2.6 TESTING

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Measurement methods to characterise BIST elements in a laboratory were presented by (Maurer et al., 2012). First the optical measurements of different layers of BIST elements are presented, before the calorimetric measurements are discussed which provide the solar thermal performance and the energy flux to the building interior with defined boundary conditions.

2.6.1 Optical measurements

Optical measurements of components for BIST are especially interesting when a new BIST element is being developed or an existing one is to be optimized. As large incidence angles of the solar radiation often occur on building envelopes, the transmittance and reflectance should be measured as a function of incidence angle. If a BIST element includes spectrally selective layers, the optical measurements should also be spectrally resolved. Furthermore, if a BIST element includes several transparent layers, polarization-dependent measurements should be performed. For a double glazed cover, the absolute error due to neglecting the polarization at an incidence angle of 60° can be at least three percentage points. If the solar transmittance of the double glazing is small, the relative error can be large. For more than two glass panes, the error is even larger.

Measurement procedures for the transmittance and the reflectance of layers in general and for (near-)normal radiation are presented by (EN 14500, 2008). The direct-direct transmittance and reflectance of thin samples can be measured for different angles of incidence with a small integrating sphere which can rotate around the sample as presented by Figure 2.6.1 (Wilson, 2007). The direct-hemispherical transmittance can be measured by a test facility as presented by Figure 2.6.2. The sample can rotate together with the large integrating sphere which measures the direct-hemispherical transmittance (Platzer, 1987). The direct-hemispherical reflectance can be measured by an irradiated rotatable sample within an integrating sphere. Light-scattering and textured components may need suitable measurement facilities as described by (Wilson et al., 2009). For materials with complex angle-dependent optical properties, photogoniometer measurements to determine the bidirectional scattering distribution function (BSDF) are recommended (Apian-Bennewitz, 2010). The hemispherical-hemispherical transmittance and reflectance can be calculated from the direct-hemispherical transmittances and reflectance at different incidence angles e.g. with the formulas provided by (EN 14500, 2008) for special cases which fulfil specified conditions of symmetry.

There are various methods to calculate the effect of multiple reflections in a stack of optical layers e.g.

- approaches for layer systems based on spectral normal-hemispherical values like (EN410, ISO9050, EN13363 or ISO15099)

[2] Non-COST Action member. Added testing experience for components for building envelopes which go beyond BISTS (like glass and conventional building envelopes), but which are very helpful to be applied for BISTS.

- detailed layer systems with angle-dependent, spectrally resolved, polarization-dependent calculation for direct and for diffuse radiation based on (Maheu et al., 1984; Maheu and Gouesbet, 1986)
- matrix methods like (Klems, 1993b, 1993a; Ward et al., 2011)
- ray-tracing methods like (Ward and Shakespeare, 1998)

When applied to opaque BIST elements, the result is typically the effective absorptance of each layer depending on the direction of incident radiation. In the case of semi-transparent BIST elements, the effective visible and solar transmittance of the BIST element depending on the direction of radiation from outside the building is typically needed and if possible also the reflectance of the BIST element from inside the building for accurate building energy simulations.

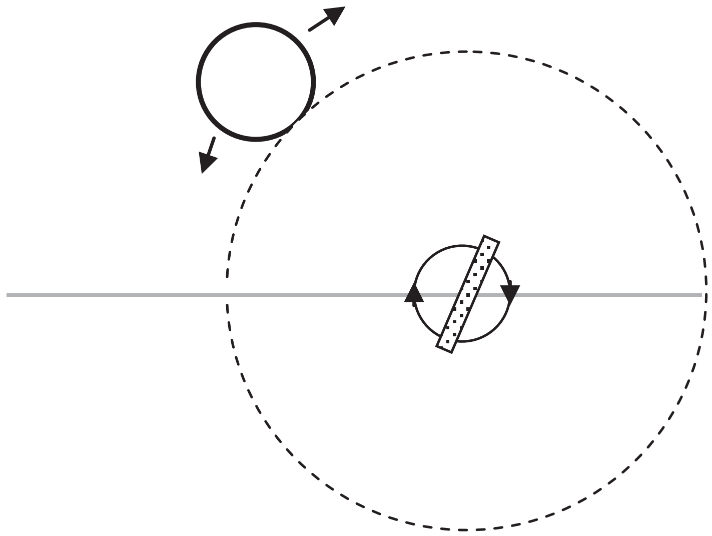

Figure 2.6.1. Schematic drawing of a centrally mounted sample which is irradiated from the left. A small integrating sphere can rotate around the sample to determine the direct-direct transmittance or reflectance for different incidence angles.

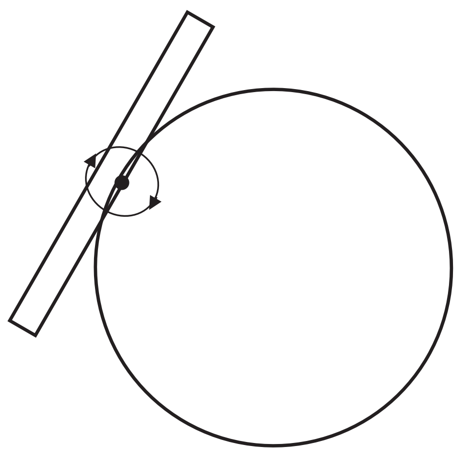

Figure 2.6.2. Schematic drawing of a test facility for the direct-hemispherical transmittance. The sample (dotted) is mounted at the opening of an integrating sphere, which can be rotated around an axis passing through the sample for different incidence angles of the radiation from the left.

2.6.2 Calorimetric measurements

Typical measurements of the solar thermal performance according to (ISO 9806, 2013) are only valid for rear-ventilated BIST installations because the same ambient temperature is assumed on all sides of the collector. If the energy flux from the BIST to the building interior cannot be neglected, a simultaneous measurement of the solar thermal performance and of the energy flux to the building interior is necessary to characterize both quantities as a function of the temperature and mass flow of the heat transfer fluid and the temperatures of the ambient air and of the interior space. A methodology to measure the energy flux of a BIST element towards the building interior is presented by (Kuhn, 2014). A measurement example for a semi-transparent facade collector to validate a BIST simulation model is presented by (Maurer, 2012). Calorimetric measurements are the most important measurements of BIST elements. Figure 2.6.3 presents a cross-section through the indoor calorimeter for building envelope elements of the TestLab Solar Facades at Fraunhofer ISE. The ambient air temperature, the irradiance and the external heat transfer coefficient can be adjusted as well as the temperature of the artificial interior and the internal heat transfer coefficient. A black absorber has the temperature of the artificial interior and absorbs nearly all radiation which is transmitted through the sample. Heat flux sensors inside the calorimeter absorber measure the energy flux to the interior. At the same time, the fluid flow and the fluid inlet temperature through the BIST element are controlled by a thermostat. The solar thermal performance can be calculated, using the measured fluid output temperature as input data.

Additional temperature sensors can be applied e.g. to investigate temperature distributions inside the BIST element. Additional edge insulation allows the measurement of centre-of-glazing values. The comparison of measurements with and without additional edge insulation is used to assess the quality of the edge design and allows BIST dimensions to be predicted for different ratios of collector area and edge perimeter.

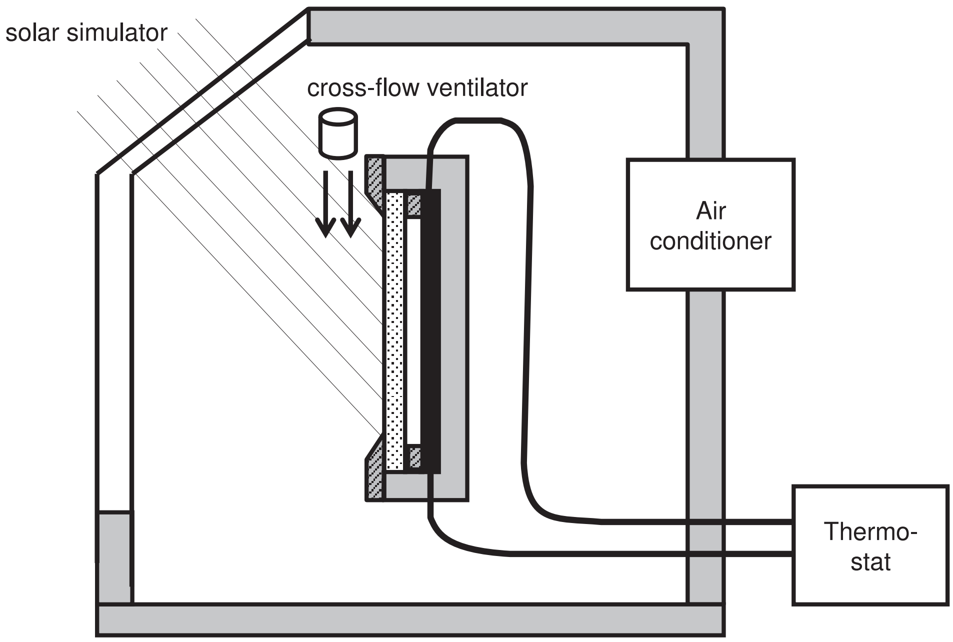

Figure 2.6.3. Cross-section through the g value calorimeter. The sample (dotted area) is irradiated by a solar simulator. The measurement chamber is air-conditioned and a thermostat controls the temperature of the black calorimeter absorber. Edge insulation (hatched area) can be applied to minimize edge effects.

In addition to the indoor calorimeter, Fraunhofer ISE has also developed an outdoor test facility for real-size building envelopes (OFREE) which also provides the energy flux to the building interior as well as the solar thermal performance. It can measure BIST elements up to 3.77 m height and 1.5 t weight and track them at defined angles with respect to the sun. OFREE can also control the temperature of the artificial interior and the heat transfer coefficient. Although the ambient temperature cannot be adjusted, the direct solar radiation has a much smaller divergence and realistic spectral properties, so it is recommended for BIST elements with strong angular or spectral dependence.

BIST installations in buildings can and should be monitored to check their real-life behaviour. However, monitoring takes a lot of time and the boundary conditions can be controlled and measured less accurately than in the laboratory. Therefore, calorimetric measurements in a test laboratory are recommended to characterize BIST elements.

REFERENCES

Apian-Bennewitz, P., 2010. New scanning gonio-photometer for extended BRTF measurements. Optics + Photonics, paper 7792-24. SPIE conference proceedings 7792.

EN 14500, 2008. Blinds and shutters - Thermal and visual comfort - Test and calculation methods. CEN 91.060.50.

ISO 9806, 2013. Solar energy - Solar thermal collectors - Test methods (DIN EN ISO 9806:2014-06). International Organization for Standardization. https://www.beuth.de/de/norm/din-en-iso-9806/205210944. Accessed 19 July 2016.

Klems, J.H., 1993a. A New Method for Predicting the Solar Heat Gain of Complex Fenestration Systems I. Overview and Derivation of the Matrix Layer Calculation. ASHRAE Transactions 100, Part 1.

Klems, J.H., 1993b. A New Method for Predicting the Solar Heat Gain of Complex Fenestration Systems II. Detailed Description of the Matrix Layer Calculation. ASHRAE Transactions 100, Part 1.

Kuhn, T.E., 2014. Calorimetric determination of the solar heat gain coefficient g with steady-state laboratory measurements. Energ. Buildings 84, 388–402.

Maheu, B., Gouesbet, G., 1986. Four-flux models to solve the scattering transfer equation in terms of Lorenz-Mie parameters. special cases. Appl. Optics 25 (7), 1122–1128.

Maheu, B., Le Toulouzan, J. N., Gouesbet, G., 1984. Four-flux models to solve the scattering transfer equation in terms of Lorenz-Mie parameters. Appl. Optics 23 (19), 3353–3362.

Maurer, C., 2012. Theoretical and experimental analysis and optimization of semi-transparent solar thermal façade collectors. Dissertation, Freiburg, 118 pp.

Maurer, C., Di Lauro, P., Hermann, M., Kuhn, T.E., 2012. Transparent solar thermal collectors – measurements and modelling. German and English version, in: Thermische Solarenergie / 22. Symposium. Ostbayerisches Technologie-Transfer-Institut e.V. (OTTI),, Regensburg.

Platzer, W.J., 1987. Solar transmission of transparent insulation material. Sol Energ Mater 16 (1-3), 275–287.

Ward, G., Mistrick, R., Lee, E.S., McNeil, A., Jonsson, J., 2011. Simulating the Daylight Performance of Complex Fenestration Systems Using Bidirectional Scattering Distribution Functions within Radiance. LEUKOS.

Ward Larson, G., Shakespeare, R.A., 1998. Rendering with radiance. The art and science of lightning visualization. Morgan Kaufmann Publishers.

Wilson, H.R., 2007. Polarisationseffekte bei winkelabhängigen Messungen von Reflexion und Transmission. Colloquium Optische Spektrometrie COSP 2007, Berlin. CD-ROM available from PerkinElmer.

Wilson, H.R., Hutchins, M.G., Kilbey, N.B., Anderson, C., 2009. Intercomparison of transmittance and reflectance measurements of light-scattering and patterned glass with spectrophotometers and integrating spheres. Final report. International Commission on Glass. http://www.icg-tc10.org/pubdetail.asp?PubID=134.