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: Korea Research Institute of Standards and Science (KRISS)

Delegate: Dong-Hoon Lee

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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:

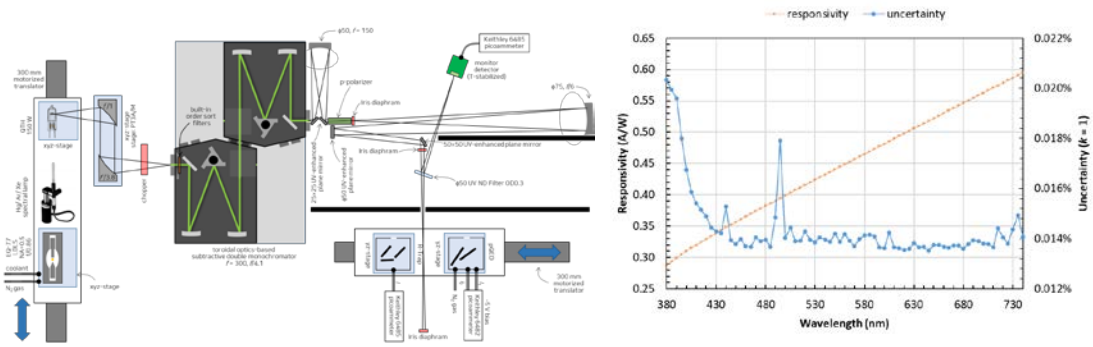
   (a) broad-band radiometric quantities:

   None

   (b) spectral radiometric quantities:

   Upgrade and extension of the spectral responsivity scale

   Starting from 2019, KRISS is improving the realization of the spectral responsivity scale. As the first step, a new facility for a more precise spectral responsivity comparison is developed, which provides a tunable monochromatic beam with well-defined spatial properties and high power stability. Using the new facility, spectral responsivity of a Si trap detector could be calibrated against a room-temperature PQED from 400 nm to 700 nm with relative standard uncertainty of 0.02 % (k = 1). This could supersede the present absolute cryogenic radiometer (ACR) of KRISS operated at a laser wavelength of 633 nm with the comparable uncertainty. A good agreement within the uncertainty between the PQED scale and the ACR scale was confirmed.

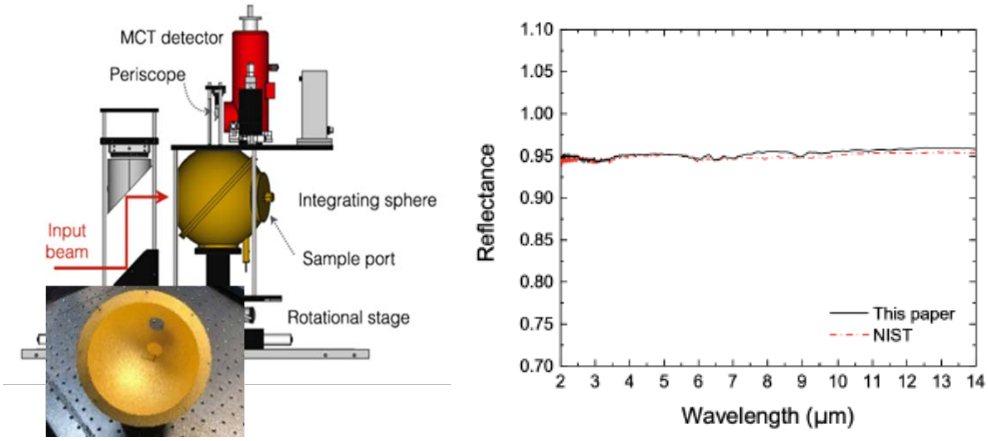


As the next step, the extrapolation of the primary calibration to a wider wavelength range from 250 nm to 1000 nm was realized by comparison with a low-NEP pyroelectric

detector. For this purpose, another comparator facility was developed, which is described in details in No. 1 of Bibliography. This extrapolation method should bridge the gap until a new mechanically-cooled ACR will be in operation. Combined with a widely tunable monochromatic source with a laser-driven light source (LDLS), the new ACR will be capable of realize the spectral responsivity scale in a wavelength range from 250 nm to beyond 2000 nm by direct comparison. The installation of the new ACR is expected in 2022-2023. (Contact: Seongchong Park, spark@kriss.re.kr)

Spectral reflectance scale in the mid-infrared

KRISS is establishing the primary scale of spectral reflectance in the mid-infrared range from 2.5 μm to 12 μm based on the third Taylor method in the geometry of (8°:d). The setup consists of a gold-coated integrating sphere and a Fourier transform infrared (FTIR) spectrometer (see No. 5 of Bibliography). Recently, the measurement uncertainty of the primary standard was evaluated to be less than 1.8 % (k = 1). In parallel, the gold-coated reference samples are developed to disseminate the spectral reflectance in the mid-infrared range. (Contact: Seon-Do Lim, sdlim@kriss.re.kr).



(c) photometric quantities:

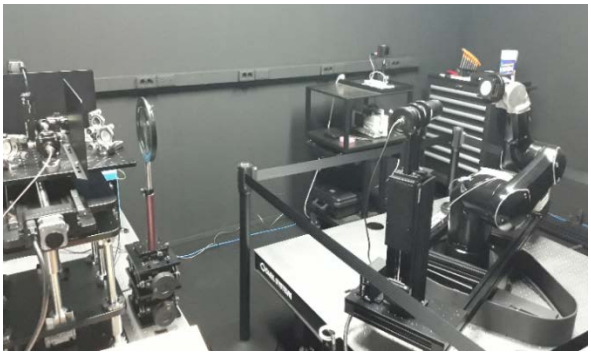
None

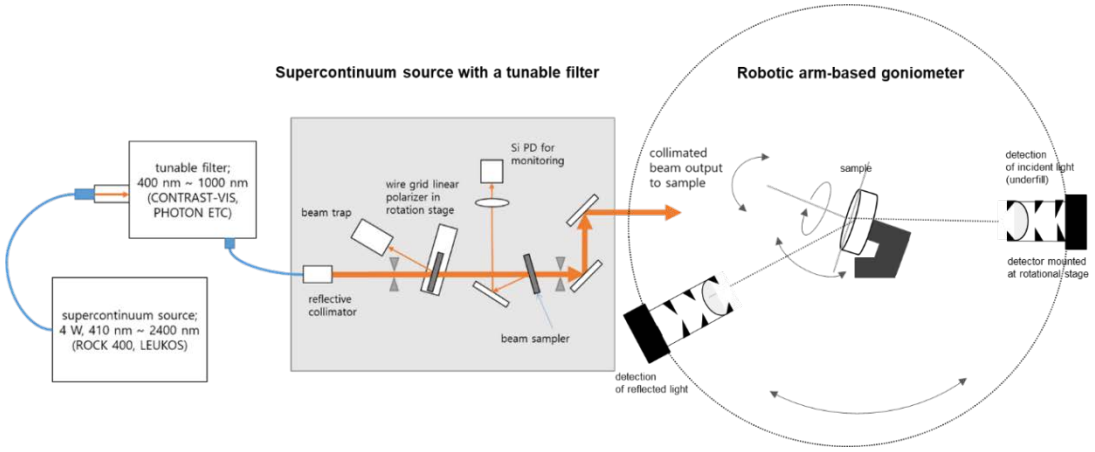
(d) other area(s) relevant to CCPR:

3-dimensional BRDF measurement facility

In the optical material metrology, we are developing a new optical scatter instrument to upgrade and extend the KRISS BRDF scale. The new facility is based on a robot goniometer combined with a tunable beam source. The beam source consists of a supercontinuum source and a tunable filter, which provides a collimated monochromatic light from 450 nm to 1000 nm with a spectral bandwidth of less than 2.5 nm (FWHM). The beam diameter at the sample was approximately 14 mm. The BRDF can be measured for incidence/reflection angles from 0˚ to 70˚ in polar and from

0˚ to 360˚ in azimuthal with a solid angle of detection of $2 \cdot 10^{-3}$ sr. The validity of the new 3-D facility was verified by comparison with the present BRDF scale in 2-dimension. The facility is subject to further improvements until the target uncertainty of less than 1 % (k = 2) is achieved in an extended wavelength range up to 2300 nm. (Contact: Jisoo Hwang, jhwang@kriss.re.kr)





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.
   - Measurement service related to CIE averaged LED intensity is terminated as there has been no request any more for the last 10 years. (Instead, there more demands on total luminous flux and total spectral radiant flux of LEDs)
3. Summarize the Capacity Building and Knowledge Transfer activities undertaken by your institute in photometry and radiometry (courses, training, …):

   KRISS is providing a training course for technical staffs of the KOLAS accredited laboratories in photometry and radiometry, normally once per year.
4. Summarize the research projects currently performed within a collaboration with one or more NMIs or DIs (name of the project, participants):

   None

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?

   - Operation of cryogenic radiometer with a tunable source from 250 nm to 2100 nm
   - Radiometry and metrology with single photon sources
   - Spectral diffuse reflectance standards in the mid-infrared range from 2 μm to 18 μm
   - Out-of-plane BRDF measurement from 410 nm to 1600 nm
   - Development of detector-based absolute radiation thermometers
   - Study on visual appearance in high-dynamic-range (HDR) conditions

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

   None

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

   1) Seongchong Park, Dong-Hoon Lee, Kee Suk Hong, *Measurement-based extrapolation of spectral responsivity by using a low-NEP pyroelectric detector*, Measurement Science and Technology, **33**, 015013 (2022)
   2) Jiman Choi, Gahyun Choi, Sun Kyung Lee, Kibog Park, Woon Song, Dong-Hoon Lee, Yonuk Chong, *Design of an Antireflection Coating for High-efficiency Superconducting Nanowire Single-photon Detectors*, Current Optics and Photonics, 5, 375 (2021)
   3) Jinhwa Gene, Dong-Il Yeom, Seung Kwan Kim, Sun Do Lim, *Long-cavity mode-locked thulium-doped fiber laser for high pulse energy*, Optics and Laser Technology, **136**, 106739 (2021)
   4) Dong-Joo Shin, Boris B. Khlevnoy, Caihong Dai, Seongchong Park, Dong-Hoon Lee, Maxim V. Solodilov, Svetlana S. Kolesnikova, Zhifeng Wu, Yanfei Wang, *Assessment of Equivalence of the Spectral Radiance Scales Following the Results of the Comparison between the National Metrology Institutes of Korea, China, and Russia*, Measurement Techniques, **63**, 1004 (2021)
   5) Jinhwa Gene, Min Yong Jeon, Sun Do Lim, *Reflectometers for Absolute and Relative Reflectance Measurements in the Mid-IR Region at Vacuum*, Sensors, **21**, 1169 (2021)
   6) Youngjoo Chae, Jisoo Hwang, *Visual Color Difference between Colored-Yarn Mixed Woven Fabrics and Their Instrumentally Measured Colors: the Effects of Individual Yarn Colors and Texture*, Fibers and Polymers, **21**, 792 (2020)
   7) CH.S.S. Pavan Kumar, Byoung Joo Kim, Deok Woo Kim, Myoungsik Cha, In Ho Bae, Kee Suk Hong, Dong Hoon Lee, *Electro-optically, widely tunable optical*

parametric oscillator based on periodically poled lithium niobate, Optics Communications, **459**, 125077 (2020)

8) In-Ho Bae, Jae-Keun Yoo, Sun Do Lim, Seung Kwan Kim, Dong-Hoon Lee, *Mid-infrared Continuous-wave Optical Parametric Oscillator with a Fan-out Grating MgO:PPLN Operating Up to 5.3 μm*, Current Optics and Photonics, **3**, 577 (2019)

9) Hee-Jin Lim, Kwang-Yong Jeong, Dong-Hoon Lee, Kee Suk Hong, *Modular system for fluorescence-based single photon generation using a retro-reflector*, Optical Materials Express, **9**, 4644 (2019)

10) Jisoo Hwang, Yejin Hong, Dong-Hoon Lee, Youngshin Kwak, Seongchong Park, Jae-Keun Yoo, YoungJoo Chae, *Experimental method for measuring color appearance shifts in high-dynamic-range luminance conditions*, Journal of the Optical Society of America A, **36**, 1940 (2019)

11) Dong-Joo Shin, Seongchong Park, Ki-Lyong Jeong, Dong-Hoon Lee, *Dual-photodiode radiometer design for simultaneous measurement of irradiance and centroid wavelength of light sources with finite spectral bandwidth*, Applied Optics, **58**, 8262 (2019)