X-RAY BEAM POSITION MONITOR SILICON PHOTODIODE MEASUREMENTS FOR THE ADVANCED PHOTON SOURCE UPGRADE

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K. P. Wootton, H. P. Cease, M. J. Erdmann, S. Oprondek, M. Ramanathan, B. X. Yang, Argonne National Laboratory, Lemont, IL 60439, USA

ABSTRACT

- To best leverage the orders of magnitude average brightness increase of multi-bend achromat synchrotron radiation storage rings, ambitious beam stability requirements are imposed.
- One system that will be employed at the Advanced Photon Source Upgrade in support of photon beam stability will be X-ray beam position monitors.
- In the present work, electrical characterisation of several types of photodiodes are evaluated for potential use in X-ray beam position monitors.

MOTIVATION

- In order to meet demanding photon beam stability requirements of the APS-U [1], hard X-ray beam position monitors are planned.
- Several geometries are foreseen, based upon the grazing-incidence insertion device hard x-ray fluorescence BPM (GRID XBPM) [2, 3].
- In the present work, electronic performance testing of silicon photodiodes for X-ray beam position monitors is presented.

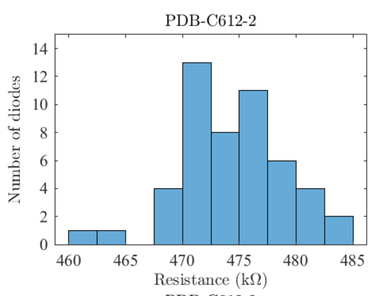
DIODE ELECTRICAL TESTS

- Diodes tested included Luna Opto-Electronics solderable silicon photodiodes: PDB-C612-2, PDB-C613-2, PDB-V615-2.
- Shunt Resistance
  Shunt resistance is defined to be the average slope of the voltage-current $V - I$ curve about 0 V. The accepted practice is to measure the current across the diode at voltages of ± 10 mV [4].
- Two-Wire Resistance
  One technique to measure resistance of the diode is to perform a two-wire resistance measurement. The current used was 500 nA.
- Diode Test
  A diode test is commonly included on multimeters. It is a voltage measurement at a nominal current. The current used was ~1 mA.
- Photocurrent
  Photodiodes in the GRID XBPM are illuminated by X-ray fluorescence from a cerium-doped YAG scintillator crystal. As a performance characteristic, we evaluate the uniformity of DC photocurrent produced by these photodiodes when illuminated by a green LED.

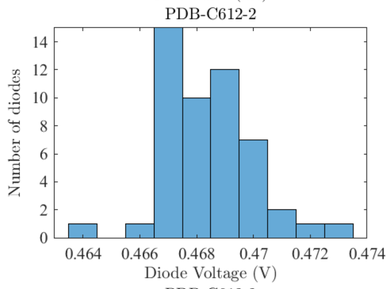
PDB-C612-2

- Very uniform distribution.

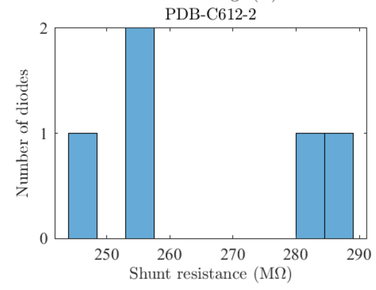
Two-Wire resistance



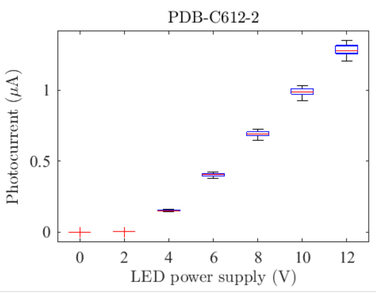
Diode voltage



Shunt Resistance



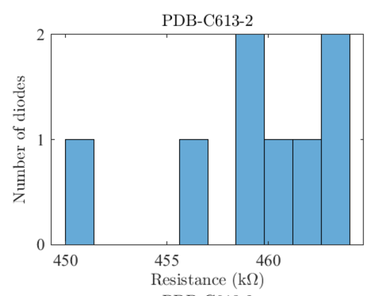
Photocurrent



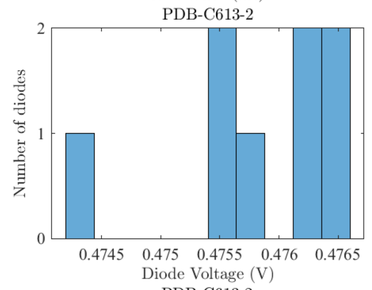
PDB-C613-2

- Very uniform distribution.

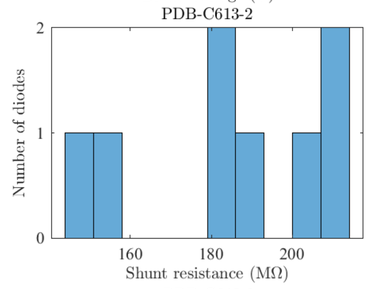
Two-Wire resistance



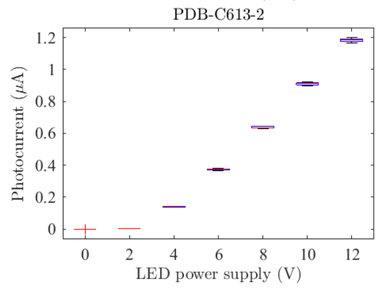
Diode voltage



Shunt Resistance



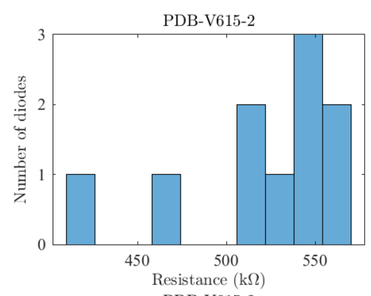
Photocurrent



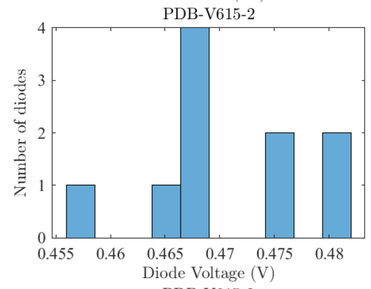
PDB-V615-2

- Much larger spread in distribution of diode parameters (approximately an order of magnitude).

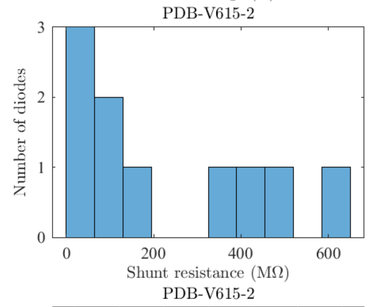
Two-Wire resistance



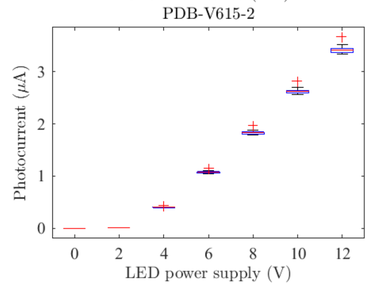
Diode voltage



Shunt Resistance



Photocurrent



SUMMARY

- For the PDB-V615-2 diode, the ratio σ_i/μ_i for the shunt resistance, two-wire resistance and diode voltage is more than an order of magnitude larger than the ratio for the PBD-C612-2 or PDB-C613-2 diodes.
- The statistical distribution of photocurrents appears similar for all three diode types, at about 1–3 %.

Table 1: Mean (μ) and Standard Deviation (σ) of Batch Measurements of Photodiodes.

Property	Units	μ_{C612}	σ_{C612}	$\frac{\sigma_{C612}}{\mu_{C612}}$ (%)
Shunt resistance	MΩ	265	19	7.1
2-wire resistance	kΩ	466	3.1	0.67
Diode voltage	V	0.465	0.001	0.28
Photocurrent	μA	1.29	0.03	2.6
Property	Units	μ_{C613}	σ_{C613}	$\frac{\sigma_{C613}}{\mu_{C613}}$ (%)
Shunt resistance	MΩ	186	26	14
2-wire resistance	kΩ	459	4.4	0.96
Diode voltage	V	0.476	0.001	0.16
Photocurrent	μA	1.18	0.01	0.95
Property	Units	μ_{V615}	σ_{V615}	$\frac{\sigma_{V615}}{\mu_{V615}}$ (%)
Shunt resistance	MΩ	220	225	100
2-wire resistance	kΩ	520	46	8.8
Diode voltage	V	0.471	0.007	1.6
Photocurrent	μA	3.44	0.10	2.8

CONCLUSION

- Electronic performance testing of silicon photodiodes for X-ray beam position monitors was presented.
- For the V615 diode, the statistical spread of shunt resistance, two-wire resistance and diode voltage is more than an order of magnitude larger than the ratio for the C612 or C613 diodes.
- The statistical distribution of photocurrents appears similar for all three diode types, within 1–3 %.

REFERENCES

[1] T. E. Fornek, "Advanced Photon Source Upgrade Project Final Design Report", Argonne National Laboratory, Lemont, IL, USA, Rep. APSU-2.01-RPT-003, May 2019.
[2] B. X. Yang *et al.*, BIW'10, pp. 233–237.
[3] B. X. Yang *et al.*, IBIC'16, pp. 78–81.
[4] P. C. Thompson and T. C. Larason, in *Proc. Measurement Sci. Conf. 2001*, Anaheim, CA, USA, 2001.