

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

Questionnaire on activities in radiometry and photometry

Reply from: Instituto de Óptica “Daza de Valdés” (IO-CSIC)

Delegate: Joaquín Campos Acosta

1. Summarize the progress in your laboratory in realizing top-level standards of:
 - (a) broad-band radiometric quantities: No progress in this area since the last report.
 - (b) spectral radiometric quantities:
 - Standards of spectral diffuse reflectance and spectral reflectance factor in the NIR have been realized.
 - A new radiant flux standard in the NIR based on a light trap configuration with InGaAs/InP photodiodes has been realized.
 - (c) photometric quantities: No progress since the last report.
2. What other work has taken place in your laboratory in scientific or technological areas relevant to the CCPR?
 - The gonio-spectrophotometer built to study multi-angle reflection properties of materials has been upgraded to perform spatial distribution of BRDF in the visible.
 - Temperature, pressure and electrical current sensors based on non-linear effects in optical fibre have been applied to new areas of distributed measurement lines in civil engineering. In particular, the ability to measure distributed temperatures over 120 km with errors less than ± 5 ° C and to detect vibrations distributed over lengths of 1.2 km up to frequencies of 40 kHz have been shown.
 - Intelligent monitoring system of cut slopes and obstacle detection in railways has been further developed.
 - Metrology for essential climate variables. Sea temperature measurements using arrays of Bragg gratings in optical fibres.
 - Design and characterization of compact spectrometers on a chip.
 - Analytical model for the photocurrent of PQED radiometers and radiometric characterization of new np induced junction diodes.
 - Spectrophotometric characterization of smart coating mortars based on eco-efficient thermochromics cements.
 - Characterization of filter radiometers for the measurement of thermodynamic temperature.

- Establishment of LED standard spectra to be recommended by international organizations.
- Colorimetric characterization of new displays and gonio-apparent materials.
- Participation in CCPR Key comparisons: CCPR-K1.a, CCPR-K2.b, CCPR-K2.a, CCPR-K3, CCPR-K4, CCPR-K5, EURAMET PR-K6.

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.

No metrological activity has been terminated in the laboratory during this period.

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 database for CMC in the area of optical fibers is not clear to customers. The presentation structure of the services does not fit to what customers are looking for.

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

IO-CSIC fully support the strategy displayed at the CCPR strategic plan document.

Perhaps it should be highlighted:

- ✓ Measurement of BRDF of materials and its spatial distribution, including translucency and subsurface effects.
- ✓ “Few photon” metrology.
- ✓ Optical properties of nano-materials and embedded devices.
- ✓ Action spectra of non-visual effects of optical radiation.
- ✓ Accurate radiant flux and energy measurements of pulsed sources in the mW to W range.

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?

- Solid state lighting. Propagation model based on radiant intensity or radiance distributions rather than in ray tracing. It may be very useful for rendering in computer imaging.
- Appearance metrology, particularly on issues attempting to relate the BRDF of gonio-apparent objects with their perceptual properties: colour, translucency, gloss and texture. Issues on modelling sparkle and graininess.
- New fields of optical radiation measurements where IRMDs (imaging radiance meter devices) can play a role on improving existing devices. Examples could be found in meteorological measurements.
- If the CCPR considers the study of nonlinear effects in fibres, including the femtosecond regime, as an interesting research project, the coordination and the collaboration with others NMIs would be necessary.

- The developments of standards for high power pulsed laser in NIR (800 - 2 000 nm), and standards and methods for measuring femtosecond pulses from mode locked optical fibre lasers.
- Nonlinear effects in fibres and crystals and their application in optical radiometry.
- Use photon sources to study the spectral yield of the eye and its relationship with $V(\lambda)$ or $V'(\lambda)$.

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 2016)

I. 2016

- J.L. Velazquez, A. Ferrero, A. Pons, J. Campos, M.L. Hernanz. Zernike polynomials for photometric characterization of LEDs. *Journal of Optics*, Volume 18, Number 2 (2016).
- A. Ferrero, B. Bernad, J. Campos, E. Perales, J. L. Velázquez, and F. M. Martínez-Verdú, "Color characterization of coatings with diffraction pigments," *J. Opt. Soc. Am. A* 33, 1978-1988 (2016).
- Juan Galindo-Santos, Aitor V. Velasco, Ana Carrasco-Sanz, Pedro Corredera. Brillouin filtering of optical combs for narrow linewidth frequency synthesis. *Optics Communications*, Volume 366, 2016, Pages 33-37.

II. 2017

- Wübbeler, G, Campos Acosta, J, and Elster, C. Evaluation of uncertainties for CIELAB color coordinates. *Color Res Appl.* 2017; 42: 564– 570. doi:10.1002/col.22109.
- C. Strothkämper, A. Ferrero, A. Koo, P. Jaanson, G. Ged, G. Obein, S. Källberg, J. Audenaert, F. B. Leloup, F. M. Martínez-Verdú, E. Perales, A. Schirmacher, and J. Campos, "Multilateral spectral radiance factor scale comparison," *Appl. Opt.* 56, 1996-2006 (2017).
- Martín, M.J., Mantilla, J.M., del Campo, D. et al. Performance of Different Light Sources for the Absolute Calibration of Radiation Thermometers. *Int J Thermophys.* (2017) 38: 138. <https://doi.org/10.1007/s10765-017-2271-1>.
- A. Laplaza a, E. Jimenez-Relinque a, J. Campos b, M. Castellote a. Photocatalytic behavior of colored mortars containing TiO₂ and iron oxide based pigments. *Construction and Building Materials*, Volume 144, 2017, Pages 300-310.
- Timo Dönsberg¹, Farshid Manoocheri¹, Meelis Sildoja^{1,10}, Mikko Juntunen^{1,11}, Hele Savin¹, Esa Tuovinen², Hannu Ronkainen², Mika Prunnila², Mikko Merimaa², Chi Kwong Tang³, Jarle Gran³, Ingmar Müller⁴, Lutz Werner⁴, Bernard Rougié⁵, Alicia Pons⁶, Marek Smíd⁷, Péter Gál⁸, Lapo Lolloi⁹, Giorgio Brida⁹, Maria Luisa Rastello⁹ and Erkki Ikonen^{1,2}. Predictable

quantum efficient detector based on n-type silicon photodiodes. *Metrologia*, Volume 54, Number 6 (2017).

- E. Borreguero^{1*}, A. Ferrero¹, S. C. K. Tang², J. Gran², A. Pons¹, S. J. Campos¹, S and M. L. Hernanz¹, S. Preliminary results of an analytical model to determine the internal quantum efficiency of a predictable quantum efficient detector. *Opt. Pura Apl.* 50 (4) 401-409 (2017).
- D H Lowe¹, A D W Todd², R Van den Bossche³, P Bloembergen⁴, K Anhalt⁵, M Ballico⁶, F Bourson⁷, S Briaudeau⁷, J Campos⁸, M G Cox¹, D del Campo⁹, M R Dury¹, V Gavrilov¹⁰, I Grigoryeva¹⁰, M L Hernanz⁸, F Jahan⁶, B Khlevnoy¹⁰, V Khromchenko¹¹, X Lu⁴, G Machin¹, J M Mantilla⁹, M J Martin⁹, H C McEvoy¹, B Rougié⁷, M Sadli⁷, S G R Salim^{7,12}, N Sasajima¹³, D R Taubert⁵, E van der Ham⁶, T Wang⁴, D Wei⁴, A Whittam¹, B Wilthan⁵, D J Woods², J T Woodward¹¹, E R Woolliams¹, Y Yamada¹³, Y Yamaguchi¹³, H W Yoon¹¹ and Z Yuan⁴. The equilibrium liquidus temperatures of rhenium–carbon, platinum–carbon and cobalt–carbon eutectic alloys. *Metrologia*, Volume 54, Number 3 (2017).
- Jost, S; Ngo, M.; Ferrero, A.; Poikonen, T.; Pulli, T.; Thorseth, A.; Blattner, P. DETERMINATION OF ILLUMINANTS REPRESENTING TYPICAL WHITE LIGHT EMITTING DIODES SOURCES. PROCEEDINGS of the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017.
- Ferrero, A.; Velázquez, J.L.; Pons, A.; Campos, J. PROPOSAL FOR A NEW GENERAL $V(\lambda)$ MISMATCH INDEX. PROCEEDINGS of the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017.
- Khalil Huraibat; Esther Perales; Eric Kirchner; Ivo van der Lans; Alejandro Ferrero; Joaquín Campos; Francisco Miguel Martínez-Verdú. Spectral and Color Characterization of a Quantum Dots Display. PROCEEDINGS of the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017.
- Adrián Fernández; Alejandro Ferrero; Manuel Melgosa. Towards a comprehensive comparison among recent colour-difference formulae. Proceedings of the 13th AIC Congress. Being color with health.
- Alejandro Ferrero; Berta Bernad; Joaquín Campos; Noël Richard; Christine Fernández_Maloigne; Manuel Melgosa. Evaluation of colour variation of grey scales with the viewing angle. Proceedings of the 13th AIC Congress. Being color with health.
- Khalil Huraibat; Esther Perales; Eric Kirchner; Ivo van der Lans; Alejandro Ferrero; Joaquín Campos; Francisco Miguel Martínez-Verdú. Spectral and Color Characterization of a Quantum Dots Display. Proceedings of the 13th AIC Congress. Being color with health.
- Khalil Huraibat; Esther Perales; Eric Kirchner; Ivo van der Lans; Alejandro Ferrero; Joaquín Campos; Francisco Miguel Martínez-Verdú. Spectral and Color Characterization of a Quantum Dots Display for Gonio-Apparent Colors. Final program and proceedings of Twenty-fifth Color and Imaging Conference.
- Hugh Podmore, Alan Scott, Pavel Cheben, Aitor V. Velasco, Jens H. Schmid, Martin Vachon, and Regina Lee, "Demonstration of a compressive-sensing Fourier-transform on-chip spectrometer," *Opt. Lett.* 42, 1440-1443 (2017).

- Alaine Herrero-Bermello, Aitor V. Velasco, Hugh Podmore, Pavel Cheben, Jens H. Schmid, Siegfried Janz, María L. Calvo, Dan-Xia Xu, Alan Scott, and Pedro Corredera, "Temperature dependence mitigation in stationary Fourier-transform on-chip spectrometers," *Opt. Lett.* 42, 2239-2242 (2017).
- Garcia Benadí, A.; Río Fernandez, J.; Nogueras Cervera, M.; Pulido de Torres, C.; García Izquierdo, C.; del Campo, D.; Corredera, Pedro. Traceable sea temperature vertical profile measured by optical fibers. DOI: 10.1109/OCEANSE.2017.8084718.

III. 2018

- A. Ferrero, J. L. Velázquez, E. Perales, J. Campos, and F. M. Martínez Verdú, "Definition of a measurement scale of graininess from reflectance and visual measurements," *Opt. Express* 26, 30116-30127 (2018).
- Alexander Kokka¹, Tuomas Poikonen², Peter Blattner³, Sophie Jost⁴, Alejandro Ferrero⁵, Tomi Pulli¹. Development of white LED illuminants for colorimetry and recommendation of white LED reference spectrum for photometry. *Metrologia*, Volume 55, Number 4 (2018).
- A. Ferrero, J. L. Velázquez, A. Pons, and J. Campos, "Index for the evaluation of the general photometric performance of photometers," *Opt. Express* 26, 18633-18643 (2018).
- E. Borreguero^{1*}, C. K. Tang², J. Gran², A. Pons^{1,S}, J. Campos^{1,S}. Preliminary results of feasibility of self-calibration of silicon pn photodiodes at room temperature using temperature sensors. *Opt. Pura Apl.* 51 (2) 50013:1-8 (2018).
- Joaquin Campos¹, Alejandro Ferrero¹, Emma Woolliams², Claire Greenwell², Agnieszka Bialek², Luisa Hernanz¹ and Alicia Pons. Principal component analysis of reference sites used for calibration and validation of Earth observation satellites. *IOP Conf. Series: Journal of Physics: Conf. Series* 972 (2018) 012004.
- G. Perez, V.R. Allegro, M. Corroto, A. Pons, A. Guerrero. Smart reversible thermo-chromic mortar for improvement of energy efficiency in buildings. *Construction and Building Materials*, Volume 186, 2018, Pages 884-891.
- J. M. Mantilla¹, M. J. Martin¹, J. Campos², M. L. Hernanz² and D. del Campo¹. Testing irradiance and radiance methods for absolute radiation thermometry based on InGaAs detectors in the NIR at CEM/CSIC. *IOP Conf. Series: Journal of Physics: Conf. Series* 1065 (2018) 122005.
- E Borreguero, A Ferrero, J Campos, A Pons and M L Hernanz. Unidimensional photocurrent model for induced-junction photodiodes. *IOP Conf. Series: Journal of Physics: Conf. Series* 972 (2018) 012015.
- C. García Izquierdo, A. Garcia-Benadí, P. Corredera, S. Hernandez, A. Gonzalez Calvo, J. del Río Fernandez, M. Nogueras-Cervera, C. Pulido de Torres, D. del Campo. Traceable sea water temperature measurements performed by optical fibers. *Measurement*, Volume 127, 2018, Pages 124-133.

IV. 2019

- R. Urbano Gutiérrez, J. Du, N. Ferreira, A. Ferrero, S. Sharples. Daylight control and performance in office buildings using a novel ceramic louvre system. *Building and Environment*, Volume 151, 2019, Pages 54-74.
- Alexander Kokka^{1,2}, Tomi Pulli¹, Alejandro Ferrero³, Paul Dekker⁴, Anders Thorseth⁵, Petr Kliment⁶, Adam Klej⁷, Thorsten Gerloff², Klaus Ludwig⁸, Tuomas Poikonen⁹ and Erkki Ikonen^{1,9}. Validation of the fisheye camera method for spatial non-uniformity corrections in luminous flux measurements with integrating spheres. *Metrologia* 56 (2019) 045002 (9pp).