New robot-based gonioreflectometer for measuring spectral diffuse reflection

D. Hünerhoff, U. Grusemann and A. Höpe

Physikalisch-Technische Bundesanstalt, Arbeitsgruppe 4.52 „Reflektometrie“, Bundesallee 100,
38116 Braunschweig, Germany

Abstract. At the Physikalisch-Technische Bundesanstalt (PTB) a new robot-based gonioreflectometer for measuring radiance factor and BRDF has been build up. The facility enables measurements of the directed reflection characteristics of materials with arbitrary angles of irradiation and detection relative to the surface normal.

Introduction

Measurements of directed diffuse reflection are an important quantity for a variety of applications in optical metrology. Measuring the BRDF allows one to describe the appearance of a material under user-defined lighting conditions. This includes calibrations for paper, textile and color industry, companies producing radiometric and photometric instruments, as well as measurements for radiometric on-ground calibration of remote sensing instruments for space-based applications on satellites.

Technical data of the gonioreflectometer

The facility uses broadband irradiation of the samples with spectrally selected detection of the reflected radiation. The unfiltered broadband irradiation is delivered by a special homemade sphere radiator with an internal 250 W quartz tungsten halogen lamp. This sphere radiator has a precision circular aperture of 4 cm and a homogeneity of the emitted radiance of ± 0.2 % within the whole opening. It is located on a large rotation stage with a diameter of 1.5 m and can be rotated 360° around the 5-axis-robot serving as the sample holder (see Fig. 1).

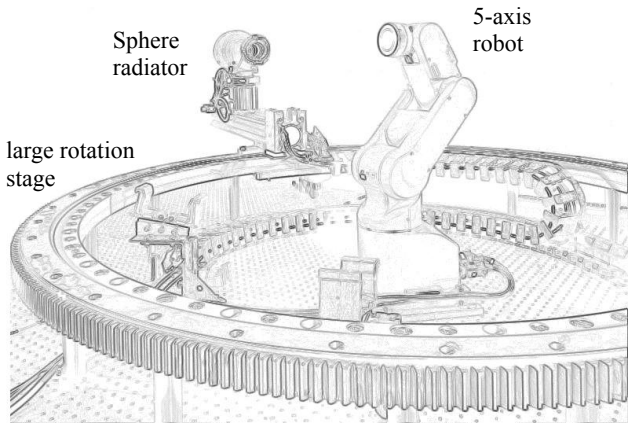

Figure 1. Schematic diagram of the gonioreflectometer facility

The direction of the detection path is fixed due to the fact that a triple grating half-meter monochromator for spectral selection of the reflected radiation is used. The sample holder is a small commercial industrial five-axis robot with an height of 550 mm, only (Fig. 1). It is able to carry and position samples with an outer diameter of up to 0.5 m and a weight of up to 2 kg. The position accuracy is 0.02 mm for arbitrary movements.

The combined adjustment of the rotation stage and the robot allows complete angular control of the directed beams of incident and reflected radiation within the full half space above the surface of the sample, allowing the measurement of out-of-plane reflection, too. The angular range of the directed radiation incident on and reflected from the sample is 0° to 85° for θ_i, θ_r and 5° to 355° for ϕ_i, ϕ_r (see Fig. 2). The apex angle of irradiation of the sample under measurement is 1.50° (solid angle $2.16 \cdot 10^{-3}$ sr), the apex angle of detection is 0.32° (solid angle $96.45 \cdot 10^{-6}$ sr), only.

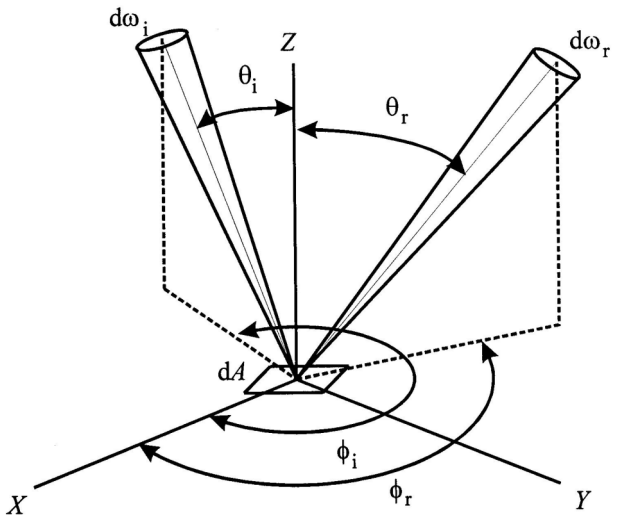

Figure 2. Geometry of incident and reflected beams at the gonioreflectometer

The current wavelength range for measurements of diffuse reflection is 250 nm to 1700 nm. It is planned to extend this range up to 2500 nm within the near future.

The facility uses a two-stage mirror-based 10:1 imaging optics to map a 20 mm circular area on the sample onto the 2 mm wide slit of the monochromator. This results in a 3 nm bandpass within the spectral range 250 nm to 900 nm and a 6 nm bandpass within the 900 nm to 1700 nm region, depending on the gratings used.

Four different detectors behind the monochromator are used for detecting the radiance signals of the incident and reflected beams: a solar blind channel PMT for the measurements between 250 nm and 350 nm, a yellow enhanced channel PMT between 300 nm and 450 nm, a silicon photodiode between 400 nm and 1100 nm, and a cooled InGaAs photodiode between 1000 nm and 1700 nm. All the signals were detected with a picoamperemeter and transferred to a computer for data storage and analysis.

The uncertainty budget for calibrations of the radiance factor and the BRDF ranges from 0.2 % in the visible spectral range to 0.5 % in the IR at 1700 nm and to 3.5 % in the UV at 250 nm.

Fig. 3 shows a typical measurement of the radiance factor of a diffuse reflecting material (Spectralon©) within the current spectral range of the facility.

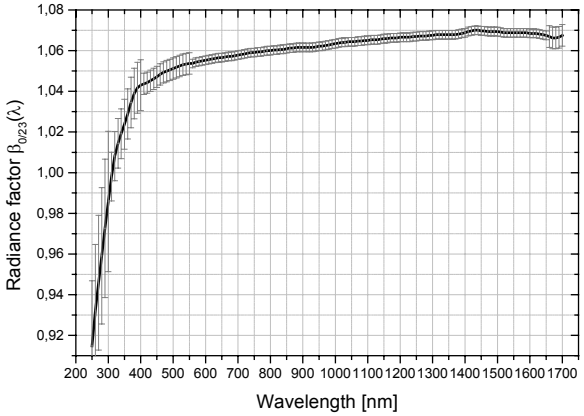

Figure 3. Radiance factor for a Spectralon© sample in 0/23 (in-plane) geometry in the spectral range 250 nm to 1700 nm

Acknowledgments The authors wants to thank B. Campe, K.O. Hauer and S. Teichert for construction and building several parts of the instrument.

References

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