Absolute Calibration Setup for Spectral Responsivity of a NIR radiation thermometer

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A new calibration facility was setup for the absolute spectral responsivity measurement of a NIR radiation thermometer at the NIMT. The concept of the setup is to measure the absolute spectral responsivity in the wavelength range of 1550 nm to 1650 nm matching to the spectral bandpass of a NIMT radiation thermometer. The new setup uses a tuneable laser as infrared source and an integrating sphere as Lambertain source. The laser output is guided with a fibre optic into the integrating sphere equipped with an precision aperture with known effective area. The spectral radiance of the source is determined via the spectral irradiance measured by an InGaAs detector with known absolute spectral power responsivity traceable to the primary detector of the PTB. First results of the spectral responsivity calibration of the NIR radiation thermometer are presented, and estimations of uncertainty for the absolute spectral responsivity are given.

INTRODUCTION

Recently the redefinition of the new kelvin allows spectral-band primary radiometry to realise the thermodynamic temperature [1]. So far many NMIs have developed capabilities for directly measuring thermodynamic temperatures at high temperatures [2,3,4]. However some NMIs have developed capabilities for directly measuring thermodynamic temperature in the middle temperature range using a NIR radiation thermometer [5,6].

Presently a cryogenic radiometer was setup at the NIMT and established as a primary standard of the absolute radiant power in the visible region. Using a fiber optic tuneable laser, the capability can be extended to the wavelength range from 1550 nm to 1650 nm, which match with the spectral bandpass of a 1600 nm radiation thermometer already used to disseminate the ITS-90. Therefore, the realisation of the new kelvin using the NIR radiation thermometer can be done at the NIMT by developing the absolute calibration setup for spectral radiance responsivity in the wavelength range. The aim of this calibration is to assign the thermodynamic temperature to fixed-point blackbodies used at the middle temperature range as shown in **Figure 1**.

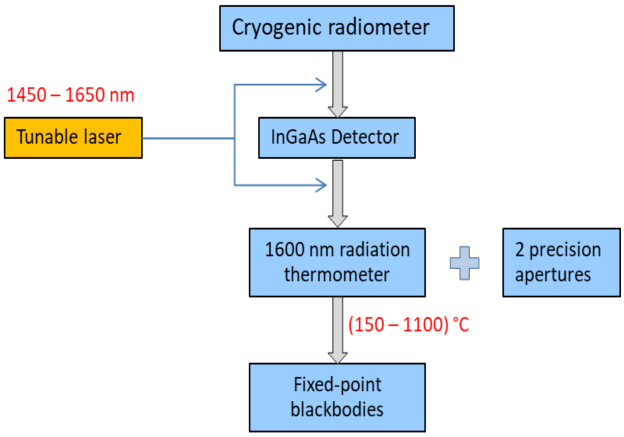

Figure 1. Traceability chain of thermodynamic temperature in the middle temperature range

CALIBRATION SETUP

A schematic diagram of the new calibration setup at the NIMT is shown in **Figure 2**. A tuneable laser is used as radiation source. By operating in constant current (CC) mode, the laser output is controlled to be stable within 0.2 %. To enable calibrating radiation thermometer, the laser radiation is introduced to an 9.75 inch integrating sphere through a 1 m fiber optics. The opening port of the sphere is equipped with a precision aperture of 10 mm in diameter due to large target spot of the radiation thermometer (3 mm). A direct substitution comparison was performed by using translation stages to move the InGsAs detector and the radiation thermometer to the measurement position. Due to the low output, the spectral radiance measured by the InGaAs detector is performed at the one half of the measuring distance of the radiation thermometer.

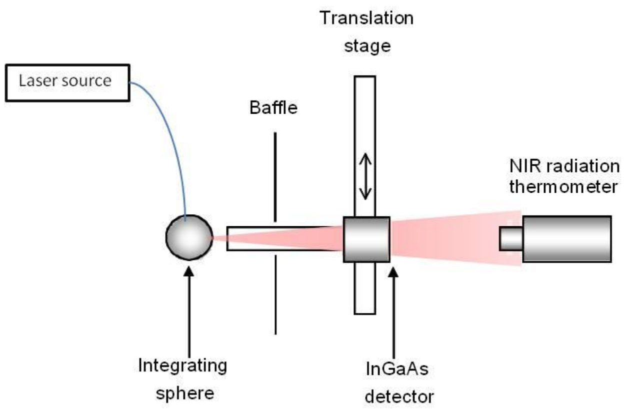

Figure 2. Calibration setup for absolute calibration for a NIR radiation thermometer

The spectral absolute radiance responsivity of the NIR radiation thermometer at each wavelength ($S_{RT}(\lambda)$) is calculated from the spectral responsivity of the InGaAs ($S_{InGaAs}(\lambda)$) by

$$S_{\mathrm{RT}}^{L} = G \cdot \frac{I_{\mathrm{ph,RT}} - I_{\mathrm{d,RT}}}{I_{\mathrm{ph,InGaAs}} - I_{\mathrm{d,InGaAs}}} \cdot S_{\mathrm{InGaAs}}^{E} \quad (1)$$

where G is the geometric factor of the measurement set up, $I_{ph,InGaAs}$ and $I_{d,InGaAs}$ is the photocurrent and the dark current of the InGaAs detector, $I_{ph,RT}$ and, $I_{d,RT}$ is the photocurrent and the dark current of the radiation thermometer.

In combination with the relative spectral responsivity measured at the spectral responsivity measurement facility [7], the absolute spectral responsivity can be determined for the whole range from 1000 nm to 2200 nm.

RESULTS AND DISCUSSION

Preliminary result for absolute spectral responsivity of the NIR radiation thermometer is graphically shown in **Figure 3**.

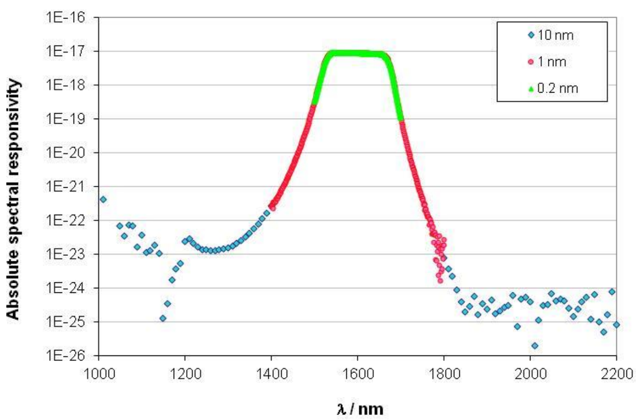

Figure 3. Preliminary measurement results for absolute spectral responsivity of the test NIR radiation thermometer

In the **figure 3**, only the calibration result at 1600 nm comes from the absolute calibration setup while the related responsivity for the whole range comes from the relative spectral responsivity facility.

The main contributions of the uncertainty for the absolute spectral responsivity of the NIR radiation thermometer are shown in **Table 1**.

Table 1. Contributions to uncertainty at 1600 nm.

Contributions of uncertainty, %	Preliminary	Provision
Homogeneity across the sphere	0.2	0.1
Stability of output signals	0.1	0.05
Calibration uncertainty	0.4	0.05
Calibration of Aperture	0.05	0.023
Distance measurement	0.1	0.05
Noise of radiation thermometer	0.005	0.005
Combine uncertainty, % (k=1)	0.47	0.13
Expand uncertainty, % (k=2)	0.94	0.26

In the present setup, the calibration uncertainty of the InGaAs detector contributes most to the overall uncertainty, which is limited to 0.94% (k=2). By improving the calibration uncertainty of the InGaAs detector to a value of 0.1%, which is straightforward, the overall uncertainty will reduce to 0.23% (k=2) corresponding to 53 mK at 150 °C, 143 mK at 420 C and 563 mK at 1100 °C.

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