High efficiency five-element trap detector with low optical losses

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We have constructed a five-element reflectance trap detector consisting of commercial n-on-p type 10 x 10 mm UVG100 photodiodes. The response uniformity of the trap at visible wavelengths is mostly at a level of ±100 parts per million (ppm) whereas its estimated reflection losses are below 1 ppm throughout most of the visible spectral range. We have measured the linearity of the trap detector as well as its spectral responsivity. The properties of the trap suggest it could be used as a reference detector in photometric and radiometric calibrations.

INTRODUCTION

Most of the photodiode-based reference detectors require calibrations traceable either to a Cryogenic Radiometer (CR) or a Predictable Quantum Efficient Detector (PQED) [1-3]. The need for regular calibrations of conventional silicon detectors based on p-n junction photodiodes (e.g S1337 by Hamamatsu) comes, among other causes, from their instability caused by short-wavelength radiation and from moisture penetration [4]. UVG-series silicon photodiodes by Opto Diode Corporation are claimed to have no surface recombination and 100 % internal quantum efficiency in the spectral range from 330 nm to 660 nm [5]. We have constructed a trap detector based on these photodiodes to study its properties in terms of possible usage in photometric and radiometric applications. Such a trap could be applied as an absolute detector for calibration of photometers despite the reduced quantum efficiency above 660 nm, i.e. at the tail of the $V(\lambda)$ curve.

DESIGN OF THE DETECTOR

The trap detector is constructed from five selected UVG100-type photodiodes. The first four are aligned under 45° and the last one at 0° angles relative to the incident beam (see figure 1). In such a configuration, the beam encounters 9 reflections before exiting the trap and theoretically has no polarization dependence. The angular alignment of the last photodiode can be fine adjusted to match the paths of the leaving and incoming beams. The total beam path in the trap is approximately 95 mm. The field of view is estimated to be ±2 degrees for a 3 mm diameter beam. Also, the holder of the photodiodes can be angularly adjusted relative to the front plane of the trap housing. This allows a good alignment of the trap relative to its housing with an installed radiometric aperture. The photodiodes are connected in parallel and operated without bias voltage.

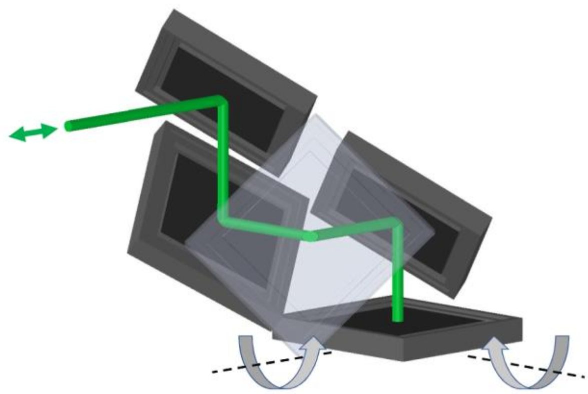

Figure 1. Beam path in the trap detector with five photodiodes. The last photodiode can be fine adjusted to match the incoming and leaving beams.

CHARACTERIZATION

Uniformity

The non-uniformity of the trap was measured at the wavelengths of 490 nm, 680 nm, 750 nm and 800 nm. As the photodiodes are tailored for the UV range, the uniformity is expected to be better at shorter wavelengths. Figure 2 shows the responsivity uniformity at 490 nm. The measured deviations are within ±75 ppm in the central region with a diameter of 6 mm. At 680 nm, 750 nm and 800 nm the non-uniformity throughout the same central region stays within ±100 ppm, ±100 ppm and ±250 ppm, respectively.

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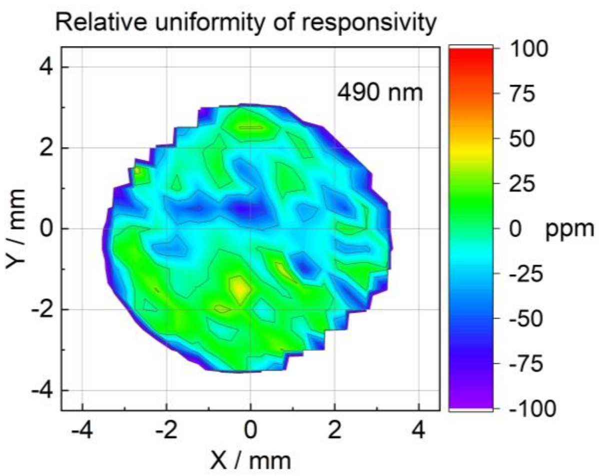

Figure 2. Relative spatial deviation of the responsivity of the trap detector at 490 nm.

Reflectance

Reflectance losses of the trap detector (figure 3) were estimated based on the single-photodiode reflectance curve provided by the manufacturer [5]. The estimated reflectance of the trap has a sharp decline from 360 nm to 500 nm having a change of reflectance from about 3500 ppm down to 0.005 ppm. We confirmed a few percent lower reflectance of a single photodiode at selected wavelengths of 532 nm, 680 nm, 740 nm, 780 and 800 nm. At 490 nm, the measured reflectance was higher than reported by the manufacturer. Despite the small discrepancies, the reflection losses of the trap were confirmed to be below 1 ppm throughout most of the spectral range of interest.

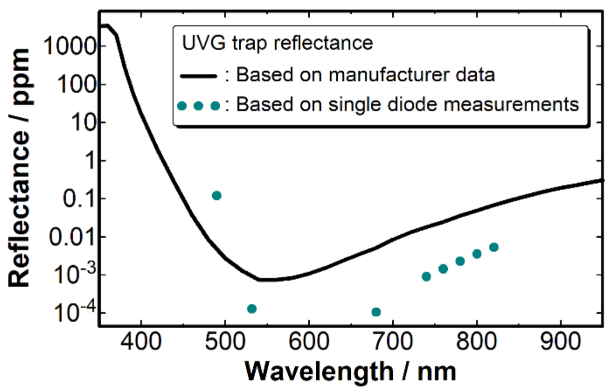

Figure 3. Estimated reflectance of the 5-element trap detector based on the single photodiode reflectance provided by the manufacturer (line). The dots show the values based on our measurements on a single photodiode.

Nonlinearity

The nonlinearity of a single UVG100 photodiode and of the trap detector was measured at 490 nm and at 680 nm, respectively. The beam diameter was about 1 mm FWHM at both wavelengths. The photocurrents were recorded at three different power levels and were compared with the photocurrents of a well-characterised reference trap detector. Up to the level of 100 µA, limited by the dynamic range of the current-to-voltage converter, both the single photodiode and the trap detector showed no nonlinear behaviour. We tested the photodiodes with -5 V bias as well. No changes were observed between biased and non-biased measurements.

Responsivity

We have carried out preliminary responsivity measurements relative to two calibrated trap detectors at wavelengths of 405 nm, 487 nm, 528 nm and 680 nm. These measurements confirmed a high quantum efficiency of the UVG100-based trap detector within the uncertainties of the measurements. More precise measurements throughout the whole spectral range of interest are planned. The results will be shown at the conference.

CONCLUSIONS

We have constructed a 5-element low-loss trap detector based on commercially available n-on-p photodiodes that are claimed to have a superior long-term stability in responsivity and close to 100% internal quantum efficiency over a broad wavelength range in the visible region. Preliminary tests of spatial response uniformity, linearity and optical losses show an excellent behaviour. The detector is considered as a cheaper and simpler alternative to the custom-made PQED detectors for use in photometric and radiometric applications.

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