

Radiometric investigation of a compact integrating sphere based spectral radiance transfer standard

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Introduction

In recent years, to fulfil the requirements of DIN EN ISO/IEC 17025, the traceability of measurements to a primary standard has become mandatory, ensuring the comparability of inter-laboratory measurements and of measurements performed over a long time period. This is also the case in the wide and ever increasing field of optical radiation measurements. To meet the demand of traceability, there is a need for highly accurate and yet simple to use robust radiometric transfer standards.

New Spectral Radiance Transfers Standards

One of the most frequently used radiometric quantity in the field of optical radiation measurements is the spectral radiance, being of importance for manufacturers of radiation sources as well as for laboratories in the calibration of their spectrometers and detection systems. The well established transfer standard for spectral radiance is the tungsten ribbon lamp. Yet of proven very high stability, this type of standard is suitable only for a small group of experienced users, i.e. national metrology institutes. For the broad community of industrial users the delicate to handle tungsten ribbon lamps are less suitable. The most promising candidates for user friendly spectral radiance transfer standards have shown to be integrating sphere based sources. In contrast to the fragile and cumbersome to align tungsten ribbon lamps, they are rather robust and offer a comparatively large and homogeneous radiating area. The emitted radiation is in good approximation lambertian and unpolarized. An important feature of this type of radiance standard is that, by adapting its design, the spectral radiance magnitude can be matched to specific calibration demands. For example, the calibration of the detection channel of a fluorometer requires a spectral radiance three to four orders of magnitudes lower than that of a tungsten ribbon lamp.

Integrating sphere radiator design

As part of the project "Development, Characterization and Dissemination of Fluorescence Standards for the Traceable Qualification of Fluorometers" the PTB and Gigahertz-Optik GmbH in close cooperation have developed and characterized a new type of integrating sphere based spectral radiance transfer standard. An image and a schematic view of the design are shown in Figure 1. The basic design consists of two hemispheres made of OP.DI.MA and separated by a nearly opaque wall with two OP.DI.MA surfaces. The 5 W, constant current driven, quartz halogen lamp integrated in the back hemisphere

illuminates through 16 holes in the wall the front hemisphere. The front hemisphere has a 20 mm diameter aperture as the radiating area.

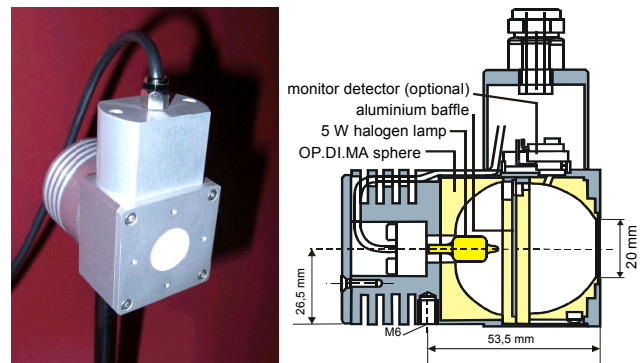


Figure 1. Compact and large radiating area integrating sphere based spectral radiance standard (left) and a schematic view of the design (right).

Radiometric Characterization

To investigate and optimize the radiometric properties of this new type of integrating sphere radiator, PTB has set up a new spectral radiance comparator facility the Spectral Radiance Comparator II. This facility is designed for low intensity measurements and traceable spectral radiance calibrations in the wavelength range from 250 nm up to 2.5 μm as they are needed i.e. for radiometric traceability in fluorometry [1,2].

The customer relevant and most important radiometric parameter investigated and optimized were:

- the distribution of the spectral radiance over the radiating area
- the angular distribution of the spectral radiance
- the mid- and long-term stability
- the influence of ambient condition changes on the spectral radiance
- the absolute spectral radiance in the UV, VIS and NIR

An optimizing process of the wall structure resulted in an excellent homogeneity of the radiating area, both in the visible and in the near infrared. Within an area of 10 mm in diameter, the relative variation of the spectral radiance is less than $5 \cdot 10^{-3}$. Measurements of the horizontal and vertical angular emission distribution proved that these sources are in very good approximation lambertian radiators: relative changes of the radiance for a $\pm 10^\circ$ change of the observation direction to the optical axis are within $5 \cdot 10^{-3}$.

Detailed and comparative results with a tungsten ribbon lamp will be presented. Furthermore, the determination of the degree of polarization of the emitted radiation in the wavelength range from 450 nm up to 1100 nm resulted in less than $4 \cdot 10^{-3}$, hence compared to tungsten ribbon lamps, these integrating spheres can be considered sources of unpolarized radiation. The temporal stability of the spectral radiance has been assessed by calibrating two integrating spheres of the same lot against a stable tungsten ribbon lamp in regular time intervals of about 100 hours. The overall time of continuous run for the integrating spheres was more than 1000 hours. The observed relative change of the spectral radiance over 100 hours of continuous operation was found to be about 1%. Within the calibration uncertainty, no change of the spectral radiance could be observed for ambient temperatures changes from 20 °C up to 30 °C.

The presented results indicate that these integrating sphere based radiators are suitable for a wide spread, easy to handle, day to day use as transfer standards for disseminating the radiometric base unit spectral radiance in the wavelength range from 350 nm up to 2 μm .

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