NIST Radiance Temperature and Infrared Spectral Radiance Scales at Near-Ambient Temperatures

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Abstract   The realization and the dissemination of spectral radiance and radiance temperature scales in the temperature range of $-50$ to $250\,^\circ\mathrm{C}$ and spectral range of $3$–$13\,\mu\mathrm{m}$ at the National Institute of Standards and Technology are described. The scale is source-based and is established using a suite of blackbody radiation sources, the emissivity and temperature of which have been thoroughly investigated. The blackbody emissivity was measured using the complementary approaches of modeling, reflectometry, and the intercomparison of the spectral radiance of sources with different cavity geometries and coatings. Temperature measurements are based on platinum resistance thermometers and on the direct use of the phase transitions of pure metals. Secondary sources are calibrated using reference blackbody sources, a spectral comparator, a controlled-background plate, and a motion control system. Included experimental data on the performance of transfer standard blackbodies indicate the need for development of a recommended practice for their specification and evaluation. Introduced services help to establish a nationwide uniformity in metrology of near-ambient thermal emission sources, providing traceability in spatially and spectrally resolved radiance temperature, spectral radiance, and background-corrected effective emissivity.
1 Introduction

NIST has a well-established measurement history of spectral radiance and radiance temperature in the spectral range below 2.5 µm [1, 2], as well as several very successful developments in near-ambient thermal infrared (TIR) radiometry. The latter include a stirred water-bath blackbody [3] and a thermal infrared transfer radiometer [4] that remain “gold standards” for their particular application. However, thermal infrared measurements have remained non-spectral, with limited temperature coverage and large uncertainties at temperatures above 75°C [5].

At the same time, many applications depend on spectral radiance and radiance temperature of reference sources in the 3–5 µm and 8–14 µm ranges, including important remote-sensing applications [6], military infrared imagers, and electro-optical systems support tasks [7]. Emerging multi- and hyper-spectral imaging technologies employed for infrared signature discrimination are adding further demands for improved capabilities in the TIR.

A facility for direct measurements of spectral directional emissivity of materials [8], developed earlier in our group as part of the Fourier Transform Infrared Spectrophotometry Laboratory, has certain capabilities for spectral characterization of blackbody (BB) sources [9]. These capabilities, along with numerous excellent contributions from other groups [10–13], have allowed us to gain the necessary experience to proceed with establishment of a dedicated thermal IR spectroradiometric facility.

The main goal of this new facility, referred to as AIRI (Advanced Infrared Radiometry and Imaging), is to adequately meet current and emerging calibration requirements of transfer standard sources and radiometers in spectral radiance and spectrally resolved radiance temperatures across the temperature range from −50°C to 1,100°C and the spectral range from 3–14 µm and beyond.

This article will briefly describe all stages of spectral radiance and radiance temperature scale realizations and transfer. These stages include the development and characterization of primary standard blackbody sources, the design and construction of a spectral comparator and precision IR pyrometers, as well as the realization of, and validated methods, algorithms, and practices for, secondary standards calibration.

2 Realization—Approach, Tasks, and Results

2.1 Nomenclature

Before proceeding with the analysis, it is necessary to briefly discuss terminology, which is somewhat specific to the thermal IR due to the non-negligible ambient background and wide use of flat-plate sources, of which the emissivity can be reasonably well determined from reflectance measurements of the coating.

The most basic unit is “spectral radiance” $L_\lambda$, which is directly related to observable radiometric values. Most of the time we will use the term “apparent radiance”