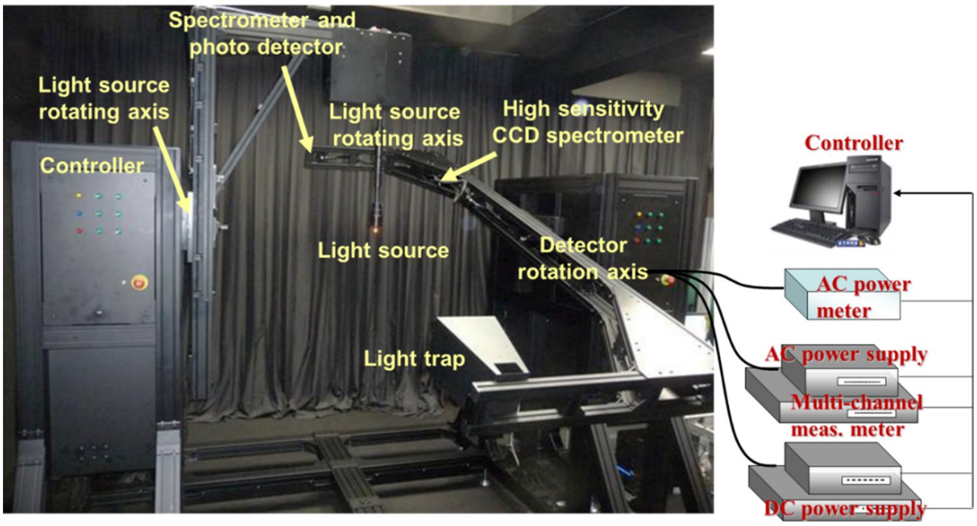


   The existing TSRF calibration system in CMS is gonio-spectroradiometer. The capability of the system is below.

   Range：0.5 mW/nm to 150 mW/nm

   Wavelength ：350 nm to 830 nm

   Relative expanded uncertainty：1.5 % to 2.8 % (Confidence level is 95 %.)

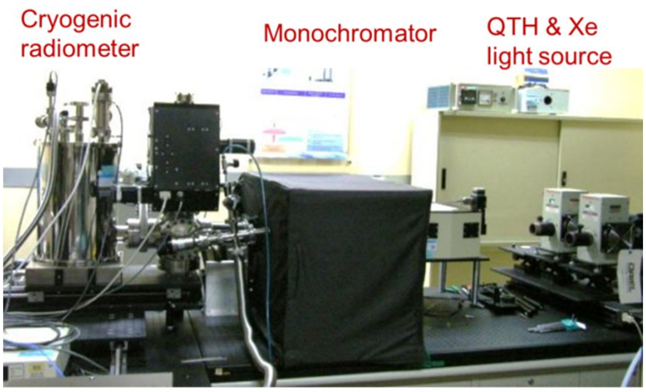


Existing gonio-spectroradiometer for TSRF

After finishing new integrating sphere system, the comparison between two systems will be checked.

Monochromator-Based Cryogenic Radiometer

After realigning the optical system, the output power is extended from 47 nW ~ 2 μW to 70 nW ~ 11 μW. The wavelength range for spectral responsivity calibration is extended from (380~1700) nm to (280~1700) nm.



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

Performance evaluation of LED road lightings by in-field measurement systems

The in-field measurement systems were established for measuring illuminance and luminance of roads.

The evaluation results by the measurement systems helped to develop and unify LED lighting safety standards applicable to local expressway in Taiwan.

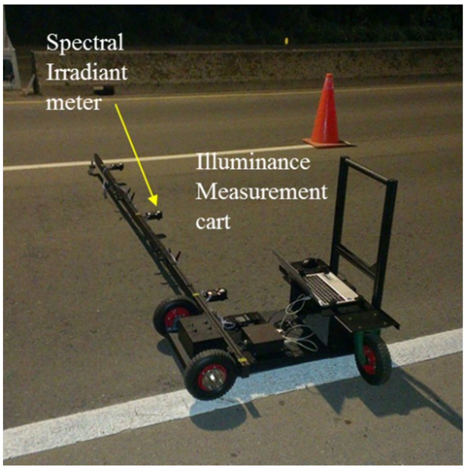
The evaluation in this work are the long-period in-field measurements, which include the luminance distribution, illuminance distribution and spectral illuminance distribution of roads or luminaires. The averages, uniformities, colorimetric and glare parameters were then calculated from these distributions. Comparisons of these results with simulations or other traditional meters show that these in-field measurements are reliable.

The measurement sampling and measuring processes of the road were mainly referred to the related CIE 140 and CEN EN standards. The road illuminance was measured with a set of calibrated illuminance meters, and the spectrometric parameters were measured with an UPRtek MK-350 spectrometer.

The road and lighting luminance were measured with an ILMD, which was home-made by a Canon 600D DSLR with (10-22) mm and (70-200) mm lens. The ILMD can be used for low luminance (0.1 ~ 10 cd/m^2), far distance (> 60 m), and low acceptance angle (≦ 0.1 deg). By using a ND filter, the ILMD can also be used for measuring high luminance (≧ 10000 cd/m^2). To compare with the results obtained by the ILMD a Konica-Minolta LS-100 and a Topcon BM-9A luminance meters with different range and acceptance angles were sometimes used for in-field measurements.

These in-field measurements were periodically performed with interval about 500 or 1000 hours. All the results were collected and systematically analysed to study the performance of these LED-lighting sections.

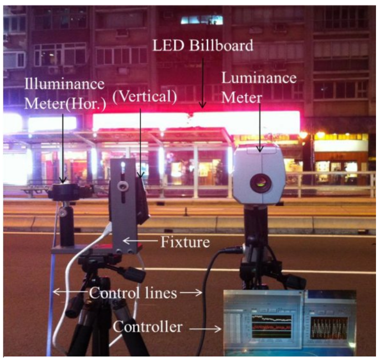
Luminance measurement system on a road



Illuminance measurement system on a road

Light pollution measurement systems

The in-field measurement systems were established for light pollution. Konica-Minolta LS-100 luminance meter was used for monitoring the luminance of LED billboard, and a Konica-Minolta T-10 illuminance meter was used for monitoring the environmental vertical illuminance and horizontal illuminance. The measurement height is set as the average pedestrian standing eye height, which is 1.5 m

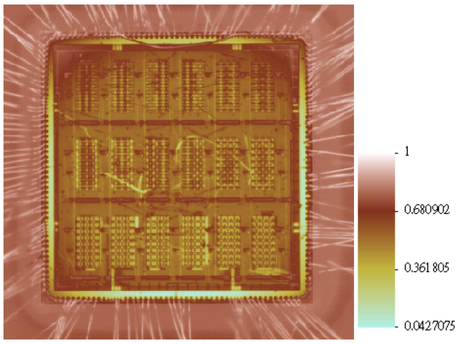


Light pollution measurement system

Luminance meter aligned with the center of LED billboard, and field of view encompassed within LED billboard. When measuring vertical illuminance, the light-receiving head facing the LED billboard along the horizontal line of sight in front, when measuring the horizontal illuminance, the light-receiving head facing the sky directly above.

Emissivity map measurement

The comparison of temperatures (temperature correlation) obtained by measuring instruments and by thermal simulation is commonly necessary. Currently the way in which thermal maps are obtained by infrared thermographer yields inaccurate results since the emissivity values of all elements in an IC are ignored and measurement method assumes a constant emissivity. Without the correct settings of emissivity in infrared thermographer, the temperature variation could reach up to as high as 300 %. Coating black paint on the IC surface is a widely used method to assume the IC with constant emissivity and simplify the measurement procedures. Coating a uniform black thin film on an IC is a highly skillful technique and the coated black paint is un-removable. In certain cases, it is not convenient or possible to do so - for example, as monitoring a working chip. CMS proposes the first practical and feasible method for emissivity map measurement. Two reference plates are utilized to obtain an emissivity map, from which real emissivity value of each pixel of the infrared thermographer is obtained. Firstly the radiances of IC and two reference plates are measured by the infrared thermographer. After that, the emissivity map of the IC can be calculated by the radiances. With the emissivity map, the high accuracy temperature map is then obtained. This work contributes to the field of thermal analysis and simulation. Accurate circuit characteristics can be obtained through accurate thermal map; on the other hand, the closeness between the thermal simulation result and the real thermal map can also be realized.



Emissivity map of the IC

Curved surface source measurement

As curved is the most common shape of current flexible products, CMS focuses on the luminance, luminous flux, colour, reflectance, and viewing angle measurement of curved surface sources, since curved surface sources are the basic components of flexible displays and flexible lighting, and those quantities are the most important characteristic for surface source.

- Luminance measurement with luminance meter

  Theoretically, the luminance measurement results for a luminance uniform flat surface source are independent of the measurement conditions such as the viewing angle and the distance between the source and the measurement device. However it is not the case for the curved surface source. A formula is derived to describe the luminance measurement result by using the luminance meter. Luminance distribution is one of the most important characteristics of a surface source. Two methods for measuring the luminance distribution of a curved surface source are investigated in this paper, the X-Y and ω–Y scanning methods. An experiment is performed to verify the possibility of estimating the ω-Y luminance distribution from X-Y scanning results, and vice versa.

- Luminance measurement with ILMD

  Due to the advantages of fast measurement speed, imaging luminance measurement device (ILMD) have become more and more popular in the recent years. However, even though an ILMD is corrected by flat field calibration, the measured results deviate from the real values when measuring curved surface sources. The deviation is larger especially when the curvature of the source is smaller or when the source is unlike a Lambertian source. A correction factors is derived to increase the measurement accuracy of the ILMD when measuring different types of curved surface sources. The issue of how the measurement conditions affect the level of image blur is also studied.
- Total luminous flux measurement with integrating sphere

  Applying integrating sphere photometer for total luminous flux measurement is a widely used method. However the measurement accuracy depends on the spatial uniformity of the integrating sphere especially when the test sample has different light distribution than that of the standard source. Therefore, spatial correction is needed to eliminate the effect caused by non-uniformity. To reduce the inconvenience of spatial correction but retain the measurement accuracy, a new type of working standard is designed for flexible and curved surface sources. Applying this new type standard source, the measurement deviation due to different orientations is reduced by an order of magnitude compared with using the naked incandescent lamp as the standard source.
- Angular dependence of colour

  Angular dependence of colour is a special characteristic of surface sources. For users who look for artistic decoration lighting, such a characteristic of mixed colour OLEDs is attractive. On the other hand, this characteristic is a drawback for the normal single colour lighting applications. To quantify this characteristic for general lighting, average colour difference between all angles CD_{avg} is recommended as it shows the best agreement of the angular colour variation with those perceived by observers.

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.

   None

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.

   The application of smart lighting may get huge growth in the near future. The related parameter or quantity need to be verified.

   For ex: Constant light output technology needs long-term stability sensor. The lifetime of LED luminaire is about 50000 ~ 100000 hr. The smart lighting system and sensor response can be stable during the whole lifetime?

Dust deposition on light output surface of luminaire is also a problem. There is no method to evaluate the decay and uniformity change caused by dust deposition.

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

   None

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?

   In response to the increasing demands from industries and to ensure the global equivalence in haze measurement, 5 NMIs (CMS, KRISS, MSL, NIM, NIMT) from TCPR applied the APMP TC initiative (TCI) project for pilot comparison of transmittance haze in 2012 and the project was performed from 2014 to 2015. The discrepancy of the comparison results highlights the insufficiency of current document standards such as ASTM and ISO. It is necessary s to deeply study the technique of haze measurement. Therefore, the second TCI project has been approved by APMP with financial support.

   It is possible that NMIs from other regions have interest to participate.

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

   None

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

(1) Hsueh-Ling Yu, Richard Young and Chin-Chai Hsiao, Luminance Measurement for Curved Surface Sources with an Imaging Luminance Measurement Device, *Meas. Sci. & Technol.* 26, 125010, 2015.

(2) Shau-Wei Hsu, Tsung-Ying Chung, Spatial and Directional Photometric Properties of a Curved AMOLED Display, *International Conference on Flexible and Printed Electronics (ICFPE)*, 2015.

(3) Shau-Wei Hsu, Tsung-Ying Chung, Near-field Analyses on Curved AMOLED Display by Directional Imaging Photometric Measurements, *International Display Workshops (IDW)*, 2015.

(4) Chao-Hua Wen, Bao-Jen Pon, Yi-Ju Wang, Ronnier Luo, Measuring the Flicker Nuisance during Playing Video on RGB LED Large-Format Displays, *The International Commission on Illumination*, 2015.

(5) Chao-Hua Wen, etc., Sub-pixel Rendering for a High Resolution OLED Display with Low Resolution Photomasks, *Society of Information Display (SID)*, 2015.

(6) Bao-Jen Pong, Shau-Wei Hsu, Chao-Hua Wen, Tsung-Ying Chung, and Shao-Tang Hung, Nonlinear analysis for monitoring and measuring of environmental light based on Ensemble Empirical Mode Decomposition, *Cross-Strait Metrology Conference*, 2015.

(7) Chao-Hua Wen and Bao-Jen Pong, Flicker Visibility of Exotic Modulation Waveforms of Peacock-Shape LED Combination Lights, *Cross-Strait Metrology Conference*, 2015.

(8) Bao-Jen Pon, Chao-Hua Wen, Shao-Tang Hung, etc., Luminance and Vertical Illuminance Survey in Metropolitan, *Cross-Strait Metrology Conference*, 2015.

(9) Yi-Chen Chuang, Shu-Fei Tsai, Wen-Chun Liu, Alternative Methods to Evaluate Photobiological Safety for the Wavelength of (2500 ~ 3000) nm, *Cross-Strait Metrology Conference*, 2015.

(10) Cheng-Hsien Chen, etc., The Adaptive Roadway Lighting for Curves by Multiple LED Emitting Modules, *Optics and Photonics Taiwan*, 2015.

(11) Cheng-Hsien Chen, Shau-Wei Hsu, Kuei-Neng Wu, and Shao-Tang Hung, The Study of Real-Time Image Luminance Measurement Device and Array-Type Illuminance Meter for In-Field LED Road Lighting Measurement and Evaluation, Cross-*Strait lighting technology and marketing seminars*, 2015.

(12) Shau-Wei Hsu, Kuei-Neng and Shao-Tang Hung, Performance of LED Road Lightings Studied by Detailed In-Field Measurements with Various Devices, *Proceedings of CIE Session*, 2015.

(13) Shau-Wei Hsu, Bao-Jen Pong, Shao-Tang Hung and Cheng-Hsien Chen, Investigation of Components of Environmental Illuminance and Luminance by EMD and Denoise Methods, *Proceedings of CIE Session*, 2015.

(14) Chao-Hua Wen, Shao-Tang Hung, Wei-Yun Liang and Shih-Kai Lin, Investigation of Flicker Metrics for Lighting on High Speed Roads, *CIE Lighting Quality and Energy Efficiency Conference*, 2016.

(15) Shau-Wei Hsu, Tsung-Ying Chung, Ambient-Light Influenced Photometric Properties of a Curved AMOLED Display by Directional Imaging Luminance Measurements, *OPTICS & PHOTONICS International Congress*, 2016.

(16) Bao-Jen Pong, Chao-Hua Wen, Shao-Tang Hung and Kuei-Neng Wu, Impacts Study of the Background Luminance and Illumination Level on Measuring of LED Billboards in Taiwan, *CIE Lighting Quality and Energy Efficiency Conference*, 2016.

(17) Tsung-Ying Chung and Shau-Wei Hsu, Ambient-Light Influenced Photometric Properties of a Curved AMOLED Display by Directional Imaging Luminance Measurements, *OPTICS & PHOTONICS International Congress*, 2016.