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Spatial uniformity and spectral responsivity measurements of large area indium gallium arsenide and germanium pohotodiodes

MOTIVATION

- Dissemination of optical power and spectral responsivity scales relies on high accuracy transfer standard detectors.
- InGaAs and Ge photodiodes are widely used in the 750 nm - 1800 nm range[1,2].
  - Although spectral range is limited by the material bandgap, the low signal to noise ratio and high spectral responsivity make them very advantageous compared to other types of detectors.
- Spatial non-uniformity can increase measurement uncertainty when calibration and application geometries are different.

EXPERIMENT

The properties of large area (5 mm diameter) InGaAs and Ge photodiodes (Table 1) were investigated for use as transfer standard detectors in the NIR.

Diode	Manufacturer	Material	Purchased
Diode 1	1	InGaAs	New
Diode 2	1	InGaAs	New
Diode 3	2	InGaAs	New
Diode 4	2	InGaAs	New
Diode 5	3	Ge	< 1 year
Diode 6	3	Ge	In use since 2000

APPARATUS

Each diode was mounted in an NRC designed photodetector housing and the spectral responsivity and spatial uniformity were measured. The spectral responsivity was measured from 900 nm to 1800 nm using the double monochromator based system shown in Figure 1.

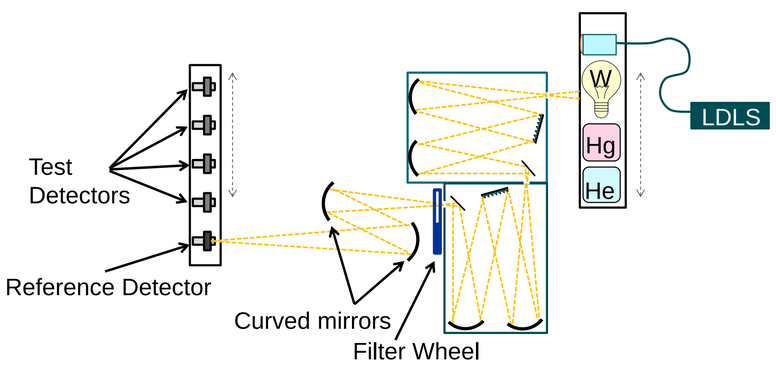

Figure 1. Spectral Responsivity Apparatus

Double monochromator based system used to measure diode spectral responsivity. NRC InGaAs sphere transfer standard used as the reference detector[3].

To measure the spatial uniformity, the diode housing was mounted to a motorized XY stage to raster a 0.22 mm focused spot from a single monochromator based system across its active area (Figure 2).

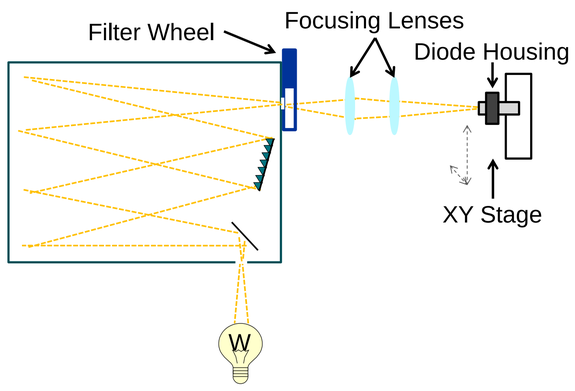

Figure 2. Uniformity Apparatus

Single monochromator based system used to measure the photodiode uniformity. The XY stage is motorized to allow the focused spot to be rastered over the surface of the diode.

REFERENCES

[1] Boivin L P and Bruce S S 2003 *Metrologia* **40** S45
[2] Werner L, Friedrich R, Johannsen U and Steiger A 2000 *Metrologia* **37** 523
[3] Boivin L P 2000 *Metrologia* **37** 273

RESULTS

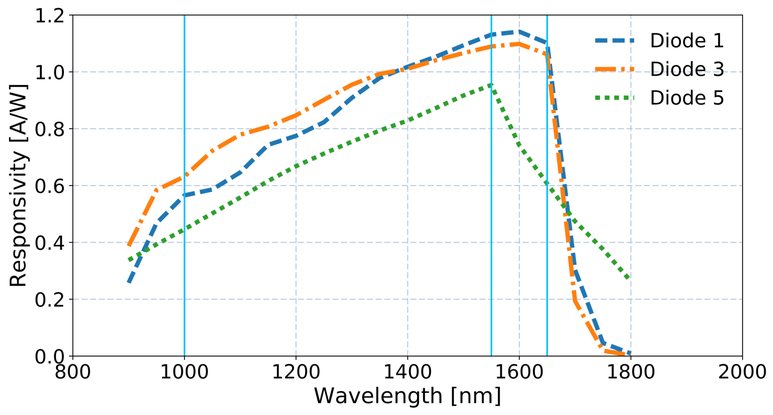

Figure 3. Diode Spectral Responsivity

Representative samples of the spectral responsivity of one diode from each manufacturer. Solid blue lines indicate wavelengths at which the diode uniformity was measured.

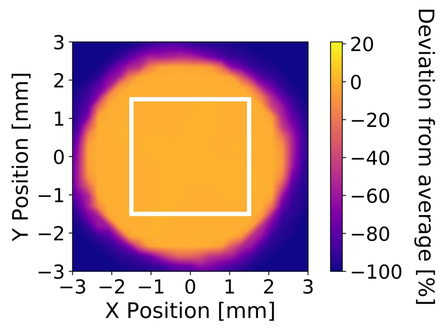

Figure 4. Diode Uniformity Sample Calculation

Sample spatial uniformity plot with the central region used to calculate the average signal indicated by the white square.

Diode uniformity was calculated by:

1. Finding the average signal collected inside the central region of the diode face (central region indicated by the white square in Figure 4).
2. Subtracting the average value from each point in the scan.
3. Dividing the difference by the average to find the percent deviation.

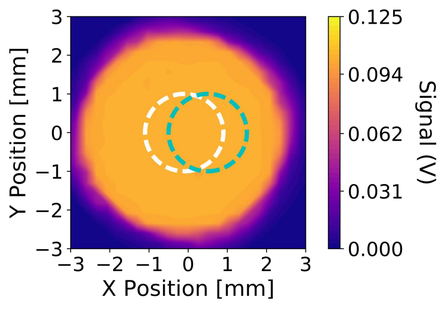

Figure 6. Effect of Uniformity on Uncertainty

Sample plot of the signal collected during uniformity measurements. The white circle indicates a 2 mm diameter spot centered on the diode face. The blue circle indicates a 2 mm diameter spot shifted from the center by 0.5 mm.

To find the effects of diode uniformity on measurement uncertainty when calibration and application configuration are different, the signal was integrated over a 2 mm diameter spot centered on the active area of the diode (white circle in Figure 6) as well as a 2 mm diameter spot offset from the center by 0.5 mm (blue circle in Figure 6) and finding the difference in signal between the two spots. By moving the offset spot around to eight different locations on the diode face, a measure of the effect of diode non-uniformity on signal collection was obtained:

- Each of the InGaAs diodes had an average change in signal of ~0.4% over the eight locations considered that did not vary considerably with wavelength.
- The Ge diodes had a wavelength dependent signal change with -0.5% at 1550 nm and ~1% at both 1000 and 1650 nm

CONCLUSIONS

- Spatial uniformity of the measured diodes varies with wavelength, manufacturer, and semiconductor material.
- Uniform response over active area helps minimize uncertainties in photodiode measurement.
- Measurements presented here can be used to elucidate uncertainty components related to uniformity and alignment during spectral responsivity measurements in the NIR region.
- Diodes 1 and 2 have the most uniform response of 0.07% and 0.14% respectively.

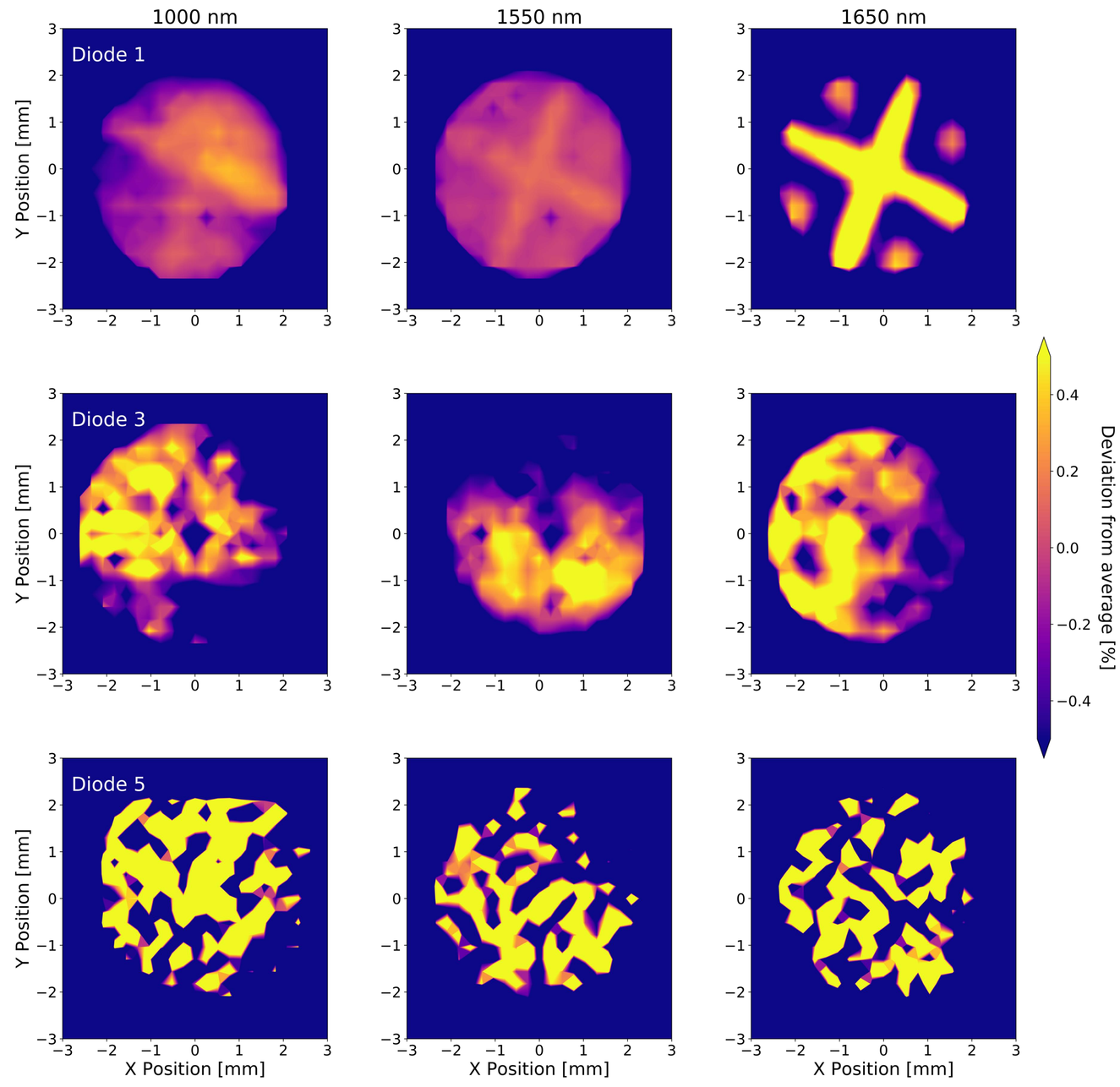

Figure 5. Diode Uniformity

Representative samples of the photodetector uniformity of one diode from each manufacturer. The uniformity of each diode was measured at 1000 nm, 1550 nm, and 1650 nm.