New method for the primary realization of the spectral irradiance scale from 400 to 900 nm

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Abstract. A method is presented to measure the absolute spectral irradiance of light sources in the wavelength range from 400 nm to 900 nm. Use is made of a double monochromator based spectrometer which is calibrated with direct traceability to the detector spectral responsivity scale maintained at the NMi-VSL. For the implementation at the NMi, at present, the uncertainty is about 0.8 % (k=2) within the wavelength range studied. A preliminary comparison with an externally calibrated irradiance standard shows agreement well within the combined uncertainty of the two calibrations.

1. Introduction

At present, the most accurate photometric and radiometric measurements are achieved for detector responsivity in the visible part of the optical spectrum. In the visible spectrum uncertainties better than a few times 10^{-4} have been reported based on absolute cryogenic radiometers. In contrast to the high accuracy achieved for responsivity, irradiance measurements have a considerably higher uncertainty of about 1%. In this paper first results of a new method will be described where the absolute irradiance responsivity of a continuously scannable spectrometer is disseminated from the responsivity of a silicon trap detector [1]. This spectrometer can subsequently be used to calibrate the spectral irradiance of photometric and radiometric sources. The direct tracability is convenient for the monochromator based facilities at the NMi-VSL, and can lead to a more convenient and accurate means of realizing the irradiance scale.

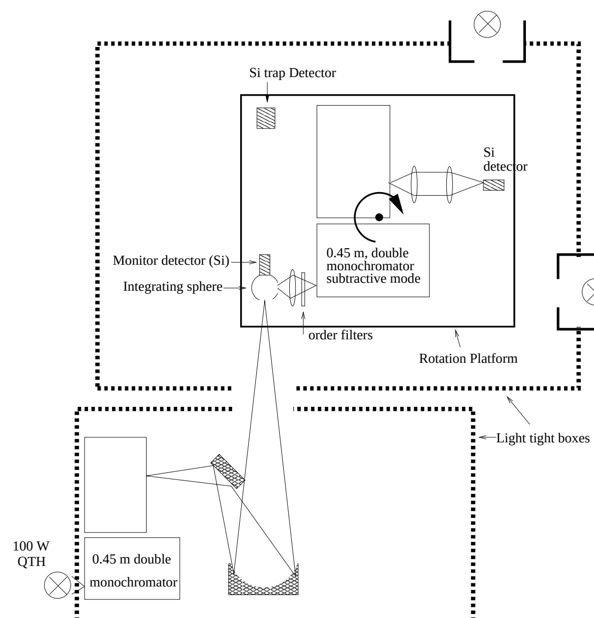

Figure 1. Layout of the ACR/SIR-facility.

2. Measurement Method

The calibration setup is schematically drawn in figure 1. The first part of the setup is a tunable lightsource consisting of a double monochromator combined with a 100 W quartz tungsten halogen lamp. The output of the source monochromator is directed to the Spectral IRradiance Facility (SIRF) setup using a mirror system. The output is focussed either to the input port of the spectrometer integrating sphere or to a silicon trap detector by rotating the rotation platform on which both are mounted to the appropriate angle. The response of the spectrometer at a specific wavelength is derived from a spectral integration of the response curve of the spectrometer, when scanning the source monochromator. The response of the SIRF spectrometer can be derived to be:

$$R_s(\lambda_0) \equiv \int R(\lambda, \lambda_0) d\lambda = \int \frac{i(\lambda_p)}{i_t(\lambda_p)} R_t(\lambda_p) d\lambda_p \quad (1)$$

Where $R_s(\lambda_0)$ is the responsivity of the spectrometer, $i(\lambda_p)$ the wavelength dependent current of the output

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detector of the spectrometer and $i_t(\lambda_p)$ and $R_t(\lambda_p)$ the current and responsivity of the trap detector respectively. The irradiance responsivity is calculated by using a separately determined value for the aperture area. For sources that have a slowly varying irradiance level around λ_0, $R_s(\lambda_0)$ can directly be used to calculate the irradiance at λ_0 from the measured spectrometer current.

3. Measurement Results

3.1. *Spectral irradiance responsivity calibration*

In figure 2 a graph is shown of $R_s(\lambda)$ for the range from 400 to 900 nm with wavelength steps of 10 nm. The shape of the wavelength dependent responsivity

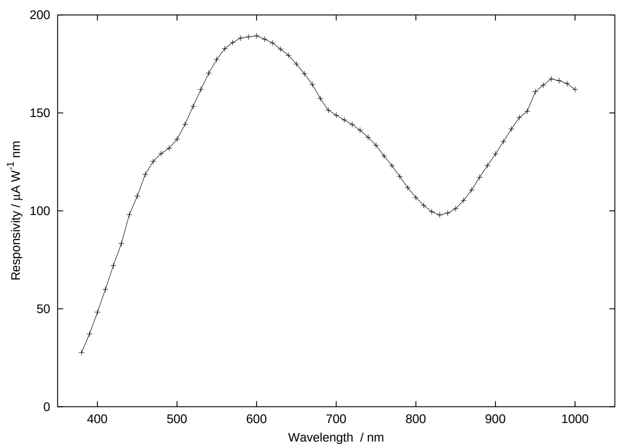

Figure 2. Responsivity of the spectrometer for different wavelength settings.

is dependent on the transmission and reflection of all the optical components and the responsivity of the silicon detector at the output port of the monochromator. A complete calibraton from 400 nm to 900 nm with 10 nm interval takes about 13 hours and is typically performed at night. The aperture area of the integrating sphere input port was determined using the "scanning spot" method as described in reference [2].

3.2. *Calibration of a FEL lamp*

Measurements were done on 1 kW FEL type lamps to test the calibration method. For reference the lamp was sent to the Optical Technology division at NIST for calibration. In figure 3 a measurement of the irradiance of this FEL lamp is shown. Analysis shows that the difference is well within the combined uncertainty of the NIST calibration and the uncertainty budget of the calibration at the NMi-VSL.

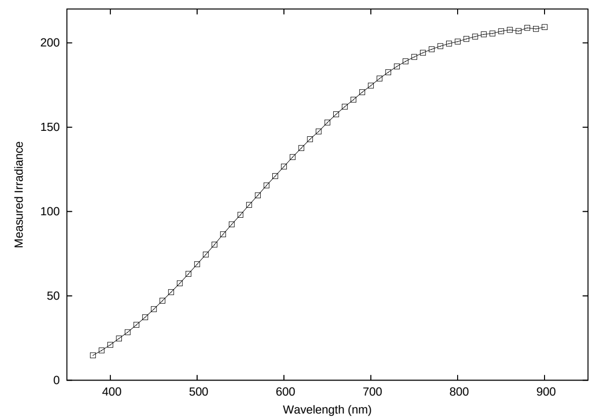

Figure 3. Irradiance measurement of FEL lamp with the calibrated spectrometer.

4. Conclusion

Results of a new method of disseminating a continuous irradiance scale in the visible part of the spectrum have been presented. The method described directly disseminates the irradiance scale from the detector scale. Preliminary comparisons with an externally calibrated irradiance source shows that the measurements agree well within the combined uncertainty of the measurements. At the moment the estimated uncertainty is about 0.8% (k=2) around 400 nm, decreasing to about 0.6% above 500 nm. Further improvement of the uncertainty and extension of the method to the IR and the UV is presently pursued at the NMi-VSL

References

1. Ham, E.W.M., Bos, H.C.D., Schrama, C.A., *Metrologia*, 2003, **40**, S177-S180.
2. Schrama C.A., Reijn H., *Metrologia*, 1999, **36**, 179-182.