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# PHOTOMETER SPECTRAL RESPONSE MEASUREMENT USING OPO TUNABLE LASER

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### PHOTOMETER SPECTRAL RESPONSE MEASUREMENT USING OPO TUNABLE LASER

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#### Abstract

This paper shows an photometer spectral response measurement method using an pulsed tunable laser. The laser is the comparator. the standard detector is a three-silicon S1337 trap detector and the detector under test is a silicon photodiode with a V( $\lambda$ )-correction filter. Due to the low noise and strong signal of the laser, we believe it will give a lower measurement uncertainty compared to traditional method for measuring S( $\lambda$ ) of the photometer

Keywords: Photometer, Spectral response, Pulsed tunable laser, Trap detector

#### 1 Introduction

Nowadays, LED and related products are widely used in everyday lighting. It is important to the get precise photometric measurement results for LED.For colour LED photometric measurement, one of the significant measurement uncertainties comes from colour correction factor (CCF)  $C_{ccf}$ , when the relative spectral response of the photometer  $S^*(\lambda)$  is different from the photopic luminous efficiency function  $V(\lambda)$ . For example, to test an LED average luminous intensity using an photometer, which is calibrated by using CIE A illuminant as light source. The CCF is determined by  $S^*(\lambda), V(\lambda)$ , spectra of measurand  $P_{LED}(\lambda)$  and spectra of CIE A illuminant  $P_{CIE A}(\lambda)$ . The CCF is defined as the following expression (1)

$$C_{\rm cef} = \frac{\int\limits_{780}^{780} P_{\rm LED}(\lambda) V(\lambda) d\lambda}{\int\limits_{380}^{780} P_{\rm CIE A}(\lambda) S^{*}(\lambda) d\lambda} \cdot \frac{\int\limits_{780}^{780} P_{\rm CIE A}(\lambda) S^{*}(\lambda) d\lambda}{\int\limits_{380}^{780} P_{\rm LED}(\lambda) S^{*}(\lambda) d\lambda}$$
(1)

Therefore, an accuracy  $S^*(\lambda)$  measurement result of the photometer helps to get a low uncertainty CCF. That means lower measurement uncertainty of LED photometric measurement, especially for blue LEDs.

#### 2 Method and Setup

The pulsed optical parametric oscillator (OPO) tunable laser of a 1 kHz repetition frequency system, which covers the range of 210 nm  $\sim$  2400 nm spectrum, was used to calibrate silicon photodiode with a low measurement uncertainty in a previous report [1]. Great potential in field of photometry and radiometry is shown. In this report, we have recently setup a photometer spectral response measurement system using an pulsed OPO tunable laser. The tunable laser system has a pulse laser of 1k Hz repetition frequency and each pulse has a  $\sim$ 5ns pulse width. In the visible range of 405 nm  $\sim$  780 nm, the width at half maximum of the pulse spectra is smaller than 0.2 nm. The facility is fully automated, easy to maintain and friendly to use.

After coming out of OPO, the laser light beam is coupled into a fibre and passes through the ultrasound bath, and then inject into an integrating sphere. The aperture of the integrating sphere is the light source for the measure system.

To measure  $S^*(\lambda)$  of the photometer, the detector under test (DUT) is made of a silicon photodiode with a  $V(\lambda)$ -correction filter. The standard detector (STD) is a three-silicon S1337 trap detector. The substitution method is used when DUT and STD are mounted on motorized

stage. Because the pulse to pulse is variation and not easy to stabilize, monitor detector (MD) is need, and be fixed with the same distance to the output integrating sphere as the DUT/STD does, with a different angle. Baffles and light traps are used to contain the stray light. The schematic is shown in figure 1.



Figure 1 – The schematic setup for photometer spectral response measurement

The response of DUT  $S_{\rm DUT}(\lambda)$  is measured using the expression (2). Here,  $S_{\rm STD}(\lambda)$  is the spectral response of the STD,  $R_{\rm DUT}(\lambda)$  is reading of DUT,  $R_{\rm MD,DUT}(\lambda)$  is the reading of MD while DUT is on ,  $R_{\rm STD}(\lambda)$  is reading of STD,  $R_{\rm MD,STD}(\lambda)$  is the reading of MD while STD is on.

$$S_{\text{DUT}}(\lambda) = \frac{R_{\text{DUT}}(\lambda)}{R_{\text{MD,DUT}}(\lambda)} \cdot \frac{R_{\text{MD,STD}}(\lambda)}{R_{\text{STD}}(\lambda)} \cdot S_{\text{STD}}(\lambda)$$
(2)

Then  $S^*(\lambda)$  is normalized result of  $S_{\text{DUT}}(\lambda)$ .

The reading of DUT,STD and MD is measured by electrometers, and same method in report[1].

### 3 Results

We test one photometer spectral response range from 405 nm to 780 nm. The relative standard deviation (RSD) of the measurement are shown in figure 1.



Figure 2 – The relative standard deviation of the measurement

The RSD is less the 0.01% in the range of 460 nm  $\sim$  580 nm, and is  $\sim$ 0.01% in the range of 440 nm  $\sim$  460 nm  $\sim$  660 nm. RSD increases in the violet zone the deep red zone, due to the weak output signal of the photometer.

For most of blue LED, the wavelength of spectra peak is of ~ 450 nm. The measurement results shows a good signal to noise ratio (> 5000:1) and good repeatability at 450 nm.Uncertainty evaluation is still on-going, however we believed it will give a lower number compared to traditional method for measuring  $S^*(\lambda)$  of the photometer. And the photometer spectral response measurement results are shown in figure3.



Figure 3 – The photometer spectral response measurement result

The uncertainties evaluation is still on-going, however, however we show a rough estimated results in table 1.

|                         | Relative standard uncertainty (%) |       |
|-------------------------|-----------------------------------|-------|
| Uncertainty component   | 450nm                             | 555nm |
| STD trap                | 0.06                              | 0.06  |
| Laser wavelength        | 0.05                              | 0.02  |
| Irradiance uniformity   | 0.05                              | 0.05  |
| Detector linearity      | 0.005                             | 0.005 |
| Electrometer linearity  | 0.02                              | 0.02  |
| Repeatability           | 0.02                              | 0.01  |
| Combined Uncertainty    | 0.10                              | 0.08  |
| U <sub>re</sub> l (k=2) | 0.2                               | 0.16  |

#### Table 1 – Rough estimated uncertainties.

### 4 Conclusion

This paper shows an photometer spectral response measurement method using an OPO tunable laser. Due to the low noise and strong signal of the laser, we believe it will give a lower measurement uncertainty compared to traditional method for measuring  $S(\lambda)$  of the photometer. An rough estimated measurement uncertainty at 450 nm is  $U_{rel} = 0.2\%$  (*k*=2).

### Reference

[1] Yuqin Zong etc., New Method for Spectral Irradiance and Radiance Responsivity Calibration using Pulsed Tunable Lasers, NEWRAD 2011 Maui,Hawaii,USA