Crosscheck on Realisation of Illuminance Scale Between NML-SIRIM and KRISS

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Abstract

We crosschecked illuminance realisations between NML-SIRM and KRISS. NML-SIRIM keeps the traceability of the illuminance scale to NPL, UK, with photometers and luminous intensity lamps annually calibrated. To prepare an artefact for the crosscheck at KRISS, we measured the spectral responsivity of a photometer using a spectral responsivity comparator traceable to a cryogenic radiometer. The external aperture area of the photometer was measured using a two-axis translator with a microscope. The uncertainty of the artefact photometer is less than 0.5 % (k=2) in terms of illuminance responsivity [3]. The crosscheck shows the agreement between two national metrology institutes are within the uncertainty maintained at NML-SIRIM.

Keywords: illuminance, realisation scale, bilateral comparison, spectral responsivity

Introduction

Illuminance scale is one of the fundamentals in the realisation of candela in optical radiation. The en route of the realisation is based on the fundamental process from the unbroken chain of traceability which includes from the primary standard disseminated to working standard and lastly the end user. There are many variations towards this realisation even though some of the national metrology institutes (NMI) does not have the primary standard but their traceability still valid. As an alternative, their artefacts need to be send for calibrations to other established NMIs for example, NIST (US), NPL (UK), PTB (Germany), KRISS (Rep. of Korea) and NMIJ (Japan). Furthermore, maintenance of the artefacts is also vital towards the performance such as reproducibility, repeatability and also accuracy. One of the methods of maintenance is through crosschecked with other NMIs scale.

This paper describes the collaboration work which have been done between National Metrology Laboratory-SIRIM (NML-SIRIM) and Korea Research Institute of Standards and Sciences (KRISS) on illuminance scale crosscheck. In this crosscheck, a comparison between reference photometer of NML-SIRIM and reference photometer of KRISS by using a luminous intensity lamp acts as transfer artefact which has been calibrated at NPL (UK).

Theoretical background

When a photometer is under a uniform and stable illumination of a lamp, the illuminance(lx) at the reference plane of the photometer is obtained by measuring the photocurrent(A) of the photometer of which the illuminance responsivity (lx/A) has been already known [2]. The illuminance E_v at the reference plane of the lamp with spectral irradiance of $E(\lambda)$ is given as

$$E_v = K_m \int E(\lambda)\cdot V(\lambda) d\lambda \ \text{(in lx)}; \quad K_m = 683 \ \text{lm/W}, \tag{1}$$

where $V(\lambda)$ is the CIE standard photopic spectral luminous efficiency. The spectral irradiance $E(\lambda)$ can be also measured using an illuminance meter with a spectral responsivity of $S(\lambda)$ in A/W and an aperture area of A, which generates the photocurrent U as

$$\begin{aligned} U &= A \cdot \int_\lambda E(\lambda)\cdot S(\lambda) d\lambda \\ &= A \cdot S_{555} \int_\lambda E(\lambda)\cdot s(\lambda) d\lambda \ \text{(in A)} \end{aligned} \tag{2}$$

If the spectral responsivity $S(\lambda)$ in A/W is decomposed into the absolute responsivity S_{555} at a wavelength of 555 nm and the relative spectral responsivity $s(\lambda)$ normalized to S_{555}, from equations (1) and (2), the illuminance responsivity R_{Vi} of the photometer can be written as

$$\begin{aligned} R_{\mathrm{vi}} &= \frac{A \cdot S_{555} \int_\lambda E(\lambda)\, s(\lambda)\, \mathrm{d}\lambda}{K_{\mathrm{m}} \int_\lambda E(\lambda)\, V(\lambda)\, \mathrm{d}\lambda} \\ &= \frac{A \cdot S_{555}}{K_{\mathrm{m}} \cdot f(e)} \quad \text{(in A/lx)} \end{aligned} \tag{3}$$

The color correction factor $f(e)$ of the photometer is defined as

$$f(e) = \frac{\int_\lambda e(\lambda)\, V(\lambda)\, \mathrm{d}\lambda}{\int_\lambda e(\lambda)\, s(\lambda)\, \mathrm{d}\lambda} \tag{4}$$

where $e(\lambda)$ is the relative spectral irradiance of the lamp.

Preparation of an artefact photometer

For the cross check, an artefact photometer was prepared from a commercial one [LMT, serial number 10A4153(c)] with an external precision aperture attached by KRISS. To measure the spectral responsivity of the artefact photometer, a spectral responsivity comparator system is used in reference towards reference single-element silicon photodiode of which scale is traceable to the cryogenic radiometer via the silicon trap detectors [1]. The system set-up is shown as Figure 1. The system consists of a double grating monochromator, a quartz halogen lamp of 100 W, collimating mirrors (f number =F/6), and a detector translator which can hold five units of detector at one time [1]. The collimating mirror at the exit port makes a circular light spot on the active surface of the detector. The spot has a diameter of about 1.5 mm and an output power of about 2 μW at 555 nm, which is monitored by a beam splitter and a silicon photodiode. A three axis-detector scanning carriage on the detector translator is installed to measure the spatial uniformity of the photometer. The whole system is covered by a light tight black box to avoid any interference from of stray lights and dust. The spectral responsivity was measured in a wavelength interval of 5 nm for the range from 380 nm to 1100 nm.

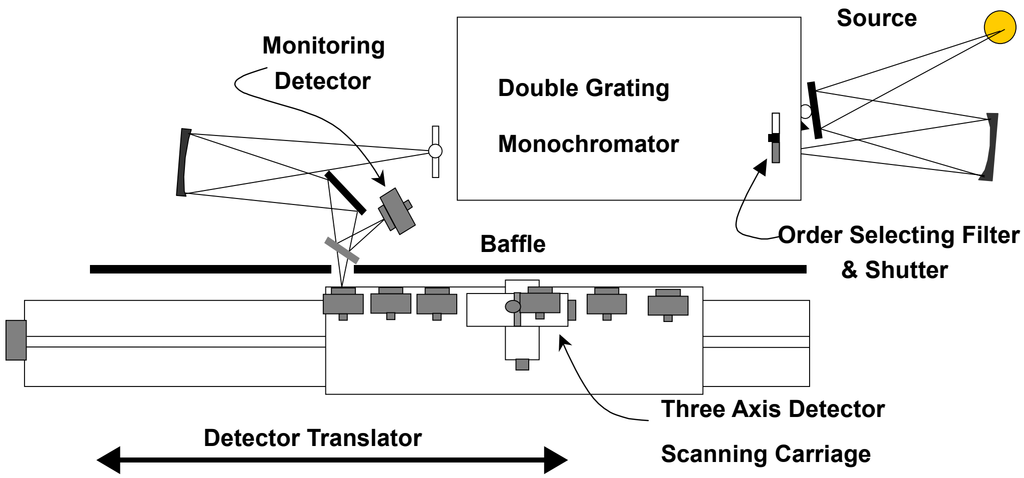

Figure 1: The arrangement set-up of Spectral Responsivity System

The external aperture with a nominal diameter of 7 mm was measured by the two-axis translator with a microscope which enables us to determine the edges as scanning the aperture. Shown in Table 1 is uncertainty components associated in the realisation of KRISS illuminance scale [1].

Uncertainty Component	Uncertainty, % (k=2)
Reference Standard	0.5
Correction to the reference colour temperature	0.04
Drift	0.06
Current Measurement	0.04
Angular alignment and distance setting	0.14
Combined Uncertainty	0.52

Table 1: Uncertainty of KRISS detector based illuminance scale

Maintenance of illuminance scale at NML-SIRIM

At presence, NML-SIRIM has two units of photometers; serial number C306/4 and C306/2 are periodically calibrated at NPL, UK on spectral responsivity and illuminance respectively. Simultaneously, one unit of Polaron standard lamp serial number Pa 762 was also sent for calibration on candela output at 2856K. The photometer was calibrated by reference to NPL, UK standards for relative spectral responsivity which traceable to NPL cryogenic radiometer at wavelength range of 380nm to 780nm at 5nm data interval. Then, the illuminance, *lux* calibration process was done against a set of luminous intensity standard lamps operating at correlated colour temperature of approximately 2856K.
After the instruments been calibrated, both photometers and the standard lamp are verified against each other. The verification process was done on a photometric bench at distance of 2.5 m between the reference plane of the photometer and the filament of the standard lamp as mentioned in calibration certificate. The output of both photometers are compared and the agreement between both photometers are within 0.1 % which reasonable to the value of Polaron luminous intensity standard lamp. The expanded uncertainty of illuminance calibration of both photometers is 0.8%.

Comparison Result of Illuminance Measurement

This comparison is to crosscheck the illuminance output of photometer between NML-SIRIM and KRISS. The experiment was done at NML-SIRIM photometric bench with inclusion of tungsten halogen standard lamp serial number Pa762. The separation distance between photometer and the front surface of the filament was 2.5 meter. The results of the experiment are shown in Table 2.

Photometer	Ratio (Pa 762)
NML-SIRIM, C 306/4	1.0039
KRISS, 10A4153(c)	1.0023

Table 2: Cross check results between NML-SIRIM and KRISS

The measurement results of NML-SIRIM photometer with comparison to standard lamp Pa762 is upper by 0.4% from the stated value and meanwhile, KRISS photometer is only 0.2% higher from standard lamp Pa 762.

Conclusion

The result shows an agreement between NML-SIRIM photometer and KRISS photometer are within the expanded uncertainty of illuminance scale which is 0.8% and 0.5% respectively. Since NML-SIRIM does have the primary standard facility, the agreement between both NMIs is satisfactory considering the fact that NML-SIRIM does have the primary standard facility. Ultimately, this exercise is an alternative method to verify the equipment performances and also illuminance scale.

References

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