Implementation of the Spectral Irradiance Standard based on a high-temperature black body

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The high-temperature black body is widely used as a primary standard source for implementation of spectral irradiance units and can be used for spectral calibration of measuring instruments. Correct determination of a relation between spectral irradiance values of the primary standard and corresponding readings of a measuring instrument, and further obtaining a measurement result from this relation requires a suitably advanced system for making comparative measurements. The presented concept of a measurement system based on modern motion control components helped to achieve a high level of precision and accuracy while achieving better performance of the comparison procedure.

PRIMARY STANDARD

High-temperature black body radiators are widely used in national metrological institutes for implementation and maintenance of radiometric units [1]. The black body BB-PyroG-3000/32 adopted in the GL Optic laboratory was developed and manufactured by All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI), Moscow. It belongs to a wide family of radiators developed in this research centre [2].

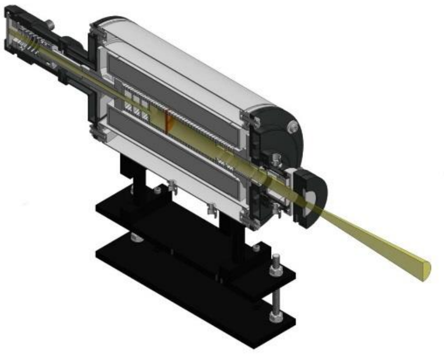

Figure 1. Cross section of the blackbody.

The radiator is based on a stack of pyrolytic-graphite rings forming a black body cavity. This cavity can be heated up to 3200 K with electric current flowing through the stack. The power supply equipped with a feedback system ensures stabilization of the black body temperature ± 0.02 K. During operation, the radiator interior must be filled with argon.

The black body casing is water cooled. In the event of a power failure in the cooling water supply the radiator may be cooled by gravitationally supplied water from a reserve tank. The radiator's properties are shown in Table 1.

MEASUREMENTS AND METHODS

Measurements of the spectral irradiance generated by a high-temperature radiator are carried out using a double monochromator MZDD3504i together with a set of detectors manufactured by SOL Instruments. These detectors are: photomultiplier, silicon diode and InGaS. Each of the Turner-Cherny scheme monochromators is equipped with automated 4-grating turret and automatic slits. The straylight with 20 nm 643.8 nm laser line is below 5×10^{-10}. The instrument can measure spectral irradiance in the range 190-2400 nm.

Table 1. Properties of BB-PyroG-3000/32 high-temperature black body radiator.

Maximum temperature	3200 K
Aperture diameter	25 mm
Cavity diameter	32 mm
Emissivity in UV-VIS-IR	≥ 0.999
Temperature resolution	0.01 K
Temperature stability	± 0.02 K
Support for HTFP	yes

The Planck's law describes the spectral distribution of the power of optical radiation emitted by a black body in thermal equilibrium based on a set temperature. Correct determination of the temperature is thus crucial for the whole measurement process. To measure the actual temperature, a Chino IR-RST65H pyrometer was used. It is a monochromatic pyrometer using a silicon photodiode as a detector. The measurement is made at a wavelength of 650 nm. The diameter of the measurement field is 0.6 mm at the distance of 400 mm. It helps to test the homogeneity of the black body emitting area.

To ensure the most accurate temperature measurement, the pyrometer can be calibrated against the rhenium-carbon high temperature fix point (HTFP), when the HTFP cell is installed in the blackbody.

The spectral irradiance measurement procedure consists of alternating measurements of the black body and a tested source for successive wavelengths within the assumed measurement range (Fig. 1).

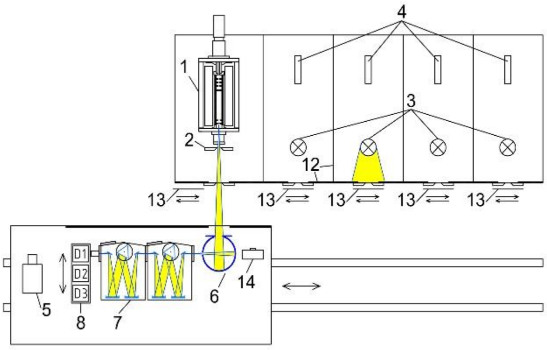

Figure 3. Optical comparator diagram: 1 - blackbody, 2 - diaphragm, 3 - DUTs, 4 – lasers, 5 – pyrometer, 6 – integrating sphere, 7 – double monochromator, 8 – detectors, 13 – shutters, 14 – array spectroradiometer.

Changes in the position of the double monochromator have a significant impact on the total measurement time and may introduce additional misalignment errors.

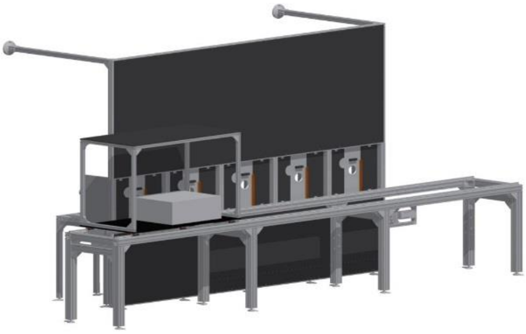

Figure 4. Optical comparator stand design.

To ensure fast switching between the two measurement positions, the optical comparator uses servomotors with built in 23-bit absolute encoders dedicated to CNC machining tools. The solution used helped to achieve positioning with standard deviation of 5 μm and with switching time between both positions of about 1.5 s.

The validation procedure revealed a known problem [3] of absorption bands caused by molecular carbon or carbon compounds presented in Figure 3. The additional array spectroradiometer used in combination with a double monochromator helps to identify and correct the deviations from the Planckian spectrum. The results obtained from this instrument are used as input data to the correction algorithm.

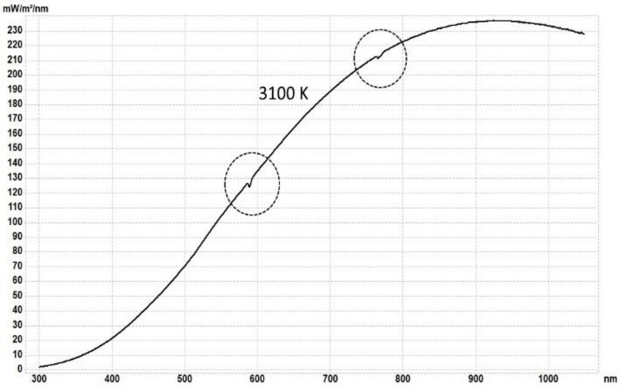

Figure 2. Spectrum with absorption bands.

CONCLUSIONS

The developed Spectral Irradiance Standard facility allows calibration with high efficiency (Figure 4). At the current stage the comparator is a subject of validation and comparative studies with national metrological institutes. The final results of these tests and the obtained calibration procedure times will be presented in the article following this abstract.

REFERENCES

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