Drift in the absolute responsivities of solid-state photodetectors at two NMIs

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Abstract.

The advent of cryogenic radiometers for the determination of detector responsivity at single wavelengths has reduced the uncertainties in such calibrations by an order of magnitude if not more (Fox et al 1990, Nield et al 1998). However, maintaining such uncertainties also relies upon the artifacts being stable over time to better than the uncertainty itself.

The stability of sets of radiometric quality (silicon) photodiodes has been followed for almost a decade in two different NMIs. The silicon photodiodes are invariably Hamamatsu S1337 or S6337 in both single and multi-element trap detector configurations. The trap configurations include 3-element (S1337) and 5-element (S1337) reflection traps as well as 4-element (S6337) transmission traps. In all cases, unless otherwise stated, the responsivities were measured at laser wavelengths using the cryogenic radiometers at the two NMIs.

At MSL the silicon photodiodes were initially stored with dust covers within the cryogenic radiometry laboratory. After observing the presence of NaCl contamination on the surfaces of some of the photodiodes within the trap detectors the storage and use of them was modified to holding them within a bell jar during periods when not in use. At NMIA the photodiodes have routinely been stored with dust caps within dry air purged containers, in addition the facility is both temperature and humidly controlled, unlike at MSL where only the temperature is controlled. Even with this handling visible changes in the front surface of the diodes does occur and it is the influence of this along with other possible more subtle changes in the detectors we are attempting to understand through this nascent collaboration.

For the silicon photodiodes above 600 nm, no responsivity drift was observed for any of the configurations. However, at shorter wavelengths, the responsivity decreases significantly with a drift rate that increases in magnitude as the wavelength decreases reaching almost -0.04 % per year near 476 nm (Figure 1). The drift rate appears to be least for the Hamamatsu S1337 single plane photodiodes that have received minimal exposure to radiation. For these devices, the annual drift rates at 476 nm vary between (-0.02 and -0.04) % per year depending on the particular photodiode while the average drift rate for the collection of these photodiodes was -0.03 %per year. The drift rates for the three different trap detector configurations are very similar and reach about -0.035 % per year at 476 nm.

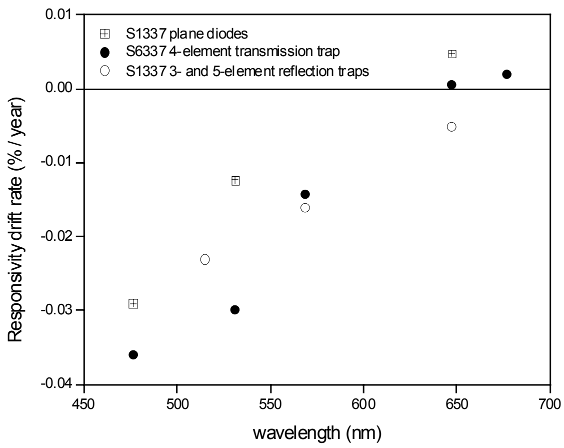

Figure 1. Responsivity drift rate, as a function of wavelength, for various silicon detectors. In the case of the NMIA detectors these have been observed over a 10 year period, the drifts at MSL have been followed for the past six years.

In each case, the trends are monotonic with similar slopes; similar drifts were observed in the detectors used in the comparison of cryogenic radiometers (Goebel et al 1999). In addition, slightly greater drift is observed for the 5-element trap detectors than the 3-element traps, this may be due to the extra exposure suffered by these devices in their use in deriving response scales in the ultraviolet and near infrared region whereas the 3-element devices have been restricted to direct calibrations in the visible region against the cryogenic radiometer.

More recent measurements at NMIA on single element diodes indicate that this behaviour extends into the near-UV region to at least around 325 nm. Indeed, at 351.1 nm calibrations of the detectors at MSL drifts over the short term of the order of -0.3% per year in reflection traps built in 1999 have been observed. However a 5-element reflectance trap detector recently fabricated from a different batch of Hamamatsu S1337 photodiodes has shown an unusually small drift of -0.005%over a one year period at this wavelength (that is within the level of measurement uncertainty) in spite of having had considerable exposure to both laser and incoherent sources.

Over a four year period, 3- and 5-element reflection traps show drifts approximately –0.02 %per year at 514.5 nm (Figure 2).

Although the optical quality, uniformity and surface characteristics of the S6337 photodiodes used in the 4-element transmission trap were not quite as good as S1337 photodiodes, their overall performance and drift behaviour are similar.

All types of silicon detector configuration appear to undergo an initial rapid decrease in responsivity over the first few years and then settle to a lower drift rate thereafter. This behaviour is not dissimilar to that reported by Werner (Werner, 1999) where Hamamatsu photodiodes were shown to drift with exposure UV laser radiation.

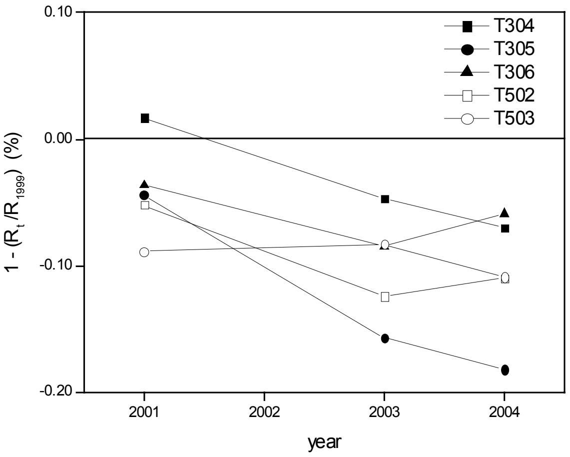

Figure 2. Short-term (5 years) responsivity drift rate at 514.5 nm for various 3- and 5-element reflection traps. Relative uncertainties for a given calibration at any year are of the order of 0.02 %.

These results can be compared with those for InGaAs photodiodes (Anadigics, 35PD10M), calibrated and monitored at NMIA, where, for example, the responsivity of a 35PD10M decreased by 0.45 % from 0.9735 A/W to 0.9692 A/W over the past seven years giving a drift rate of about 0.06 % per year. A collection of similar windowed and windowless photodiodes suffered a decrease in responsivity of about (0.2 – 0.5) % over the past seven years giving an average annual drift rate of the order of (-0.03 to -0.07) %. InGaAs photodiodes appear more prone to long-term responsivity drift compared with silicon photodiodes.

Acknowledgements

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