

## Rotational radiance invariance of diffuse reflection standards

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**Abstract.** Standards for diffuse reflection calibrations must not have any texture, i.e. their reflection behaviour should be independent of their rotational orientation. Explicit goniometric measurements on a selection of samples made of different materials show that is only half the truth. The absence of an obvious internal structure can nevertheless lead to variations in the reflected radiance of up to 1.2 % depending on the rotational orientation of the sample.

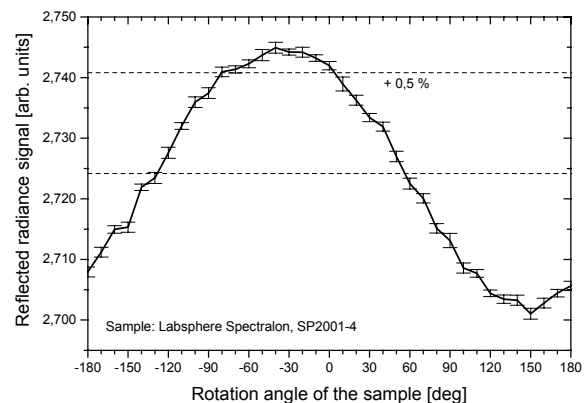
### Results and discussion

Diffuse reflection materials are important calibration standards for a variety of applications in optical technology. They have applications in radiometric and photometric measurements, like radiance factor, BRDF and colorimetric quantities.

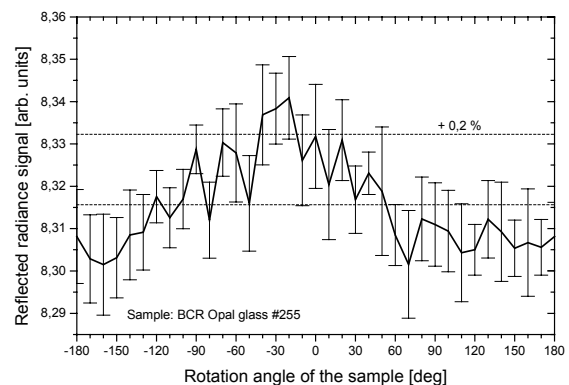
A selection of 16 different reflection standards were measured on PTB's new gonioreflectometer. Their radiance was recorded while there were rotated 360° around an axis collinear with their surface normal. The radiance signal was taken from a circular area 2 cm in diameter. The apex angle of detection was 0.32° (solid angle  $96.45 \cdot 10^{-6}$  sr), only. The samples were irradiated by a special homogeneous sphere radiator (solid angle  $2.16 \cdot 10^{-3}$  sr) with an inhomogeneity of only 0.2 % across the whole beam profile emitted from the circular aperture of the lamp with a diameter of 4 cm. The measurements were taken at a wavelength of 950 nm with a high precision Si photodiode connected to a picoamperemeter. The reflection geometry was 45/0 in an in-plane configuration for all of the measurements.

Different kinds of reflection standards with varying materials and technologies were examined. Pressed BaSO<sub>4</sub> tablets, primed BaSO<sub>4</sub> standards (special kind of BaSO<sub>4</sub> standard fabricated by the PTB), opal glasses and sintered PTFE based reflection standards (like Spectralon® and identical materials).

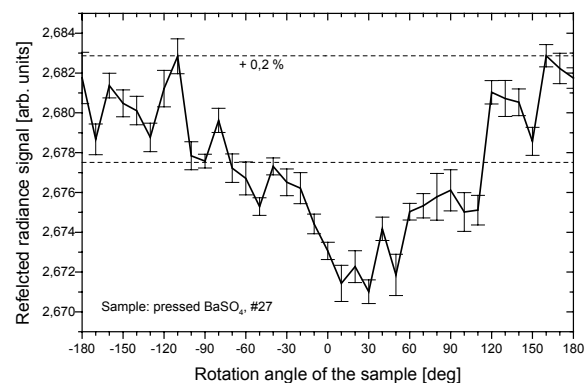
The subsequent three diagrams show the influence of the rotation of the samples on their reflected radiance signals. Fig. 1 shows the rotational reflection behaviour of a Spectralon reflection standard. Shown as dashed lines are the mean value and the 0.5 % deviation line. Connected with the full 360° rotation is a variation of approximately 1.2 % in the radiance signal. Displayed in Fig. 2 is the measured signal of the matte side of an opal glass from the European Commission (a so called BCR 406A opal glass). The variation in the radiance signal for a full 360° rotation is about 0.4 %. Fig. 3 shows the same data for a pressed BaSO<sub>4</sub> tablet. The overall change in the radiance signal for a full 360° rotation is also about 0.4 %.



**Figure 1.** Orientation dependence of the reflected radiance of a Spectralon reflection standard for a full 360° rotation



**Figure 2.** Orientation dependence of the reflected radiance of a BCR opal glass reflection standard for a full 360° rotation



**Figure 3.** Orientation dependence of the reflected radiance of a reflection standard made of pressed BaSO<sub>4</sub> for a full 360° rotation

For all of the analysed reflection standards no obvious texture structure was visible, even when examined under a microscope. The influence of distance variations between the irradiating lamp and the sample during the rotation measurements were also tested. This distance change is 4/100 mm at maximum for a full 360° rotation of a sample mounted in the sample holder of the gonireflectometer. Although this has a small affect on the irradiation  $E_i$  of the sample, the influence on the reflection signal is only 0.01 %.

## **Conclusion**

Standard materials of diffuse reflection should be handled with caution when there are used in directional reflection geometries. The absolute reflection depends on the rotational orientation of the sample relative to the plane spanned by the beams of the incident and reflected radiation. Even small rotations about the surface normal can lead to deviations in the reflected radiance almost in the percent range similar to the measurement uncertainties of most of the goniometric calibration facilities. This underlines the necessity to indicate the orientation of samples during their calibration and also to reproduce this orientation when making adjacent measurements using the calibration data.

**Acknowledgments** The author wants to thank B. Campe and K.O. Hauer for the preparation of several samples.

## **References**

W. Erb, Li Zai-Qing und P. Nikolaus, Super-Reflexion bei diffus reflektierenden Materialien, *Optik*, 71, No. 2, 80-88, 1985