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A comparison of the performance of a photovoltaic HgCdTe detector with that of large area single pixel QWIPs for infrared radiometric applications

Evangelos Theocharous [a,*], Juntaro Ishii [b], Nigel P. Fox [a]

[a] National Physical Laboratory (NPL), Teddington TW11 OLW, UK
[b] National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba Central 3, Tsukuba, Ibaraki 305-8563, Japan

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Abstract

The performance of two single pixel, large area quantum well infrared photodetectors (QWIPs) were compared with that of a commercially available 2 mm diameter photovoltaic (PV) HgCdTe detector. Parameters which were compared include the absolute spectral responsivity, noise equivalent power (NEP), spatial uniformity of response, non-linearity and stability. Both detector types were shown to have sufficiently high spectral responsivity and D^* values to satisfy a number of applications in infrared radiometry when operated at 77 K. However, the spatial non-uniformity of response of both QWIPs examined was unacceptably high. Furthermore the spatial uniformity of response of the same detectors was shown to be strongly dependent on the state of polarisation of the incident radiation as well as also exhibiting some dependency on wavelength. The spatial uniformity of response of the PV HgCdTe detector was shown to be very poor due to the very low shunt resistance of this detector. However, it exhibited no polarisation dependency and only a slight dependency on wavelength for wavelengths below 5 μm. Neither detector type could be considered for high accuracy radiometric applications in their current form.
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1. Introduction

A previous evaluation of infrared detectors for radiometric applications has shown that the performance of commercially available detectors is far from ideal, for wavelengths longer than 5 μm [1]. For example, large area (up to 4 mm × 4 mm active area) photoconductive (PC) HgCdTe detectors exhibit very large (>20%) spatial non-uniformities in their response [1] whereas thermal detectors such as pyroelectric detectors based on non-hygroscopic crystals have relatively low specific detectivity (D^*) values. Extrinsic photoconductors require cooling to well below 77 K and are not

* Corresponding author. Tel.: +44-20-8943-6977; fax: +44-20-8943-6935.
E-mail address: theo.theocharous@npl.co.uk (E. Theocharous).
URL: http://www.npl.co.uk.

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available with sufficiently large active areas [2]. Additionally, the response of PC HgCdTe devices has been shown to be non-linear at relatively low levels of incident photon irradiance [3]. If the operating temperature of the detector is restricted to 77 K or higher, then PV HgCdTe detectors offer the highest D^* values in the 8–12 μm spectral region. However, PV HgCdTe detectors whose response extends to 12 μm are currently available with active areas upto 2 mm diameter which is smaller than the active areas required for the majority of applications in infrared radiometry [1]. QWIPs [4] are now well established for use in state-of-the-art cooled thermal imaging systems. For fundamental optical measurement applications, for example infrared spectral responsivity standards [5], it is normal (and sufficient) to use a single element detector [1]. Some QWIPs are made from layers of $GaAs/Al_xGa_{1-x}As$ which can be mass grown on large substrate wafers. The fabrication of these materials is well established and promises to deliver large area, single pixel photodetectors with high spatial uniformity of response. The purpose of this paper is to report the results of the comparison of the performance of a 2 mm diameter commercially available PV HgCdTe with that of two 5 mm × 5 mm active area single pixel, nominally identical, QWIPs which were commissioned by NPL and manufactured by QWIP Technologies, USA. For convenience the two QWIPs will be designated QWIP-A and QWIP-B throughout this paper. Preliminary results of the evaluation of one of these QWIPs (QWIP-A) have been reported elsewhere [6].

2. Detector characterisation facilities and method

The spectral response of the large area single pixel QWIPs commissioned by NPL peaked at around 8.5 μm. The grating design and polish was chosen in order to minimise the sensitivity of the detectors to the state of polarisation of the incident radiation and to support optimisation of the D^* and spatial uniformity of response of the QWIPs. According to the manufacturers of the QWIPs, the detail design of these detectors can be found in Ref. [7]. The performance of QWIPs improves as their operating temperature is reduced below 77 K [8]. While such reduced temperatures can be readily achieved with two stage mechanical coolers, they are relatively expensive and can add some complications for evaluation purposes. For economy and experimental convenience both QWIPs were mounted on the cold fingers of liquid nitrogen-cooled cryogenic dewars for operation at 77 K. The side-looking dewars were fitted with ZnSe windows whose surfaces had anti-reflection coatings optimised for the 8–12 μm wavelength range. The windows had a small wedge angle (≈0.1°) to prevent interference effects. The dewars were also fitted with a cold field stop which limited the detector field of view (FOV) to a ±15° angle in order to limit the noise contribution due to the thermal background radiation [2,9].

The PV HgCdTe detector was purchased as a standard off-the-shelf product from Infrared Associates, USA. The detector (model number MCT-13-2.0PV) was fitted in a side-looking liquid nitrogen-cooled dewar (model number KR-323) which was also fitted with a wedged ZnSe window. Both faces of this window were also coated with anti-reflection coatings optimised for the 8–12 μm spectral region. The detector had a 2 mm diameter active area and the literature supplied with this detector specified the detector FOV as being 60°. A dedicated trans-impedance amplifier supplied by the detector manufacturer was used to amplify the output of this detector but its performance was found to be poor so it was replaced by another trans-impedance amplifier specially assembled for NPL by Vinculum Services of Royston, UK. The Vinculum Services amplifier was based on a Burr Brown OPA627 integrated circuit which has a very low input noise voltage (the manufacturer specifies a value of 15 $nV\,Hz^{-1/2}$ at 10 Hz) so it provides optimum performance when used with PV detectors of low shunt resistance such as the PV HgCdTe detector [2].

The performance of the QWIPs and PV HgCdTe detector was compared using the NPL infrared detector characterisation facilities [10]. These include the NPL infrared spectral responsivity measurement facility, spatial uniformity of response and linearity characterisation facility. The NPL infrared spectral responsivity measure-

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