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Infrared Physics & Technology 46 (2005) 339–349
INFRARED PHYSICS & TECHNOLOGY
www.elsevier.com/locate/infrared

Reversible ageing effects in cryogenically cooled infrared filter radiometers

E. Theocharous [a,*], G. Hawkins [b,1], N.P. Fox [a]

[a] Optical Radiation Measurement Team, National Physical Laboratory, Teddington TW11 OLW, UK
[b] Infrared Multilayer Laboratory, Department of Cybernetics, The University of Reading, Whiteknights, Reading, Berkshire RG6 6AY, UK

Received 6 May 2004
Available online 10 July 2004

Abstract

In this paper we report the observation of drifts in the responsivity of cryogenically cooled InSb detector-based infrared filter radiometers which have very strong wavelength dependence. These drifts can result in the increase or decrease of the response of the filter radiometers by over 5%. The origin of these variations was investigated and was shown to arise due to a thin film of ice formed on the multi-layer bandpass filter used to define the spectral response of the filter radiometer. The thin layer of ice interacts with the characteristics of the filter (which itself consists of a number of thin layers) and modifies the filter spectral transmission thus modifying the response of the filter radiometer of which the filter is part of. These observations are particularly relevant to space instruments which use infrared filter radiometers for earth observation. Debris from the spacecraft engines is known to accumulate on cold surfaces of instruments carried on board. The deposition of this debris on cold filters can modify the spectral response of the instruments, which use these filters to define a spectral response.

Keywords: Infrared; Filter radiometer; Cryogenically cooled detectors; Ageing; Ice; Space instruments

1. Introduction

Infrared radiometric applications require the use of infrared detection systems whose characteristics are stable with time [1]. Theocharous and Fox [2] reported gradual reductions in the spectral response of infrared detectors cooled to 77 K in some well-defined wavelength regions. These regions coincide with the absorption bands of solid ice [3] so the origin of these bands was assigned to the deposition of a thin film of solid ice on the surface of the cryogenically cooled detector. The film of ice spectrally filters radiation incident on the detector so radiation whose wavelength coincides with the absorption bands of ice is absorbed

* Corresponding author. Tel.: +44-20-8943-6977; fax: +44-20-8943-6935.
E-mail addresses: theo.theocharous@npl.co.uk, et@npl.co.uk (E. Theocharous), g.j.hawkins@reading.ac.uk (G. Hawkins).
[1] Tel.: +44-118-378-8224; fax: +44-118-378-8220.

1350-4495/$ - see front matter
doi:10.1016/j.infrared.2004.06.002

by the ice, giving rise to a reduction in the apparent response of the detector at these wavelengths. The magnitude of these absorption bands was found to increase slowly with time, which suggests that water/moisture present inside the dewar vacuum gradually migrates onto the surface of the detector where it builds up with time as solid ice. When the detector was allowed to warm up, water appeared to migrate to other parts of the dewar because, when the detectors were cooled again to 77 K, the absorption due to the ice-bands was significantly smaller but gradually increased with time [2]. The magnitude of the "ice-bands" decreased slightly after the dewar vacuum was evacuated. However, the "ice-bands" were completely eliminated after the dewar was simultaneously baked at around 55 °C whilst being evacuated. Unfortunately the bands gradually reappeared and their magnitude grew larger over the period of a few weeks [2]. This has been attributed to the gradual migration of water into the dewar vacuum. The migration is believed to be via the rubber O-rings used to seal the dewar window and the window holder [4]. In some dewar types which use Indium O-ring seals, these bands take considerably longer to develop.

NPL has developed a number of infrared filter radiometers for use in a number of applications including the measurement of the absolute spectral radiance of low temperature sources and the determination of the radiant temperature of ambient temperature blackbody sources [5]. The filter radiometers consist of cryogenically cooled infrared photon detectors such as photovoltaic InSb and photoconductive HgCdTe detectors with a bandpass filter transmitting over a well-defined wavelength region, mounted on the cold shield of each detector. Infrared filter radiometers whose response peaks at 2.4, 3.7, 4.7 and 10.3 μm have been assembled.

Whilst calibrating the spectral irradiance responsivity of the 3.7 μm filter radiometer significant drifts were observed in the measured response as a function of time. These drifts were not general but at specific wavelengths. Further confirmation for the existence of these drifts was provided when this particular filter radiometer was used to monitor the spectral radiance of a Gallium fixed point blackbody at its melting point using the AMBER facility [5]. Although the radiance of the Gallium blackbody was shown to be stable when other filter radiometers were used, the output from the 3.7 μm filter radiometer was suggesting that the radiance of the Gallium blackbody was decreasing by approximately 0.1% per day.

The purpose of this paper is to describe our investigation to identify the source of the drifts in the response of the 3.7 μm filter radiometer and to explain the process which generates the observed drifts in its spectral response.

2. Method

Fig. 1 shows a schematic diagram of a 3.7 μm filter radiometer. It is based on a 7 mm diameter photovoltaic InSb detector mounted on the cold finger of a standard liquid Nitrogen cooled side-looking dewar. The cold shield of the dewar was modified to accept the 3.7 μm interference bandpass filter which was specially manufactured for NPL by the Department of Cybernetics of the University of Reading, UK. This means that the bandpass filter is operated at temperatures approaching 77 K and is thus an effective cold filter. Cold filters are a well established way of improving the detector noise equivalent power (NEP) over specific wavelength regions by reducing the shot noise due to the thermal background signal, which is normally the dominant noise component in infrared photon detectors [6,7]. A 1 mm thick sapphire window with a 0.1° wedge angle (to avoid interference fringes when used with laser radiation) is used to maintain vacuum and a 4 mm diameter thin-film aperture is pressed against the sapphire window. This aperture is used to define the effective area of the filter radiometer. The absolute spectral irradiance response of these radiometers is calibrated against transfer standard detectors which are themselves calibrated against the NPL primary standard cryogenic radiometer [8]. Because the filter radiometer is calibrated and used in an irradiance mode, knowledge of the area of the thin film aperture is not required. The absolute spectral irradiance responsivity of the 3.7 μm filter radiometer measured using the NPL