Improving the spectral radiance and irradiance facility at NPL

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The use of blackbodies as a reference standard in spectral irradiance scales is common in many NMIs. This has been the basis of the NPL SRIPS facility for a number of years. This facility has recently been upgraded with new component systems, revised operation processes and analysis software, to improve the uncertainties obtained and robustness of operation. The upgrade has required a re-evaluation of the uncertainty budget. The opportunity was also taken to carry out a detailed health and safety review of the blackbody system and the laboratory environment.

INTRODUCTION

Blackbodies are commonly used as references, by NMIs across the globe, to define spectral radiance and irradiance scales [1, 2, 3]. An ultra-high temperature blackbody source with a pyrolytic graphite core design is implemented at NPL, allows temperatures in the range of 3000 K to 3100 K to be reached, allowing use across the UV to near-IR spectral range while maintaining good stability and uniformity of the source, to 0.0053% and 0.05%, respectfully, with the stability measurement occurring at 800 nm. The blackbody provides an ideal primary source to operate alongside FEL standard lamps and the systems calibrated by them [4, 5].

The ultra-high temperature blackbody is the sourced used within the semi-automated Spectral Radiance and Irradiance Primary Scale (SRIPS) facility. The SRIPS facility is used to calibrate a range of irradiance and radiance standards, from FEL lamps to integrating spheres, in the range of 250 nm to 2500 nm. Within NPL, these standards are used to disseminate calibration references to other spectroradiometer systems, including the NPL Reference Spectroradiometer, as well as to calibrate band & hyperspectral imagers and spectroradiometers for external stakeholders, including those used in ESA, EC Copernicus & national space agency Earth observation (EO) programmes. The dissemination of the SI through the SRIPS facility creates a crucial link to the pinnacle of the optical radiation traceability chain, the Cryogenic Radiometer, as shown in figure 1. The SRIPS facility also provides the same vital link to a number of industries, including but not limited to, manufacturing, medicine, photobiological safety, and film & television, either directly or indirectly through another NPL facilities.

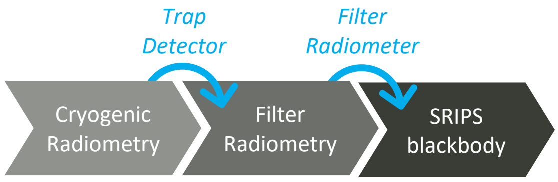

Figure 1. The traceability chain linking various NPL facilities together, from the primary standard for optical measurement, the Cryogenic Radiometer, to the ultra-high temperature blackbody in the SRIPS facility.

NPL SRIPS FACILITY

The blackbody is operated at a nominal 3050 K, a temperature chosen to ensure a balance between producing an adequate output power across the whole spectrum and maintain the longevity of the cavity. Accurate temperature stability and temperature knowledge of the blackbody cavity is needed to meet the radiometric uncertainty requirements. An optical feedback system maintains the stability of the cavity via current control to 0.4 K. To determine the cavity temperature, a calibrated filter radiometer (FR), with a peak response at 800 ± 5 nm, is used, allowing the radiance of the blackbody radiation to be measured over a narrow spectral band [6].

The blackbody emitted radiation is collected by an integrating sphere, and is wavelength selected by a double additive monochromator system, before it exits onto a selection of detectors, the specific detector selected for the wavelength of interest.

The FR measurements are used to calculate the cavity temperature using knowledge of the FR responsivity [7]. The calculated blackbody temperature is then used to determine the spectral radiance output of the blackbody across the spectrum range. The ratio between the spectral radiance computed using Planck's Law and the spectral data collected after passing through the monochromator system is determined at each individual wavelength and recorded as the system calibration factor (SCF),

$$SCF(\lambda) = \frac{L_{\mathrm{BB}}(\lambda)}{S_{\mathrm{BB}}(\lambda)} \tag{1}$$

where L is the theoretical radiance, and S is the measured detector signal.

The irradiance source under test is treated in the same way; with the source emission collected by the integrating sphere, passing through the monochromator and sampled by the detector bank. The SCF is applied along with a geometric factor, g, to adjust the units from radiance, L, to irradiance, E, as given by

$$E_{\mathrm{SUT}}(\lambda) = \frac{\pi g}{A} \cdot \frac{L_{\mathrm{BB}}(\lambda)}{S_{\mathrm{BB}}(\lambda)} \cdot S_{\mathrm{SUT}}(\lambda) \tag{2}$$

where A is the area of the aperture on the integrating sphere, and S is the signal from the source under test. $E_{\mathrm{SUT}}(\lambda)$ gives the final spectral irradiance data [5].

UPGRADING THE SRIPS FACILITY

Since the initial completion of the facility in 2002, SRIPS has undergone a series of upgrade projects. The most recent upgrade has focused on ensuring the long-term reliability of the system.

Within the SRIPS facility, there are key components which are fundamental to operation. Namely, the blackbody pyrolytic graphite core, its power supply & control, the monochromator and integrating sphere, and detector components – all components have been reviewed and either maintained, replaced or their long-term operation de-risked. The blackbody core was replaced, along with sufficient spares to allow SRIPS to operate for the next decade. An additional bespoke power supply has also been procured to safeguard this long-term operation plan. Additionally, the monochromator has been replaced with a new double additive monochromator with larger diffraction gratings, increasing the system throughput at the extremes of the spectral range.

The software used to operate SRIPS has been updated to streamline the data collection and analysis. The uncertainty budgets have also been revised following a complete re-evaluation at the contribution level, with inspiration taken from collaborations with EO metrology projects, changing the approach to uncertainty analysis to a more visual and coherent style [7].

Finally, all aspects regarding the safe operation of the ultra-high temperature blackbody in a laboratory setting has been reviewed, with the aim of ensuring a best practice approach is undertaken with the spectral irradiance scale systems. All physical safety features required for the operation have been considered, with particular regard for the water-cooling system and argon used to purge air from the blackbody cavity, as well as, the health implications of particulate emission from the cavity.

This paper will describe the upgrade project outcomes and safely best practise conclusions.

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