The establishment of the NPL infrared relative spectral responsivity scale using cavity pyroelectric detectors.

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Abstract. The establishment of a relative spectral responsivity scale requires the availability of a detection system with a known relative spectral responsivity. NPL has addressed this requirement by designing a new detector with a measurable relative spectral response profile in the 800 nm to 25 µm wavelength range. The new detector is based on a large area pyroelectric detector which is prepared for NPL by John Lehman of NIST Boulder. The large area pyroelectric detector is enclosed in a removable gold-coated hemispherical reflector. The novel feature of the new cavity pyroelectric detector is that the hemispherical reflector is removable. This makes the relative spectral responsivity of the new detector self-calibrating. A number of these cavity pyroelectric detectors were fabricated. Three have been selected and are currently being used as the primary standards for the establishment of the NPL relative spectral responsivity scale in the infrared. The presentation will summarize the design and performance characteristics of the new NPL cavity pyroelectric detectors and will demonstrate how they are being used to establish the NPL relative spectral responsivity scales in the infrared.

Introduction

A number of authors reported the assembly of cavity pyroelectric detectors based on a reflective hemispherical reflector mounted above a large pyroelectric detector [1, 2]. Some of these devices were designed to be used with lasers and their design if far from ideal when used with non-collimated radiation over a wide spectral region from sources such as monochromators. For example the design of the cavity pyroelectric detector reported by Day et al. [1] assumes that the coating of the pyroelectric detectors has a dominant specular reflection. This design was copied in the cavity pyroelectric detectors reported by Nettleton et al [2]. The aim of both these designs was to reduce the variation in the relative spectral responsivity of the pyroelectric detector by the addition of the reflective hemisphere so as to make it insignificant over the range of wavelengths of interest. Boivin reported an electrical substitution radiometer incorporating a hemispherical reflector [3]. The aim of his work was to reduce the uncertainty associated with the measurement of the absorbance of the black coating deposited on his thermal-detector-based radiometer. However, his work still required the measurement of the spectral absorbance of a witness sample.

The purpose of this paper is to report the construction of new design of Cavity Pyroelectric Detector (CPD) which is modular and allows the "self-calibration" of the relative spectral responsivity of this detector. Over thirty of these detectors have been assembled by John Lehman of NIST Boulder on behalf of NPL. The aim of this paper is to discuss the performance of these detectors, as well as the way they are being used to establish the NPL relative spectral responsivity scale in the 0.8 µm to 25 µm wavelength range.

Results

The design of the new NPL cavity pyroelectric detectors was completed in 1996. They are being referred to as the new detectors to distinguish them from a previous design [2] which was essentially a copy of the design reported by Day et al [1]. The new NPL CPDs have a modular design, as can be seen from figure 1. The modular design allows components to be easily interchanged and provides the means to determine the relative spectral responsivity of these detectors without the need to characterise witness samples. Each CPD incorporates a pyroelectric detector module designed and assembled on behalf of NPL by John Lehman of NIST Boulder. The pyroelectric detector incorporated in the NIST pyroelectric detector module has an 8 mm diameter active area and is based on a 10 mm diameter LiTO$_3$ crystal which is approximately 50 µm thick. Metal electrodes are deposited on both the surfaces of the LiTO$_3$ crystal and one side is coated with a gold-black coating [4]. This pyroelectric detector module is housed in a larger cylindrical housing made of anodized Aluminium so that the plane of the detector is at an angle of 20^o to the axis of the CPD cylindrical housing, as shown in Figure 1. Furthermore the centre of the pyroelectric crystal lies on the axis of the CPD cylinder (see Figure 1). Finally a reflective hemisphere with a 20 mm diameter is mounted on top of the pyroelectric detector so that the centre of the pyroelectric detector coincides with the centre of the reflective hemisphere. The reflective hemisphere has a 3 mm diameter aperture which is located so that the centre of this aperture coincides with the axis of the cylindrical body. All gold-coated reflective hemispheres used during the course of this work were nominally identical.

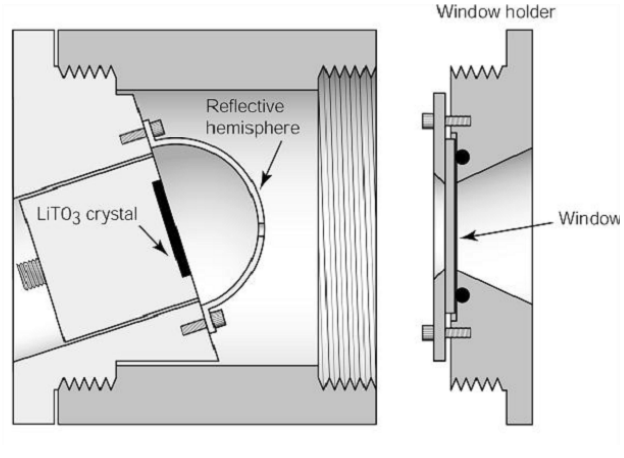

Figure 1. Then new NPL cavity pyroelectric detector.

A total of 35 CPDs have been assembled and studied over the period from 1998 to 2003. The gain G(λ) [5] as a function of wavelength was measured for the majority of these CPDs. Figure 2 shows the spectral responsivity of a 3 mm by 3 mm Pt-black-coated pyroelectric detector measured in the 0.8 µm to 25 µm wavelength range relative to both the CPD75 and pyroelectric detector 75 i.e. against the same pyroelectric detector, with and without a gold-coated reflective hemisphere. These plots are typical for the pyroelectric detectors with the very best quality gold-black coatings. Division of the two traces shown in Figure 2 gives the relative spectral responsivity of CPD75 relative to pyroelectric detector 75. This ratio is also the gain G(λ) resulting from the addition of the reflective hemisphere onto the pyroelectric detector. The values of G(λ) as a function of wavelength for CPD75 are shown in Figure 3. Figure 3 shows that the gain is greater than unity for all wavelengths. This confirms that the gold-black coating deposited on pyroelectric detector 75 is not perfect and that the addition of the hemisphere redirects some of the radiation reflected by the gold-black coating back to the gold-black coating thus enhancing its effective absorbance and therefore its response. Moreover Figure 3 shows that G(λ) increases monotonically with increasing wavelength. This indicates that the reflectance of the gold black coating gradually increases with wavelength (assuming the effective reflectance of the reflecting hemisphere is not a function of wavelength). This observation is in agreement with measurements of the reflectance of all good quality gold-black coatings [6].

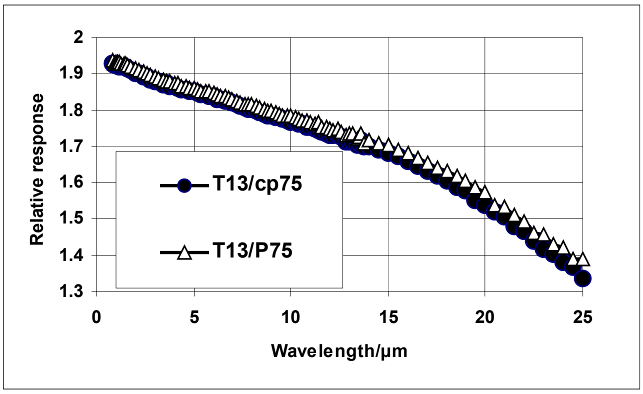

Figure 2: Spectral response of a 3 mm by 3 mm Pt-black-coated pyroelectric detector measured in the 0.8 µm to 25 µm wavelength range relative to both CPD75 and pyroelectric detector 75

All parameters of the cavity pyroelectric detectors were fully evaluated and will be presented at the meeting. These include their relative and absolute spectral responsivities, spatial uniformity of response, linearity of response, temperature coefficient of response, temporal response, long term stability and noise characteristics.

The presentation will also describe how the relative spectral responsivity of a cavity pyroelectric detector is estimated from the knowledge of its gain G(λ) as a function of wavelength. It will also deal with the uncertainty budget developed to estimate the uncertainty of the NPL infrared relative spectral responsivity scale.

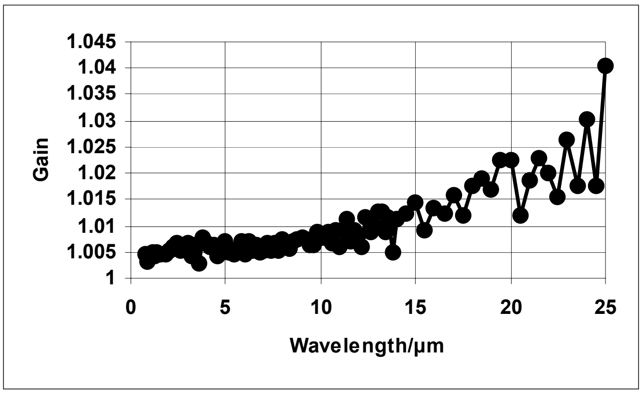

Figure 3: Gain in the 0.8 µm to 25 µm wavelength range measured when a reflective hemisphere was added to pyroelectric detector 75.

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Reference

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