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: Czech Metrology Institute (CMI), Czech Republic

Delegate: Dr. Marek Šmíd

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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:

Predictable Quantum efficiency Detectors:

- CMI has continued in performing annual characterization of PQED long term stability via regular comparison with CMI primary absolute cryogenic radiometer facility, publication of the results of this long term (more that decade) characterization is under preparation.
- together with partners from Aalto, Finland and JV, Norway we have provided and validated experimental methods leading to determination of the responsivity of Predictable Quantum Efficient Detector over a wide spectral range based on a 3D model of charge carrier recombination losses. Results published

Radiation-pressure-based radiometry:

- In close collaboration of CMI (CZ), NIST (US) and HiLase (CZ) we have demonstrated for the first time, to our knowledge, the SI-traceable measurement the extreme laser pulse energy output (100 J, 10 ns, 1 kHz repetition rate, 1 kW average power) via measurement of photon momentum. Results published

Fibre optics:

- CMI proceeded with further characterization of our construction of fibre-coupled cryogenic bolometer and its validation towards CMI traditional CR based scale and investigation

(b) spectral radiometric quantities:

BRDF, BTDF measurements:

- The CMI is continuing the development of its robot based gonio spectro-photometer facility in order to establish independent traceability chains of gonio spectrometric quantities both in in plane and off plane configurations. In particular the facility has been recently extended its capabilities to measure the total diffuse reflectance and the BTDF. CMI is also participating in two pilot studies for comparison of BRDF and BTDF quantities with other European NMIs.

(c) photometric quantities:

Photometry, LED sources:

- In collaboration with PTB and Aalto laboratories CMI proceeded with development and application of LED-based standard sources and non-filtered primary photometer technologies as a supporting methodology for future primary scales in photometry. CMI developed the method to establish the unit candela based on application of unfiltered PQED absolute standard detector and Luminous intensity LED standard lamp. The new realisation of candela was compared with the current realisation based on primary photometers traceable to the CMI cryogenic radiometer. The relative deviation of the two independent realisations was within the measurement uncertainty.

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

Quantum photonics:

- We have performed the further gradual development of CMI low photon flux standard detectors applicable for performing direct SI traceability (down to classical CR based standard) for low photon fluxes measurement at the levels of approximately 100 kcps
- CMI started works supporting deeper theoretical inside into physics of Quantum-dots-based single photon source as a future standard sources for quantum photonics industries

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.

   Non

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

   CMI organized the bilateral comparison to support the irradiance spectral responsivity scale of the NIS (National Institute for Standards, Egypt). The comparison artefact (DUT) is a 3-element silicon trap equipped with a precise optical aperture. The measurement of the Irradiance spectral responsivity of the DUT in spectral range 420 nm – 900 nm.

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

- Project 15SIB07, PhotoLED, Future photometry based on solid-state lighting products; VTT (Finland); Aalto (Finland); CMI (Czech Republic); CSIC (Spain); Metrosert (Estonia); BFKH (Hungary); PTB (Germany); RISE (Sweden); VSL (Netherlands)
- Project 16NRM08, BiRD, Bidirectional reflectance definitions; CNAM (Paris); Aalto (Finland); CMI (Czech Republic); CSIC (Spain); PTB (Germany); RISE (Sweden)
- Project 17FUN06, SIQUST, Single-photon sources as new quantum standards; PTB (Germany); Aalto (Finland); CMI (Czech Republic); INRIM (Italy); Metrosert (Estonia); NPL (United Kingdom); VTT (Finland)
- Project 18SIB03, BxDiff, New quantities for the measurement of appearance; CNAM (France); Aalto (Finland); CMI (Czech Republic); CSIC (Spain); DFM (Denmark); METAS (Switzerland); PTB (Germany); RISE (Sweden)
- Project 18SIB10, chipS·CALe, Self-calibrating photodiodes for the radiometric linkage to fundamental constants; JV (Norway); Aalto (Finland); CMI (Czech Republic); CNAM (France); INRiM (Italy); Metrosert (Estonia); PTB (Germany); TUBITAK (Turkey)
- Project 19ENV04, MAPP, Metrology for aerosol optical properties; SFI Davos (Switzerland); Aalto (Finland); CMI (Czech Republic); NPL (United Kingdom); PTB (Germany); VSL (Netherlands)
- Project 19ENV07, MetEOC-4, Metrology to establish an SI traceable climate observing systém; NPL (United Kingdom); Aalto (Finland); CMI (Czech Republic); PTB (Germany); SFI Davos (Switzerland)
- Project 19NET02, EMN-Quantum, Support for the European Metrology Network on Quantum Technologies, INRIM (Italy); CMI (Czech Republic); GUM (Poland); LNE (France); NPL (United Kingdom); OBSPARIS (France); PTB (Germany); TUBITAK (Turkey)
- Project 19NRM06, MeTISQ, Metrology for testing the implementation security of quantum key distribution hardware; INRIM (Italy); Aalto (Finland); CMI (Czech Republic); DFM (Denmark); Metrosert (Estonia); NPL (United Kingdom); PTB (Germany)
- Project 20FUN05, SEQUME, Single- and entangled photon sources for quantum metrology; PTB (Germany); Aalto (Finland); CMI (Czech Republic); DFM (Denmark); JV (Norwa)y; Metrosert (Estonia); TUBITAK (Turkey)

- Project 20IND05, QADeT, Quantum sensors for metrology based on single-atom-like device technology; INRIM (Italy); Aalto (Finland); CMI (Czech Republic); DFM (Denmark); PTB (German)y; TUBITAK (Turkey)

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?

   All CMI needs for international collaboration are currently covered by projects running in the frame of European partnership in metrology

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

   Non

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

Tran, T., Porrovecchio, G., Smid, M., Ikonen, E., Dönsberg, T., & Gran, J. (2022, March). Determination of the responsivity of Predictable Quantum Efficient Detector over a wide spectral range based on a 3D model of charge carrier recombination losses. *Metrologia*. doi:10.1088/1681-7575/ac604b

Williams, P. A., Rogers, K. A., Divoky, M., Porrovecchio, G., Tesař, J., Smid, M., & Lehman, J. H. (2022, February). Extreme laser pulse-energy measurements by means of photon momentum. *Optics Express, 30*(5), pp. 7383-7393. doi:10.1364/OE.448815

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Ferrero, A., Perales, E., Basic, N., Pastuschek, M., Porrovecchio, G., Schirmacher, A., . . . Blattner, P. (2021, March). Preliminary measurement scales for sparkle and graininess. *Optics Express, 29*(5), pp. 7589-7600. doi:10.1364/OE.411953

Ferrero, A., Basic, N., Campos, J., Pastuschek, M., Perales, E., Porrovecchio, G., . . . Martínez-Verdu, F. M. (2020, November). An insight into the present capabilities of national metrology institutes for measuring sparkle. *Metrologia, 57*(6). doi:10.1088/1681-7575/abb0a3

López, M., Meda, A., Porrovecchio, G., (Kirkwood), R. A., Genovese, M., Brida, G., . . . Kück, S. (2020, November). A study to develop a robust method for measuring the detection efficiency of free-running InGaAs/InP single-photon detectors. *EPJ Quantum Technology, 7*(14). doi:10.1140/epjqt/s40507-020-00089-1

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Kokka, A., Pulli, T., Ferrero, A., Dekker, P., Thorseth, A., Kliment, P., . . . Poikonen, T. (2019, June). Validation of the fisheye camera method for spatial non-uniformity corrections in luminous flux measurements with integrating spheres. Metrologia, 56(4), p. 045002. doi:10.1088/1681-7575/ab17fe

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