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IMPROVED CALIBRATION CAPABILITIES FOR INFRARED RADIATION THERMOMETERS AND THERMAL IMAGERS IN THE RANGE FROM -60 °C TO 960 °C AT THE PHYSIKALISCH-TECHNISCHE BUNDESANSTALT

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Summary:

At the Physikalisch-Technische Bundesanstalt (PTB), the national metrology institute of Germany, the calibration facility for thermal imager, infrared calibrators, and radiation thermometers has been updated to improve the calibration service. An additional cesium-heatpipe blackbody was installed to close the temperature gap from 270 °C to 500 °C and a new sodium-heatpipe blackbody was taken into operation. In addition, the precision of the positioning of the devices under test was improved and the new blackbodies were characterized and tested. The calibration facility now marks the state-of-the-art in terms of achievable uncertainties and automatization.

Keywords: metrology, radiation thermometry, infrared, calibration, uncertainty evaluation

Introduction

The main tasks of the department "Detector radiometry and radiation thermometry" of the Physikalisch-Technische Bundesanstalt (PTB), the national metrology institute of Germany, are non-contact temperature measurements (radiation thermometry) from -170 °C to 3000 °C and the quantitative measurement of electromagnetic radiation from the UV, to the visible and to the far infrared spectral range (THz radiation). This includes the realization, dissemination, and further development of the radiation temperature scale from -170 °C to 3000 °C by means of methods based on radiation thermometry and radiometry and the calibration of radiation temperature standards and radiation temperature devices [1]. The existing calibration facility for thermal imagers was enhanced to provide the calibration service for radiation temperature devices for the next 4 years as the current low temperature infrared calibration facility of PTB is going through a major revision.

The Thermal Imager Calibration Facility

The Thermal Imager Calibration Facility (TI-CF) (see Fig.1) of PTB provides radiation temperatures in the range from -60 °C up to 962 °C by means of four different heatpipe blackbodies [1]. Traceability to the ITS-90 is provided by standard platinum resistance thermometers (SPRTs) that measure the temperature of the heatpipe blackbodies very close to the bottom of the cavities (see schematic in Fig. 1). In addition to the existing ammonia- and water-heatpipe blackbodies, two new heatpipe blackbody cavities have been taken into operation.

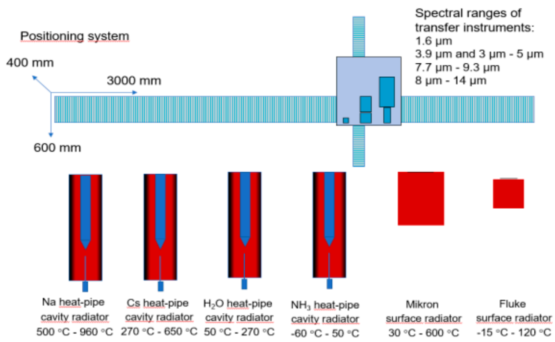

Fig. 1. Schematic of the TI-CF. The main components of the TI-CF are a high-precision positioning system, 6 different blackbodies and a set of radiation thermometers and thermal imagers as transfer instruments.

The new blackbody cavities are a Cs- and a Na-heatpipe blackbody. With the new blackbodies, the radiation temperature can be disseminated seamlessly from -60 °C up to 960 °C with uncertainties, that we believe, are among the smallest world-wide. Two surface radiators allow for the full illumination of FPA-Sensors in thermal imagers. A high-precision positioning system enables controlled pixel-by-pixel movement of thermal imaging cameras. This is of utmost importance for the application of a non-uniformity correction method developed at PTB, which can also be used for non-uniform radiation sources [2].

Characterization of the heatpipe blackbodies

The blackbodies were characterized, and the corrections of the radiation temperature $t_{r,90}$ were determined following the guidelines published in [3]. The most important correction term accounts for the emissivity of the blackbodies. The calculation of the uncertainty components with respect to the emissivity was carried out for both isothermal and non-isothermal blackbody conditions. For the isothermal condition the emissivity of the surfaces of the blackbodies were measured at the emissivity measurement under air facility of PTB [4] by means of samples that have identical layer thickness of the paintings as the cavities (for the ammonia- and water heatpipes) or come from the same blanks as the material for Inconel cavities (Cs- and Na-heatpipes). As an example, the results for an Inconel 600 sample are shown in Fig. 2. With this information the effective emissivity of the cavities was calculated using Steep 321 [5].

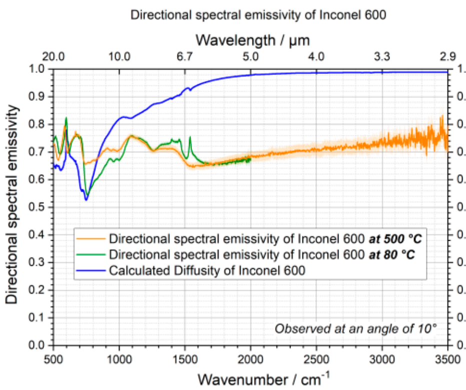

Fig. 2. Measured spectral emissivity of an Inconel 600 sample from the manufacturer of the Cs- and Na- heatpipe cavities and calculated diffusivity plotted over the wavelength.

To calculate the effective emissivity for non-isothermal blackbody conditions, the temperature profile along the cavity walls must be known. The temperature profiles were measured with a radiation thermometer and were compared with the results of the Steep 321 simulation. In an iterative process the temperature profiles in Steep 321 were adjusted until the measured and simulated temperature profiles matched. These measurements were performed at different temperatures. The difference of the isothermal and non-isothermal effective emissivity was included in the uncertainty budget. In addition, the radiation temperature corrections of the existing ammonia-heatpipe blackbody have been calculated accounting for the non-isothermal condition.

Results

Due to improved characterization methods in combination with Monte-Carlo-calculations of the effective emissivity, the uncertainties of the radiation temperature have been significantly reduced. This holds especially in the temperature range from 50 °C to 270 °C and temperatures between 270 °C and 350 °C where the uncertainties could be reduced up to a factor of 8 (see Fig. 3). The low temperature infrared calibration facility and the TC-IF have been compared by means of several transfer radiation thermometers at the wavelengths 1.6 µm and 3.9 µm and in the range from 8 µm to 14 µm and showed a very good agreement within the stated uncertainties.

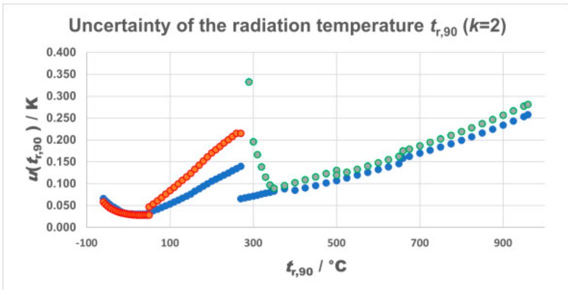

Fig. 3. Comparison of the uncertainties of the re-characterized TC-IF (blue dots) and the previous uncertainties of the ammonia- and water-heatpipe (red dots) and the Cs- and Na-blackbodies of the low temperature infrared calibration facility (green dots).

These results ensure that the calibration service can be maintained without any restrictions for customers in the coming years.

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