Infrared Radiometry at LNE: characterization of a pyroelectric detector used for relative spectral responsivity measurement

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Abstract. Measurement facilities for detector calibration in the Infrared on the spectral range 1µm-14µm are currently setting-up. Four techniques are developed: Monochromator, Laser, Fourier Transform spectrometer and Blackbody. Characteristics of the measurement set-ups are presented. The traceability to SI units is showed. Result of the characterization of a pyroelectric detector as well as the preliminary results of the comparison between the different techniques on near IR detector are presented too.

Introduction

LNE, Laboratoire National de Métrologie et d'Essais, as the French National Metrology and Testing Laboratory is developing a new platform for Infrared and Laser radiometry. Laser facility has been built and offers calibration services over a wide range of power and wavelengths in CW or pulse mode. UV, visible and near Infrared (NIR) radiometry calibration services are also available. The laboratory is now in the process of extending the spectral range to Mid IR and Far IR up to 14µm to address the industrial needs in domains such as temperature measurement using thermal camera. Calibration techniques used, traceability to SI units and the main result concerning the characterization of a flat response detector are described in this paper.

Measurement techniques

Measurement set-ups based on four different techniques have been recently developed [1-2]. The aim is to compare detector calibration results in order to achieve a good agreement between these complementary techniques. They are:
- **Monochromator based techniques:** the set-up uses a 460mm focal length single monochromator equipped with a set of interchangeable gratings and filters order. The source is either a Tungsten-Halogen lamp or a 900°C Blackbody cavity. The output from the monochromator is focused onto the reference detector or the detector under calibration using gold plated mirrors. Detector signals are measured with lock-in amplifier.
- **Laser based technique**: the laboratory is equipped with a set of CW IR lasers (NdYag, HeNe and CO2) with wavelength ranging from 1.06µm to 10.6µm. The output power is measured using a power meter that we have developed [3].
- **Fourier Transform spectrometer based technique**: a Brucker® type 55 spectrometer is used as a reference instrument with the step-scan analysis technique. Sources include a Tungsten-Halogen lamp and a globar lamp. The spectral range is 1µm-20µm.
- **Blackbody based technique**: the output of a Blackbody cavity of a known temperature is used as a reference source. Combination of the output spectral power distribution and the transmission of a well characterized interference filter gives access to a known monochromatic beam irradiance.

Traceability

Calibration performed using the monochromator based technique is traceable to the cryogenic radiometer of LNE-INM through a silicon photodiode. The Hamamatsu® type 1337 is calibrated on the spectral range 400nm-1100nm. This detector is used to calibrate a NIR detector such as Ge or InGaAs on the spectral range 800-1700nm using this procedure:
- The relative spectral sensitivity of the NIR detector is measured using a reference pyroelectric detector
- Then absolute sensitivity of the InGaAs detector is determined using the Si detector at wavelengths corresponding to the overlapping wavelength range of the two detector types.

The two measurements are combined to get the spectral sensitivity of the InGaAs over the entire spectral range.
Mid IR and Far IR detectors are calibrated using the same procedure in a cascade traceability scheme.
This traceability scheme applies also to the Fourier Transform spectrometer based technique.

Laser based technique calibration is traceable to the electrical units. The power meter used as a reference is a thermal cavity. Temperature increase due to laser beam absorption is related to the same temperature increase due to the electrical power dissipated by a resistor wrapped around the cavity.

Blackbody based technique is traceable to the temperature scale and to radiometry through the measurement of the transmission of the interference filters.

The traceability scheme is summarized in table 1.

Technique	Traceability
Monochromator	Cryogenic radiometer Cascade calibration scheme starting with a Si detector
Laser	Electrical power
Fourier Transform spectrometer	Cryogenic radiometer Cascade calibration scheme starting with a Si detector
Blackbody	Temperature and radiometry

Table 1: Traceability scheme

Results

IR radiometry calibration capability of the laboratory relies on the use of a pyroelectric detector chosen for the wavelength non-selectivity . The schematic of the detector is shown on figure 1. The detector consists in a 60° cone shape pyroelectric sensor put in a laboratory-made housing with a 12mm diameter input aperture which can be fitted with interchangeable windows and vacuum pumped.

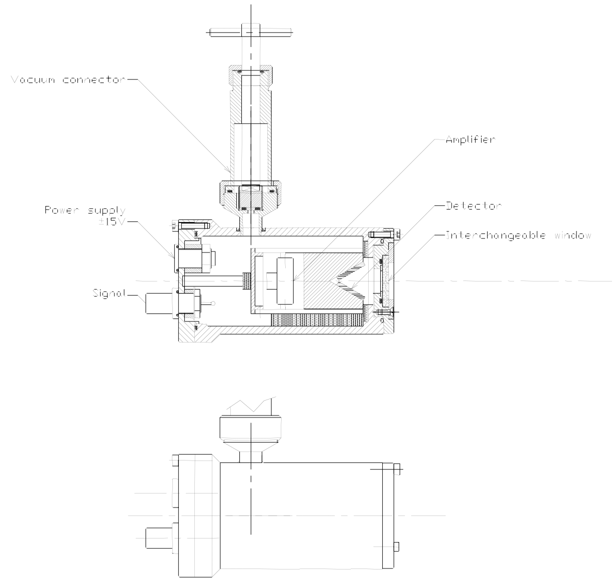

Figure 1: Schematic of the pyroelectric detector

The detector is characterized for two parameters: spatial sensitivity [4] and spectral response flatness. Reflectance measurement of the sensitive area is performed to evaluate the spectral response flatness. This is done by measuring the total reflected power with an integrating sphere. The result is shown on figure 2 on the spectral range 2µm-12µm.

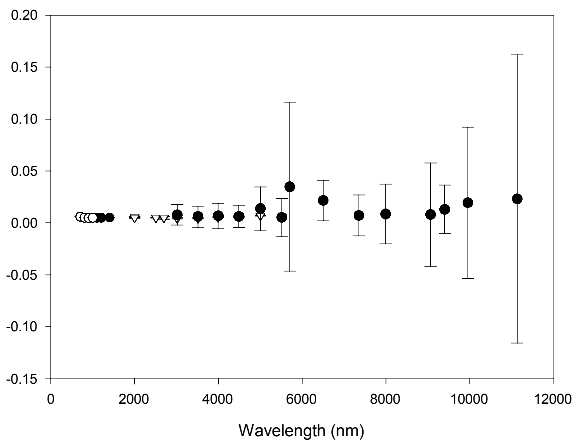

Figure 2: Spectral reflectance of the pyroelectric detector

It has been found that spectral sensitivity of this pyroelectric detector is nearly wavelength independent. Increase of the reflectance around 6µm is due to fluctuation in ambient air characteristics. Additional measurements will smooth-up this feature.

In order to validate the results obtained with the different techniques, we have performed measurement on Si and InGaAs detectors using the monochromator and the laser based techniques. Agreement between the two techniques are found to be better than 1% which is below the uncertainty level for monochromator radiometry (1.5%) and for laser radiometry (2%).

Conclusion

Infrared or Laser techniques used to characterize a new pyroelectric detector has been described and the scheme of validation processes outlined.

Works are currently still under way to extend the spectral range for the monochromator and laser based techniques comparison and for monochromator and FT spectrometer based techniques comparison

Therefore future work will concentrate on the optimization of the techniques applied, and on the investigation of the measurement protocols differences.

References

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