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Realization of spectral irradiance responsivity at NIS-Egypt

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ABSTRACT

Realization of the absolute spectral irradiance responsivity of photodetectors in A/W/cm^2 is a fundamental requirement for many photometric, radiometric and colorimetric applications. This work aimed to develop a standardized radiometric setup for realizing the absolute spectral irradiance responsivity in the range of 500 nm–950 nm at the National Institute of Standards (NIS), Egypt. A silicon trap detector, calibrated against the primary standard cryogenic radiometer, is used as a transfer standard for the calibration of S2281 Hamamatsu silicon photodiode, as a working standard, using a lamp-double monochromator based system. The accompanied uncertainty components affecting the measurements were investigated.

1. Introduction

Irradiance responsivity for most photometric and radiometric detectors in A/W/cm^2 can currently be established with the highest accuracy by using detector-based methods [1–6]. Towards increasing the accuracy of photodetectors on a large extent, the calibration of irradiance responsivity of such detectors is necessary. Spectral responsivity of an optical detector describes the spectral dependence of its output electrical signal in amperes or volts to the input optical power in watts, quantified as a quotient of the detector output by a monochromatic radiation input at each wavelength [5,7–10]. In the visible spectrum uncertainties better than 10^{-4} in detector responsivity were reported based on the absolute cryogenic radiometer [7]. At NIS institute, the standard detector used for realizing the spectral irradiance responsivity in the range from 500 nm to 950 nm is a 3-element silicon photodiode reflection trap detector accompanied with a precision aperture, designed and fabricated in Hohenheide Inc. in Estonia (see Fig. 1). It was calibrated by the national metrology institute of Finland, MIKES, traceable to the cryogenic radiometer. The relative expanded uncertainty ranges from 0.5% to 4.0%, depending on the calibrated wavelength region. The spectral irradiance responsivity of a photodetector is considered as the product of the spectral power responsivity in A/W by the area of its precision aperture in m^2 [6,11–13].

On the other hand, the spectral irradiance responsivity scale at NIS is realized traceable to the calibrated trap detector using the Hamamatsu S2281 silicon photodiode as a working standard, accompanied also with a precision aperture (see Fig. 2). This scale is realized in the range from 500 nm to 950 nm in 10 nm steps. The photosensitive area of the photodiodes was calibrated by using the overfilled irradiance mode, instead of underfilled, for our measurements [2].

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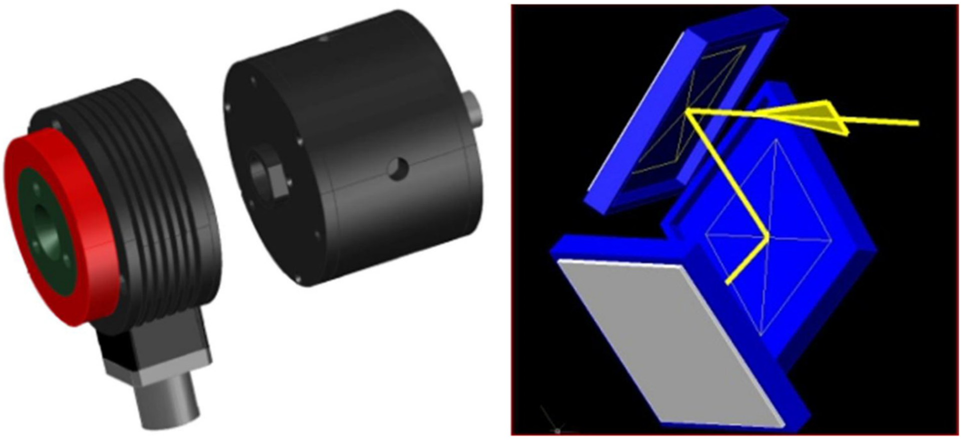

Fig. 1. Schematic diagram for 3-element reflection trap detector.

Fig. 2. Hamamatsu S2281 silicon photodiode.

Lamp-monochromator based system which consists of quartz tungsten halogen lamp, double monochromator, integrating sphere and photodetectors is used to measure the absolute spectral irradiance responsivity of Hamamatsu S2281 silicon photodiode.

The procedure used to transfer the scale from the trap detector to silicon photodiode is so-called substitution method [11,14,15]. In the direct substitution method, both detectors are located in the same focal plane and translated into the incident monochromatic beam path. First the trap detector which measures the monochromatic optical power, then the S2281 photodetector that also makes the same measurement. In this work, various measurements systems were established in order to develop a standardized radiometric setup for evaluating the absolute spectral irradiance responsivity between 500 nm–950 nm wavelength ranges at NIS.

2. Experimental setup

The experimental setup and instrumentation used to disseminate the absolute spectral irradiance responsivity scale based on lamp-monochromator system is shown schematically in Fig. 3. Appropriate fore-optics contain a double monochromator, which produces a monochromatic light, accompanied with an integrating sphere coated by sintered PolyTetraFluoroEthylene (PTFE) that has high diffuse reflectance in the usable spectral range [16]. This integrating sphere was used to build a uniform, monochromatic, and quasi-Lambertian source of high spectral radiant flux to improve the uniformity of the radiance at the exit port. A high intensity source, 1KW Quartz Tungsten Halogen (QTH) lamp, is used in the usable spectral range from 500 nm to 950 nm to get a sufficient output signal in the exit monochromator port and to overcome the radiance losses caused