Near Infrared Spectral Responsivity Realization based on Cryogenic Radiometer

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A new monochromator-based cryogenic radiometer facility has been set up at the China National Institute of Metrology. The realization of the spectral responsivity scale in near infrared spectral range is presented based on the cryogenic radiometer facility which covers spectral range from 900 nm to 1600 nm. The uncertainty of spectral responsivity of the transfer standard detector is analysed.

INTRODUCTION

Lasers are commonly used at discrete wavelengths when calibrating responsivities of photodetectors against a cryogenic radiometer (CR) [1]. However, it is complicated and expensive to set up a laser system covering continuous wide spectrum. A monochromator and broadband source method then becomes a convenient alternative to lasers [2, 3]**.** A new cryogenic radiometer facility was installed for spectral responsivity realization at NIM, which works with a monochromator and a supercontinuum white light source to increase signal level. InGaAs trap detectors were developed as transfer standards, and their spectral responsivity was calibrated against the new cryogenic radiometer facility.

MONOCHROMATOR-BASED CRYOGENIC RADIOMETER FACILITY

Facility

The configuration of the new facility is shown in Figure 1. The system consists of a light source unit, a double monochromator unit, and a transfer unit. In the light source unit, different types of sources (QTH lamp, laser and supercontinuum light source) are mounted on a linear translation stage for alignment to the monochromator entrance slit. The double monochromator unit includes a predisperser prism and a transmission grating for low stray light and high throughput. The transfer unit includes a Y shape mechanism system connected to the same incident window, two vacuum chambers for cryogenic radiometer and transfer detector respectively, and a translation stage for switching between the two chambers automatically.

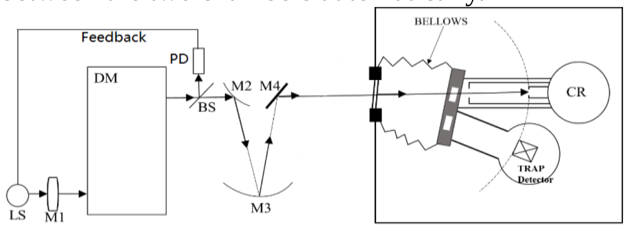

Figure 1. Schematic diagram of the NIM monochromator-based cryogenic radiometer facility for detector calibrations.

Principle

The spectral responsivity measurement process is Detector-CR-Detector type, in which transfer standard detector and cryogenic radiometer are alternatively aligned into the same optical beam. The detector output current is amplified and measured by voltmeter. The spectral responsivity of transfer standard detector at certain wavelength can be calculated as:

$$R = k_{\mathrm{ACR}} \cdot \frac{\left[\left(S_1 - S_{1\mathrm{B}}\right) + \left(S_2 - S_{2\mathrm{B}}\right)\right]/2}{P_{\mathrm{EH}}} \qquad \textbf{(1)}$$

where R is the responsivity of the transfer standard detector to be measured, P_{EH} is the effective heating power measured by cryogenic radiometer, S_1 and S_2 are the detector output current before and after cryogenic radiometer measurement, $S_{1\mathrm{B}}$ and $S_{2\mathrm{B}}$ are the background current, and k_{ACR} is the correction coefficient for the cavity absorptance, non-equivalent effect and the stray light.

Transfer standard

For near infrared spectral range, a three-element reflection InGaAs trap is used as transfer standard. The photodiodes are with a 10mm diameter circular sensitive area. The non-uniformity, polarization effect and angular dependence of the InGaAs trap detector are measured to ensure its performance as a transfer standard.

Source power stability

For the supercontinuum white light source, the power stability is improved significantly by an external power feedback unit. The power stability measurement, with a standard derivation of roughly 0.01%.

RESULTS

Under the condition of supercontinuum source and monochromator, and an optical power level of ~20μW at 1550nm, power responsivity measured by cryogenic radiometer is shown in Figure 2, with a relative standard derivation of less than 0.01%.

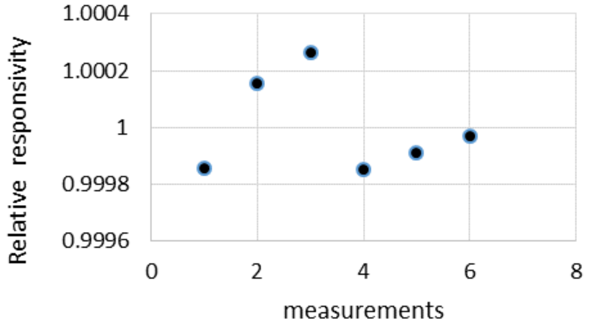

Figure 2. Power responsivity repeatability of transfer standard against cryogenic radiometer at 1550nm.

Spectral responsivity of the InGaAs trap detector calibrated against cryogenic radiometer is shown in Figure 3.

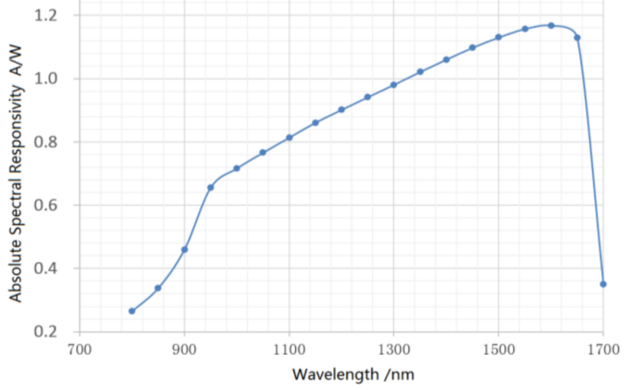

Figure 3. Spectral responsivity measurement result of InGaAs trap detector based on monochromator

Uncertainty induced by stray light, wavelength accuracy, bandwidth effect, geometrical effect, and polarization effect are evaluated. To evaluate uncertainty induced by supercontinuum light source, an InGaAs trap detector is calibrated directly against the cryogenic radiometer using laser and supercontinuum light source both at a certain wavelength. The responsivities of InGaAs trap detector at 950nm for the two types of sources are measured and analysed.

Measurement uncertainty budget of responsivity of the InGaAs trap detector at 1550nm is shown in Table 1.

Table 1. Uncertainty of responsivity of the InGaAs trap detector at 1550nm

Source	Uncertainty (%)
Cavity absorptance and non-equivalence effects	0.01
Radiometer external electrical calibration	0.01
Beam geometrical effect	0.01
IV amplifier and Voltmeter	0.01
Polarization effect	0.01
Bandwidth effect	0.01
Wavelength accuracy	0.01
Repeatability	0.01
Combined standard uncertainty	0.03

CONCLUSION

A new cryogenic radiometer facility was set up at NIM working with monochromator and a supercontinuum white light source. As a transfer standard, performance of an InGaAs trap detector has been characterized. Spectral responsivity is realized and maintained by transfer standard covering spectral range from 900nm to 1600 nm.

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