Power and wavelength-meter in one for lasers and other narrow-band light sources based on the dual-photodiode radiometer concept

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We are developing a radiometer, which can simultaneously measure radiant power and centroid wavelength of narrow-band light sources in a wavelength range from 400 nm to 900 nm. The device consists of an integrating sphere and two photodiodes attached on that. One of the photodiodes is accompanied with a dielectric filter to make its spectral responsivity different from the other. The accuracy of the power and wavelength measurements using this device is being tested both numerically and experimentally.

MOTIVATION

Wavelength-tunable narrowband light sources with a spectral bandwidth of less than 10 nm, including lasers, are widely used in the field of radiometry, especially for spectral characterization and calibration of optical sensors and detector systems. The radiant power and centroid wavelength of such a source are the important quantities, which need be monitored by using two separate instruments, a power-meter (i.e., a radiometer calibrated against radiant flux) and a wavelength-meter (or a spectro-radiometer).

Our motivation is to develop a two-in-one instrument, which can simultaneously measure radiant power and centroid wavelength in a single reading. The concept of the dual-photodiode radiometer is applied, which is described and demonstrated in Ref. [1]. The main challenge of our experimental realisation of this concept is to cover a wide wavelength range from 400 nm to 900 nm. As the development is still in progress, we present in this paper the preliminary results achieved so far.

CONSTRUCTION

Figure 1 shows the schematic design of the dual-photodiode radiometer developed. The flux to be measured is entered into a small-sized integrating sphere with an inner diameter of 50 mm, which is attached with two Si photodiodes. One of them is accompanied with a dielectrically coated filter, which makes the spectral responsivity of one detector different from the other.

As described in Ref. [1], the dual-photodiode radiometer concept works only when the following conditions are fulfilled: First, spectral responsivity of each detector should be a linear function against wavelength within the bandwidth of the incident light. Second, the responsivity ratio of the both photodiodes should be a monotonic function against wavelength. The measured spectral responsivities of each photodiode are shown in Figure 2 together with their ratio as a function of wavelength. The condition of the linear function seems to be fulfilled from 400 nm to 900 nm. However, the ratio is not a monotonic function below 500 nm. Therefore, the device constructed for the first test can be used only in a

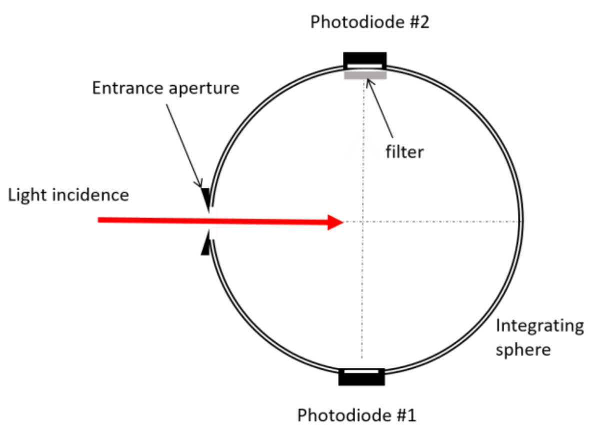

Figure 1. Schematic design of the dual-photodiode radiometer for simultaneous measurement of radiant flux and centroid wavelength.

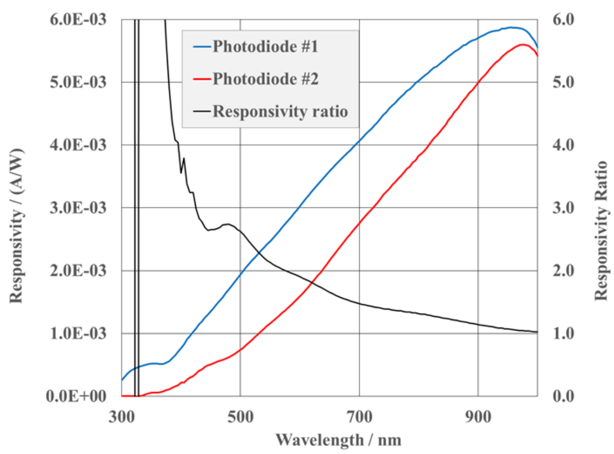

Figure 2. Measured spectral responsivity of the photodiodes #1 and #2, and their ratio of the dual-photodiode radiometer shown in Fig. 1.

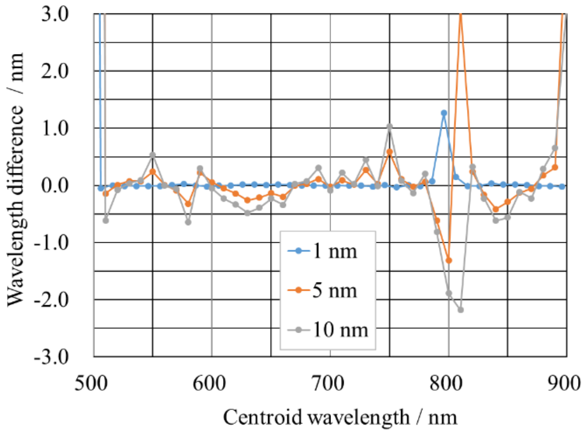

Figure 3. Measurement errors for centroid wavelength expected from the numerical simulation based on the measured spectral responsivities of Fig. 2 and a Gaussian function input with a spectral bandwidth of 1 nm (blue), 5 nm (red), and 10 nm (grey).

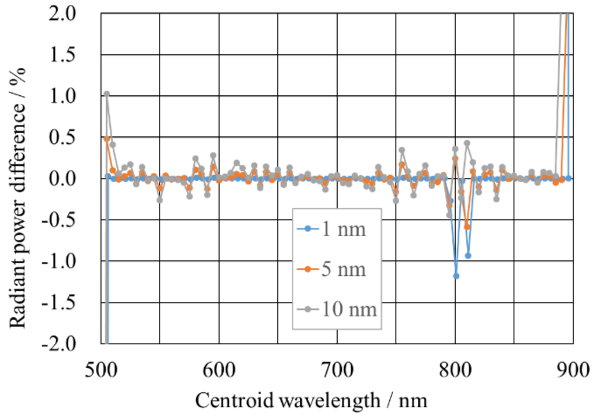

Figure 4. Measurement errors for radiant power expected from the numerical simulation based on the measured spectral responsivities of Fig. 2 and a Gaussian function input with a spectral bandwidth of 1 nm (blue), 5 nm (red), and 10 nm (grey).

wavelength range from 500 nm to 900 nm. A revision of the filter coating is required to extend the working range.

NUMERICAL TEST RESULTS

The expected accuracy of the dual-photodiode radiometer is first tested based on a numerical simulation. Similar to Ref. [1], we took a Gaussian function with a spectral bandwidth (FWHM) of 1 nm, 5 nm, and 10 nm at various centroid wavelength as the input light. For each input light, we calculated the centroid wavelength and radiant power by using the measurement equations of the dual-photodiode radiometer based on the measured data of Fig. 2.

Figure 3 and Fig. 4 show the simulation results for centroid wavelength and radiant power, respectively: the difference of the "measured" values and the "true" values are plotted as a function of wavelength from 500 nm to 900 nm for different values of source spectral bandwidth.

We see in the results of Fig. 3 and Fig. 4 that a high measurement error is expected in the near of 500 nm, 900 nm, and 800 nm, where the spectral responsivity of the photodiode #1 severely deviates from a linear function. Except these regions, the maximum errors are kept small. For a spectral bandwidth of less than 1 nm, the expected errors for centroid wavelength and radiant power are less 0.1 nm and 0.1 %, respectively. The errors generally increase as the spectral bandwidth of the source increases, but well below 0.5 nm and 0.3 % for centroid wavelength and radiant power, respectively, except several problematic regions where the spectral responsivity is strongly non-linear against wavelength.

Based on the numerical test results with the measured spectral responsivities, we obtained valuable information on how to modify the spectral transmittance of the filter to achieve the high accuracy in the whole target range from 400 nm to 900 nm.

FURTHER TESTS IN PLAN

To be a practical measurement device, the proposed dual-photodiode radiometer needs to be also tested for various response characteristics such as angular and spatial uniformity, stability, and non-linearity against incident power. For application with lasers, polarization dependence will be also tested. As the target application of this two-in-one device, we will monitor the radiant power and centroid wavelength of a tunable laser and of a monochromator-based tunable light source.

REFERENCES

1. Dong-Joo Shin *et al.*, Dual-photodiode radiometer design for simultaneous measurement of irradiance and centroid wavelength of light sources with finite spectral bandwidth, Applied Optics, 58, 8262-8271, 2019