A Blackbody for Calibration of Hemispherical Infrared Detectors

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A new blackbody has been developed at the Physikalisch-Technische Bundesanstalt (PTB) to allow accurate calibration of infrared detectors with a hemispherical acceptance angle. The aim is to significantly reduce the uncertainty of long-wave downward irradiance measurements that are fundamental for investigation of the energy budget of the Earth – a key topic in climate research. The new Hemispherical Blackbody was designed to specifically meet the requirements for tracing such measurements to the SI.

PROJECT OBJECTIVE

Ground-based, low-uncertainty measurements of the hemispherical long-wave downward atmospheric radiation, which is strongly connected to the greenhouse effect of the earth, are performed globally with pyrgeometers and are for example organised within the Baseline Surface Radiation Network (BSRN). To achieve low measurement uncertainties highly accurate detector calibration is necessary. Such calibration measurements are performed as comparisons to the World Infrared Standard Group (WISG), operated at the World Radiation Center (WRC) in Davos. For an improved traceability of the WISG to the SI, a new blackbody as a dedicated calibration source for pyrgeometers is proposed in the framework of the EU co-funded research project MetEOC3 – “Further metrology for Earth Observation and Climate” [1]. One of the aims in this project is to reduce the uncertainty of hemispherical long-wave downward irradiance measurements from currently 5 W/m^2 to less than 2 W/m^2. As a substantial uncertainty component contributing to the overall uncertainty of this irradiance measurement, the new blackbody calibration source needs to feature an irradiance uncertainty of less than 0.5 W/m^2. In combination with the “Infrared Integrating Sphere” (IRIS) instruments [2] calibrated against the blackbody, irradiance responsivity traceable to the SI can be transferred to the WISG with the required uncertainty.

DESIGN OF THE BLACKBODY

Based on numerical simulations with the Monte-Carlo ray tracing software “STEEP3” [3], the design for the new blackbody was optimised. Particular attention was given to the specific requirements for calibrating detectors with a hemispherical acceptance angle. Several design aspects such as geometry and coating were considered in the simulations in order to identify an ideal design with high effective emissivity and low angular variation. A selection of the most promising candidates is pictured in Figure 1. A low dependence of the effective emissivity on the opening angle is advantageous for transferring measured radiation temperatures at normal incidence to the hemispherical opening angle and therefore to the irradiance of the blackbody onto the aperture area.

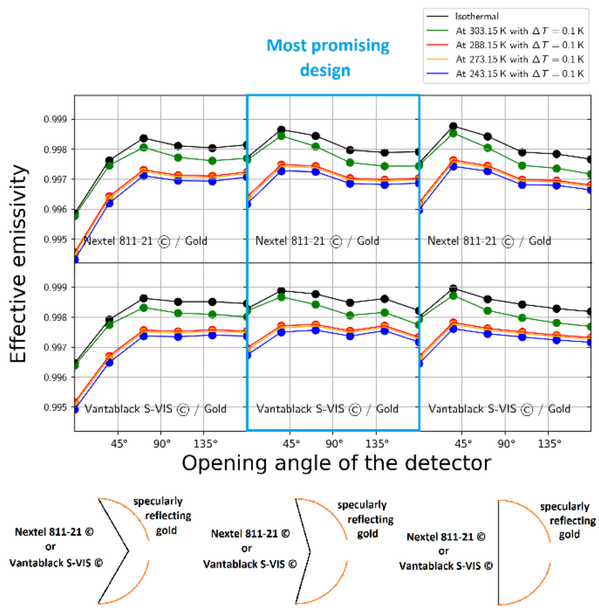
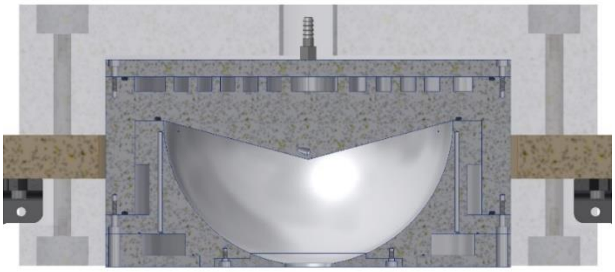


Figure 1. Monte-Carlo ray tracing simulations were carried out to obtain the effective emissivity for several design candidates of the new blackbody. Attention was given to the geometry and coating to identify a design with high effective emissivity in combination with low angular variation.

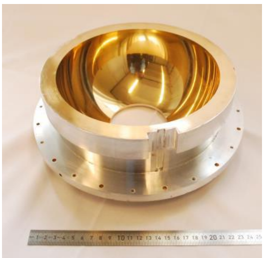
In addition, a highly reflecting golden hemisphere surrounding the highly emitting black cone is considered beneficial regarding the temperature non-uniformity of the blackbody cavity [4].

The Hemispherical Blackbody, presented in Figure 2, was designed, developed and brought into operation at the Physikalisch-Technische Bundesanstalt (PTB). To characterise the blackbody, simulations and comparison measurements were carried out. The latter took place against one of several heatpipe blackbodies that serve as national standards for the radiation temperature scale at the PTB [5].



(a)

(b)



(c)

Figure 2. The Hemispherical Blackbody dedicated for the calibration of hemispherical infrared detectors. The design (a) includes a highly emitting black cone (b) and a highly specularly reflecting golden hemisphere (c).

SCOPE OF THE PRESENTATION

The development, the thorough characterisation process and first applications of the Hemispherical Blackbody will be presented as well as the main technical features and objectives.

REFERENCES

1. *Metrology for Earth Observation and Climate.* www.meteoc.org. Visited 18th December 2019. National Physical Laboratoy.
2. J. Gröbner, A Transfer Standard Radiometer for Atmospheric Longwave Irradiance Measurements, *Metrologia*, 49.2, S105-S111, 2012.
3. A. Prokhorov, Monte Carlo Method in Optical Radiometry, *Metrologia* 35.4, 465-471, 1998.
4. T. Quinn et al., A Black-Body Cavity for Total Radiation Thermometry, *Metrologia* 23.2, 111-114, 1986.
5. J. Hollandt et al., High-Accuracy Radiation Thermometry at the National Metrology Institute of Germany, the PTB, *High Temperatures – High Pressures*, 35/36.4, 379-415, 2003-2004.