Consultative Committee for Photometry and Radiometry (CCPR)
24th Meeting (19 - 20 September 2019)

Questionnaire on activities in radiometry and photometry

Reply from:

Delegate:

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

   1. Laser Energy Measurements

      Laser energy measurement system was established and measurement scale was linked to continuous wave (CW) power scale. Link from CW power to pulse energy was realized by generating modulated pulses from CW beam by using optical chopper, where CW signals were measured by reference optical power meter and modulated pulsed-signals were measured by calorimeter. In this interconnection CW Nd:YAG laser was used and pulse length was modulated to the order of milliseconds. The realized energy scale was transferred from calorimeter to laser energy meters through using pulsed Nd:YAG laser having one fundamental (at 1064 nm) and two harmonics (at 532 nm and at 365 nm) with nano-second level pulse length.

   2. Radiance Measurements

      The radiance scale was realized by establishing laser based radiance measurement system consisting of laser sources, integrating sphere and a detector traceable to electrical substitution cryogenic radiometer. Following the realization of radiance scale the radiance responsivity of double monochromator and telescope was obtained at three fields of views (5mRad, 7mRad and 11mRad). This provides the radiance measurements of any radiance sources.

   3. Establishment of traceability chain in spectral irradiance measurements from 300 nm to 1100 nm

      The previous last traceability in spectral irradiance measurements was based on filter radiometer. Within a content of an internal project the irradiance measurement system was upgraded by using a developed spectroradiometer, which consists of two separate mini spectroradiometers operating at different spectral spans, an integrating sphere and suitable fiber optics patch cords. The optical characterizations of the new developed spectroradiometer, such as effective area of the sphere opening, stray light error, irradiance responsivity, non-linearity and angular dependence of the irradiance responsivity were investigated within this study with expanded uncertainties from 1.4% to 2.3% and (k=2).

4. Extending the spectrometric measurement capabilities from 250 nm to 2500 nm

   TÜBİTAK UME previous spectral reflectance and transmittance measurement system was based on Bentham Monochromator facility and related reflectance and transmittance accessories. The wavelength range of this system range from 300 nm to 1800 nm. In the content of an internal project, a new spectrometer was purchased and characterized so as to both improve and extend the spectrophotometric measurements. With the present measurement facility regular/diffuse reflectance and transmittance measurements ranges were extended to wavelength range from 250 nm to 2500 nm. Transmittance and absorbance scales were also improved.

5. Establishment of Robot Based Absolute Diffuse Reflectance Measurement System

   TÜBİTAK UME regular and diffuse reflectance measurement reference standards has been traceable to other NMIs. In order to realize these references at TÜBİTAK UME, a project work was started in 2018. In this project, gonioreflectometer system has been developed for measuring radiance factor and BRDF. The gonioreflectometer system consists of four main parts; a large rotation stage with 1.5 m diameter, a laser driven broadband plasma source connected to a collimator through an integrating sphere for creating a uniform beam, 6-axis robot with +/- 0.02 mm positioning accuracy and 2.5 kg sample carrying capacity, detection system (Back illuminated single stage TE cooled Si CCD detector for 250 nm – 1100 nm and 512 pixel 2-stage TE cooled InGaAs detector for 1100 nm – 2500 nm). In this system receiver sample distance is 650 mm and the incident angles are 0° - 85° for sample size up to 125 mm.

(c) photometric quantities :

1. Establishment of traceability of light flux measurement scale

   The present luminous flux measurement system; based on substitution principle using a reference lamp, has been upgraded to the absolute-integrating-sphere method. Calibrated photometer head, spectrophotometer, apertures and light source (used as an external source) were used at the new system. With the detailed characterization of the measurement system, the factors for spatial correction of the integrating sphere, illumination homogeneity of the external source, falling angle of sphere's external source into the integrating sphere and light absorption within the sphere were derived and the expanded uncertainty for this measurement approach was calculated as 1.05% (k=2). Performance of this luminous flux measurement facility was tested by international comparisons.

2. Development of spectrally tunable LED-based reference integrating sphere

   A project work on development of the spectrally tunable LED light source using a large number of high-power LEDs has been studied. In this work, an integrating sphere with four input ports will be used. The output port which will has a capability of producing any spectral distribution, mimicking various LED light sources in the visible region by feedback control of the radiant power emitted by individual LEDs. The integrating sphere will also be equipped with a mini-spectrometer in order to measure mixed inner radiance distribution from the LEDs. Multi chip LEDs (TO-66 type each has 60 chips array inside) will be used in order to construct LED-heads and to install them to the input ports. When the project completed the source will be used as a transfer standard for colorimetric, photometric and radiometric applications.

3. Construction of a differential spectral responsivity measurement system

   A monochromator-based Differential Spectral Responsivity (DSR) measurement system was designed and constructed to determine the spectral responsivity of a single or multi-junction photovoltaic devices (solar cells). The DSR setup contains a constructed solar simulator, a LED-based Bias Light Source, a DC Voltage Bias circuit and a probe beam optical power tracking and correction circuit controlled with an ADuC847 microcontroller card together with an embedded C based software. By using the constructed DSR measurement system, the SR calibration of the monolitic triple-junction GaInP/GaInAs/Ge solar cells were performed within the EURAMET Joint Research Project (EMRP SolCell project ENG-51, SolCell).

4. Determination of ageing mechanisms of OLED panels.

   In the content of EMRP MeSaIL project in order to determine the degradation rate of the optical performance of OLEDs besides photometric measurement systems a UV preconditioning system was established and used. The UV preconditioning system used for the ageing of OLED has both UVA and UVB lamps covering the wavelength ranges 280 nm - 320nm and 320 nm - 400 nm respectively. Moreover, this system at 30 cm distance has 250W/m^2 irradiance with the 15 % inhomogeneity distribution.

5. Establishment of Near Field Measurement System for Led Based Light Sources

   TÜBİTAK UME has started to establish a Near-Field goniophotometric facility for LEDs photometric measurements. The goniophotometric system with CMOS imaging camera can measure ray data of the LEDs. Additionally, the luminous intensity distribution, the luminous flux and spectral/colorimetric data can be obtained. Traceability of measurement is a problem for imaging light measurement device (ILMD) based systems. TÜBİTAK UME plans to work on measurement uncertainties and traceability chain of this imaging system at the beginning of the 2020.

6. Establishment of LED Measurement Facility

   Integrating sphere systems with photometer or spectrophotometer are commonly used for luminaire measurements. Because of increasing in manufacturing of LED based luminaires, obtaining and providing the traceability chain for LED measurement is obligatory. Therefore, a new integrating sphere measurement system was established for LED measurements. The system has capability for measuring the spectral radiant flux, the spectral luminous flux, and total luminous flux and color parameters as well. LED sources, derived either AC or DC can be measure with this new system. As this project is still ongoing in the next stage development of LED transfer standards is planned. With the measurement capabilities of this system TÜBİTAK UME has participated related EMPIR 2019 projects.

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

   1. Establishment of Measurement Systems for the Performance Measurements of Terrestrial Photovoltaic (PV) Modules

      The test conditions and requirements for determining the performance parameters of PV modules are described in IEC 61215 standard. The performance parameters of PV modules are short-circuit current, I_{sc}; open-circuit voltage, V_{oc}; maximum power, P_{max}. According to IEC 61215 standard, change in these performance parameters of PV modules have to be evaluated by exposing the modules to various tests like diagnostical, electrical, thermal, environmental, mechanical and optical. In order to meet the measurement demands in photovoltaic field, performance measurement systems were established in TÜBİTAK UME. With these systems, in addition to test measurements, research and development works are also carried out for the requirements of industry in the field of PV. Moreover, using these system

TÜBİTAK UME has been working in EMPIR PV Enarate project and will take part in EMPIR project related to PV works.

2. CCPR Comparions that TÜBİTAK UME Participated

    i. CCPR PR-K2.b "Spectral Responsivity 300 nm 1000 nm"

3. EURAMET Comparions that TÜBİTAK UME Participated

    i. EURAMET.PR-K6 "Regular transmittance 380 nm to 1000 nm"
    ii. EURAMET.PR-K4.3 "Bilateral Comparison on Luminous Flux"

4. COOMET Comparions that TÜBİTAK UME Participated

    i. COOMET.PR-S9 "Colour Transmitted"
    ii. COOMET PR-K1b Irradiance

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.

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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.

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

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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?

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

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

1. Pons, A., Campos, J., Sametoglu, F. "Bilateral comparison of luminous flux (EURAMET.PR-K4.3)", Metrologia, 56 (1A), 02003 2019.
2. Sametoglu, F., Celikel, O., Witt F. "A differential spectral responsivity measurement system constructed for determining of the spectral responsivity of a single-and triple-junction photovoltaic cells", European Physical Journal of Applied Physics, 80(2), 21001, 2017.
3. F.Sametoglu. "Establishment of The Spectroradiometer-Based Spectral Irradiance Scale at TÜBİTAK UME". 13th International Conference on New Developments & Applications in Optical Radiometry (NEWRAD2017), p.155-156, 13-16 June 2017, Tokio, Japan.
4. F.Sametoglu, O.Celikel. "Construction of Differential Spectral Responsivity Facility for Determining the Spectral Responsivity of Solar Cells". 13th International Conference on New Developments & Applications in Optical Radiometry (NEWRAD2017), 13-16 June 2017, p.61-62, Tokio, Japan.
5. Bounouh, A., Almuneau, G., Baumgartner, H., Cuenat, A., Gambacorti, N., Hoffmann, J., Kern, R., Kienberger, F., Krupka, J., Lackner, D., Pollakowski, B., Rodriguez, T.G., Sametoglu, F., Usydus, L., Winter, S., Witt, F. "The EMRP project Metrology for III-V materials based high efficiency multi-junction solar cells", 29th Conference on Precision Electromagnetic Measurements, CPEM 2014, Rio de Janeiro-Brazil, 318-319, 2014.
6. Celikel O., Sametoglu F. Fiber Coupled Integrating Sphere Based-Laser Energy Meter. Patent. US 9,874,482B2, JP6263637B2 and EP3097395A1.
7. J. Askola, Y. Çalkin, A. Vaskuri, T. Poikonen, and E. Ikonen: "Accelerated ageing of organic LED panels using ultraviolet exposure", Lighting Res. Technol. 2018; 0: 1-12
8. Traceability of laser pulse energy measurements by linking reference standards for CW and pulsed measurements Bazkir O., Meric S., Mahmoud K. IOP Conf. Series: Journal of Physics: Conf. Series 972 (2018) 012013
9. Determination of Temperature Dependent Electrical Performances of Terestrial Photovoltaic Modules, PV CON 2018, Ö Bazkır, S Meriç