

# Comparison of EUV Semiconductor Photodiode Sensors

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# Abstract

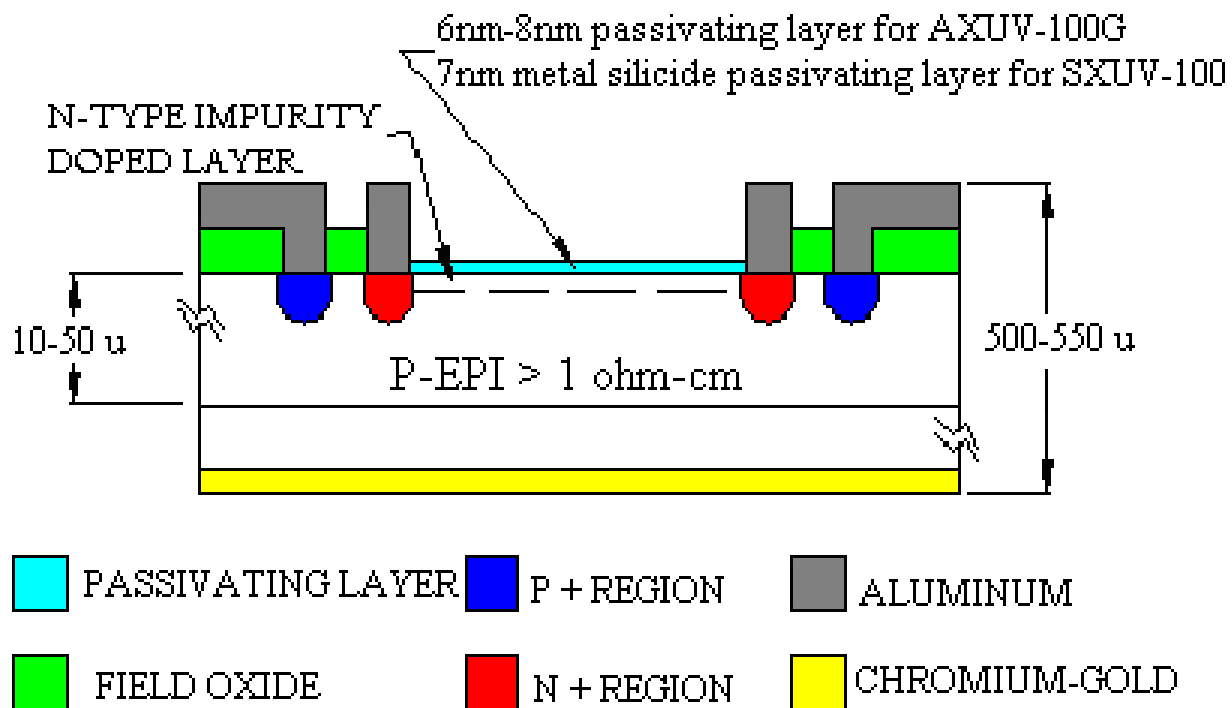
- Performance of four types of semiconductor photodiode detectors for EUV photon detection will be reported. These are silicon photodiodes with and without directly deposited EUV metallic filters and GaAsP, and GaN photodiodes.
- Only silicon photodiodes were found to have 100% internal quantum efficiency (13 nm responsivity in excess of 0.25 A/W) and acceptable uniformity to make precise EUVL source characterization.
- Quantum efficiency stability of the silicon diodes with metal silicide was found to be the best among all the semiconductor photodiodes tested. No change in their responsivity was noticed after exposure to 160 kJ/cm<sup>2</sup> fluence of 13 nm photons.



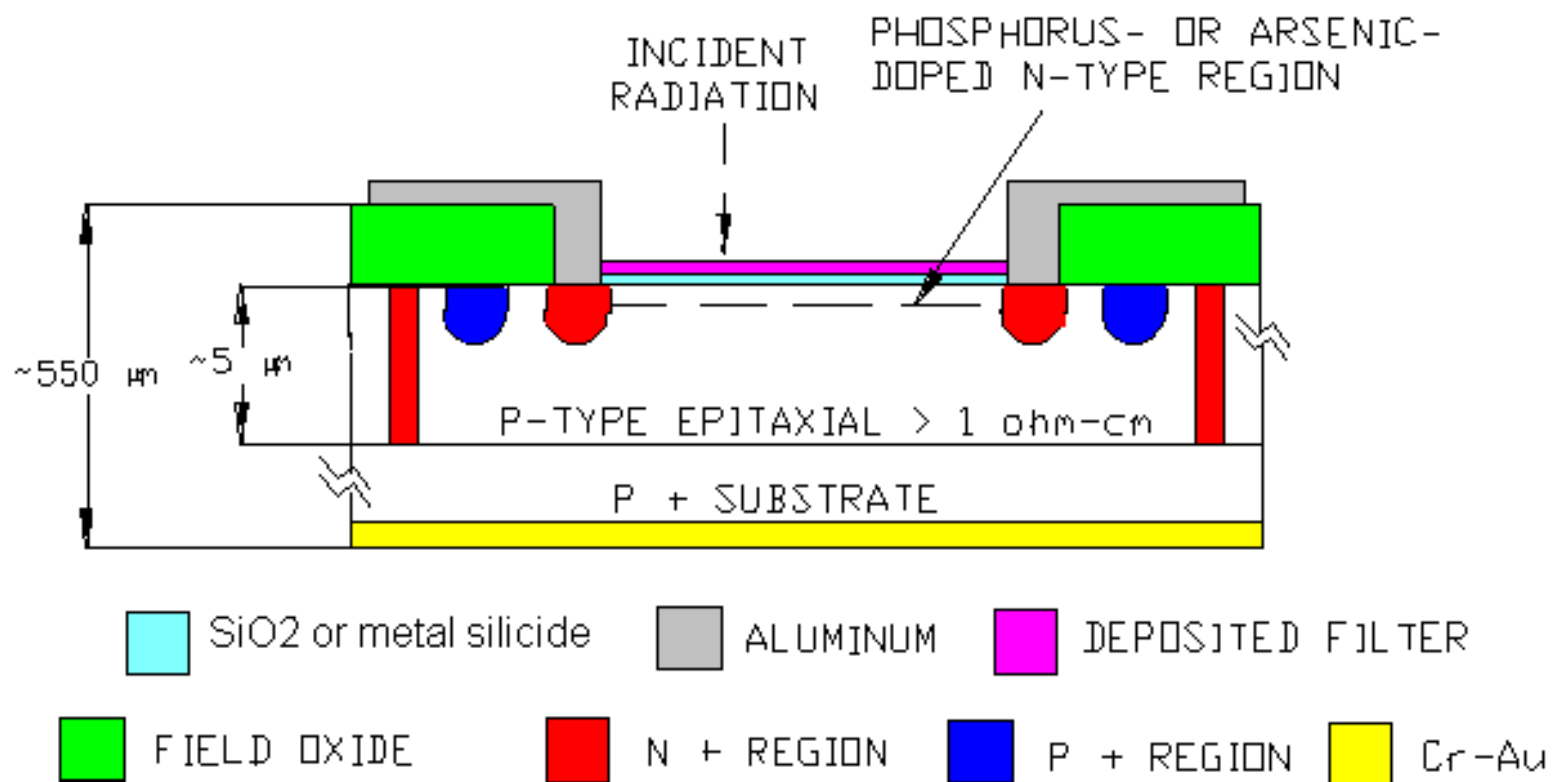
# Abstract (cont.)

- Silicon photodiodes with Mo/Si directly deposited filters were found to have far superior filter stability than the diodes coated with Zr/Si and Zr/C filters. These diodes were found to have visible light blocking in excess of six orders of magnitude and a narrow passband of 12 to 16 nm making them very useful for EUVL source characterization.





**Figure:** Structure of AXUV-100G and SXUV-100 photodiodes



**Figure:** Structure of the AXUV/SXUV photodiode with directly deposited filter

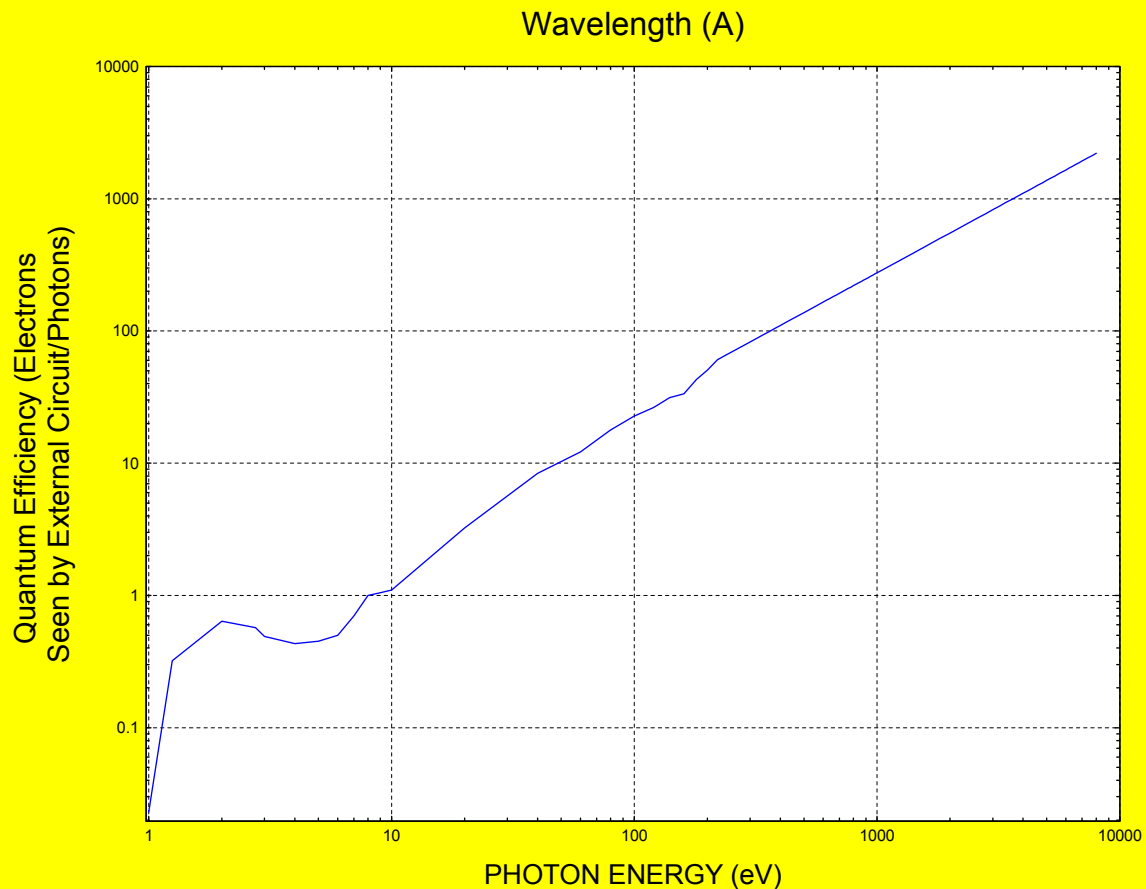


Fig: Typical quantum efficiency of AXUV photodiodes

Figure: Quantum Efficiency of the AXUV-100G photodiode



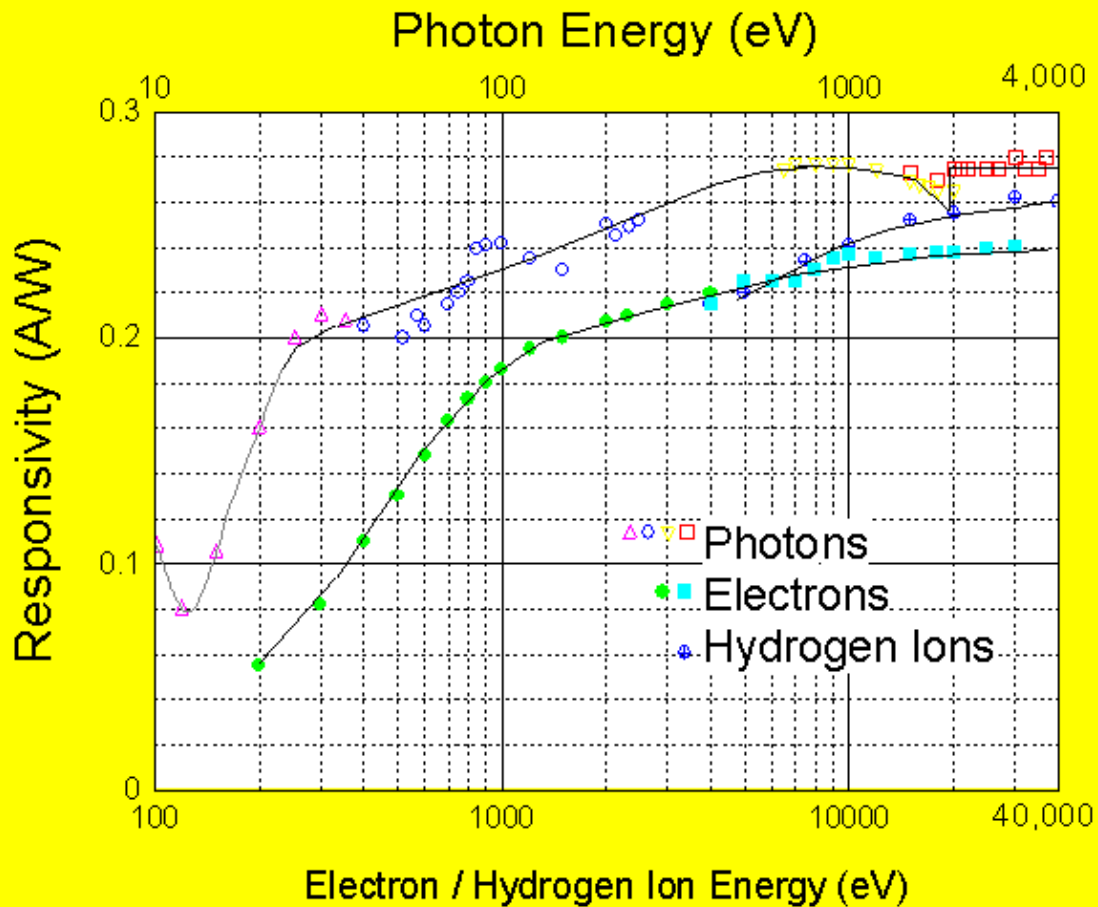


Figure: Responsivity of AXUV photodiodes

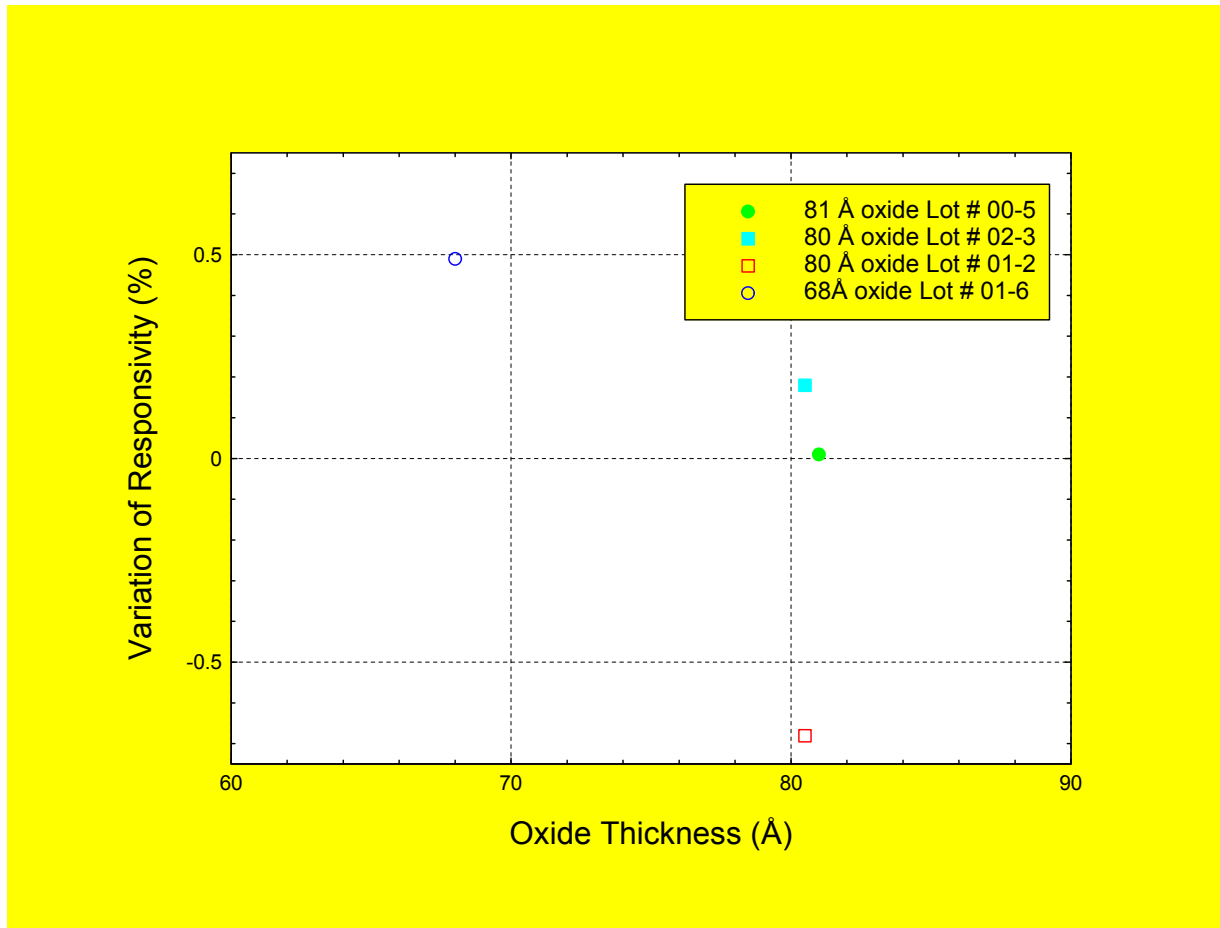


Figure: 13.6 nm responsivity variation of AXUV photodiodes produced over a 2 year period with different oxide thicknesses. Note that the NIST measurement uncertainty at 13.6 nm is 8%

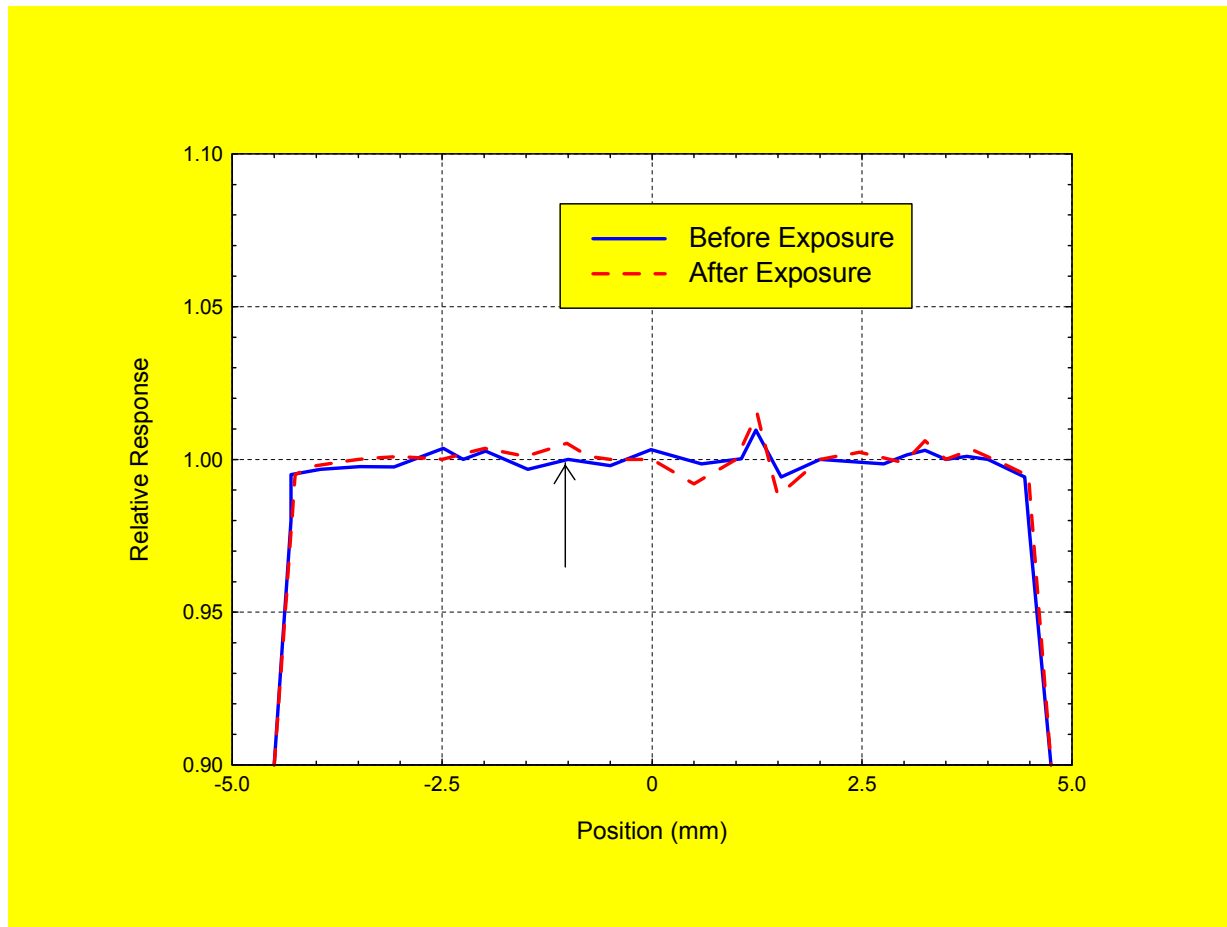


Figure: Line scan of the SXUV-100 diode with 12.4 nm beam before and after exposure to  $10^{22}$  photons/cm<sup>2</sup> 100eV photons

## AXUV Photodiodes with Integrated Filters for 13 nm

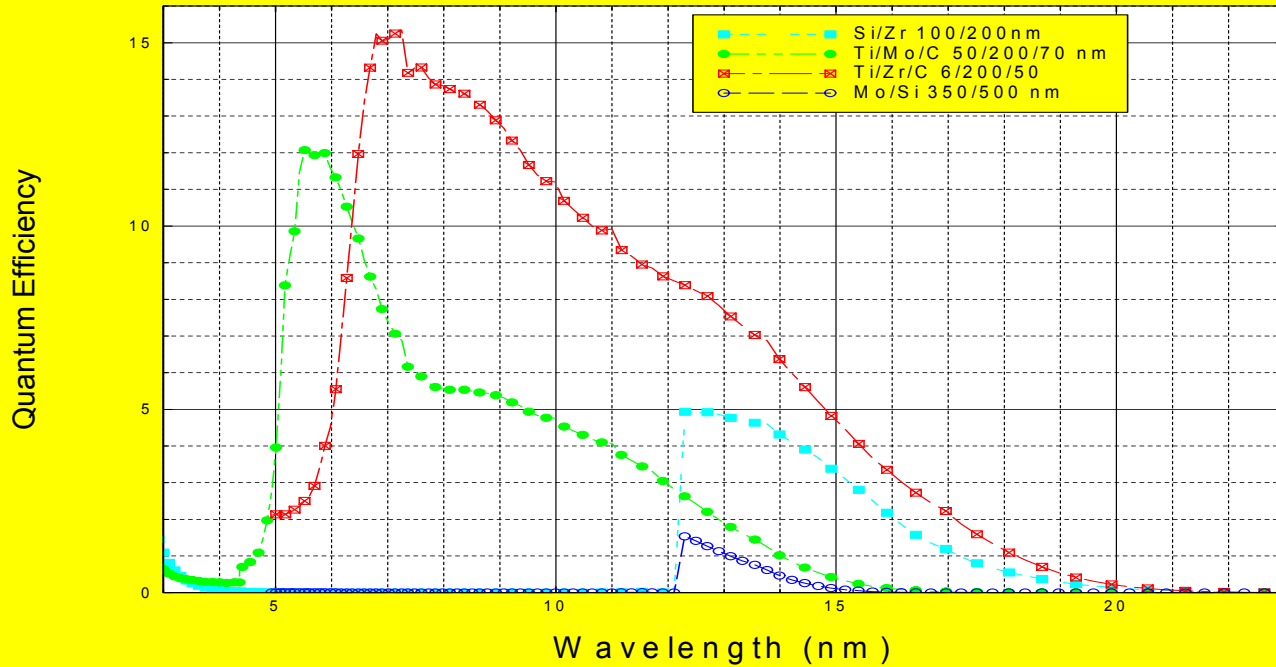


Figure: Quantum Efficiency for AXUV photodiodes with directly deposited filters for 13 nm

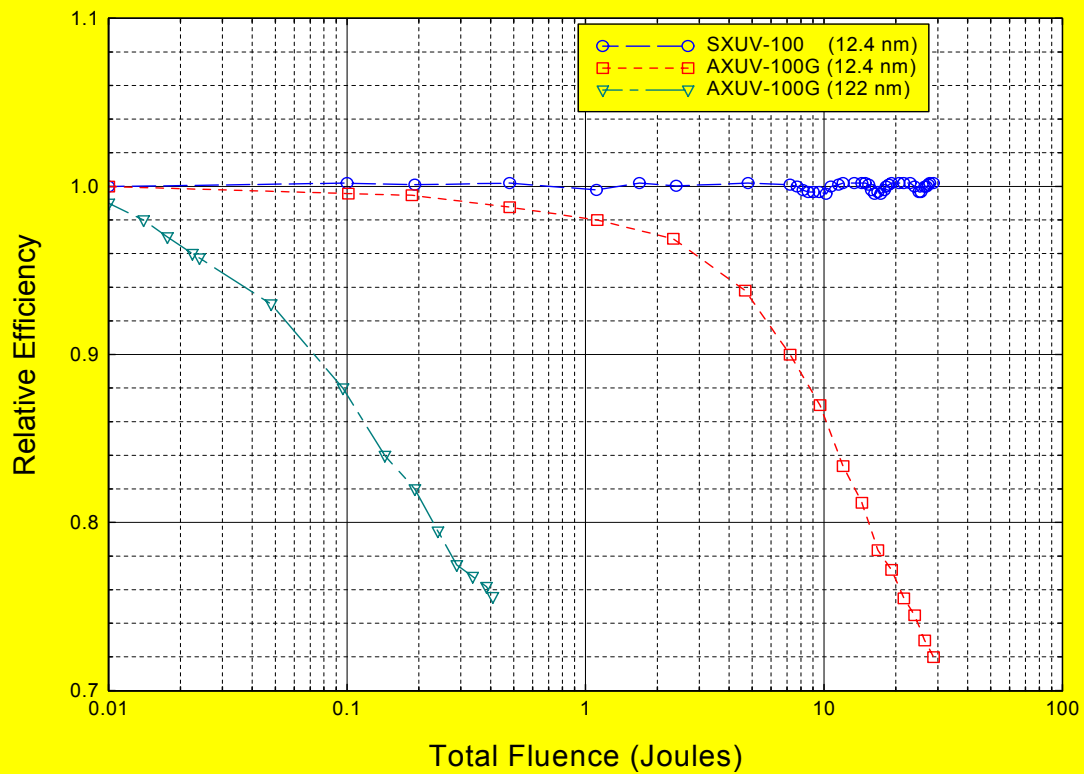
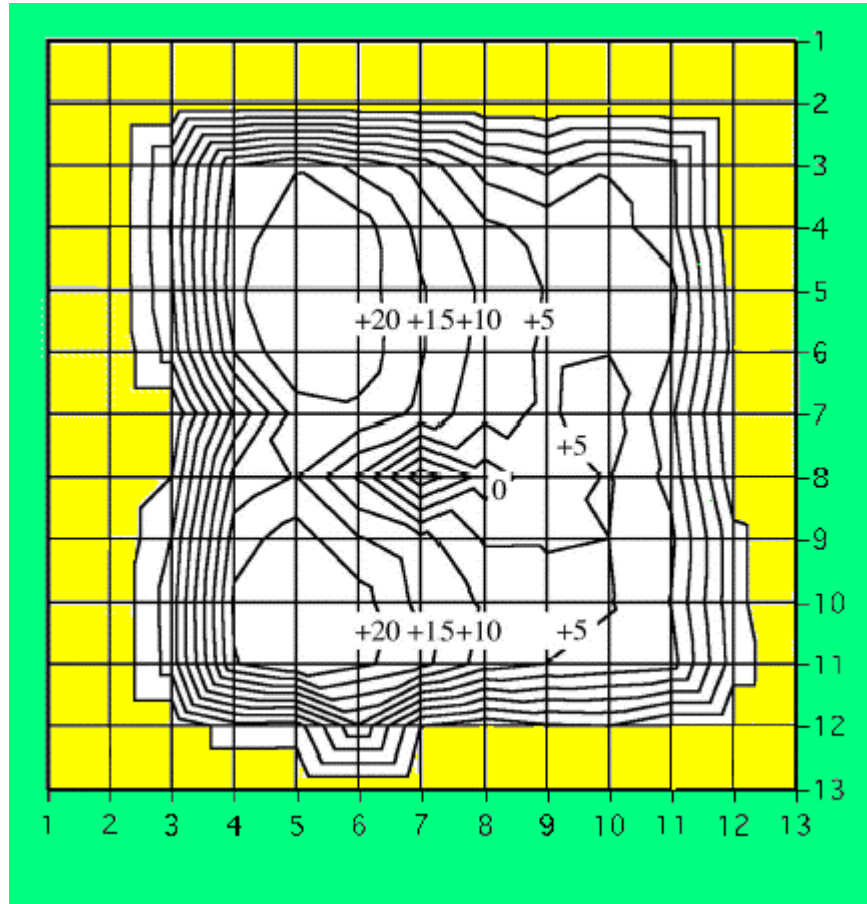
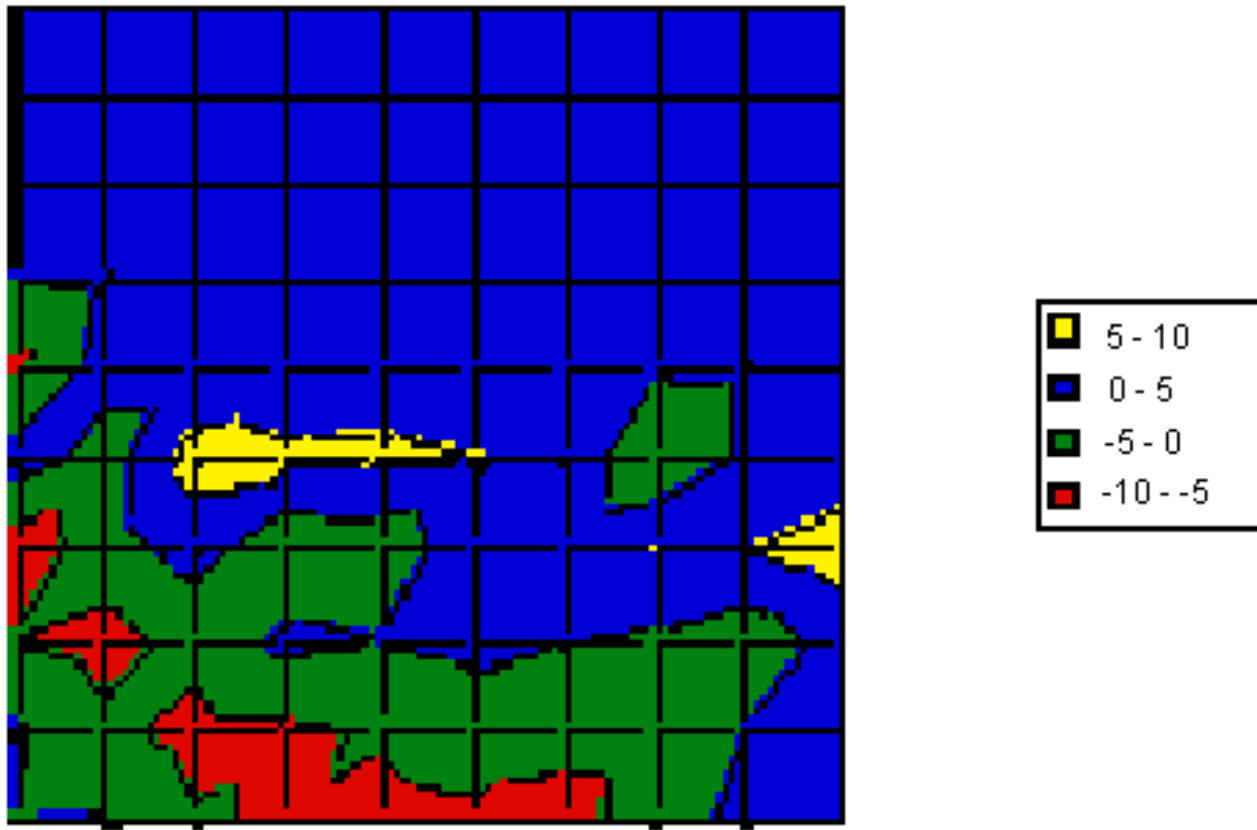


Figure: Relative responsivity of SXUV-100 and AXUV-100G photodiodes when exposed to 100eV and 10 eV photons



**Figure:** Spatial uniformity of responsivity at 122 nm wavelength of a 5 mm<sup>2</sup> active area Au/AlGaN (24% Al) Schottky photodiode. The contours are 5% steps in quantum efficiency, measured relative to the mean value. The pixel size is approximately 280 μm, which is slightly smaller than the beam size.



**Figure: Spatial uniformity of a AuGaAsP Schottky photodiode mapped with 58 nm radiation using a 1 mm diameter spot. Pixels shown are 1 mm x 1 mm.**

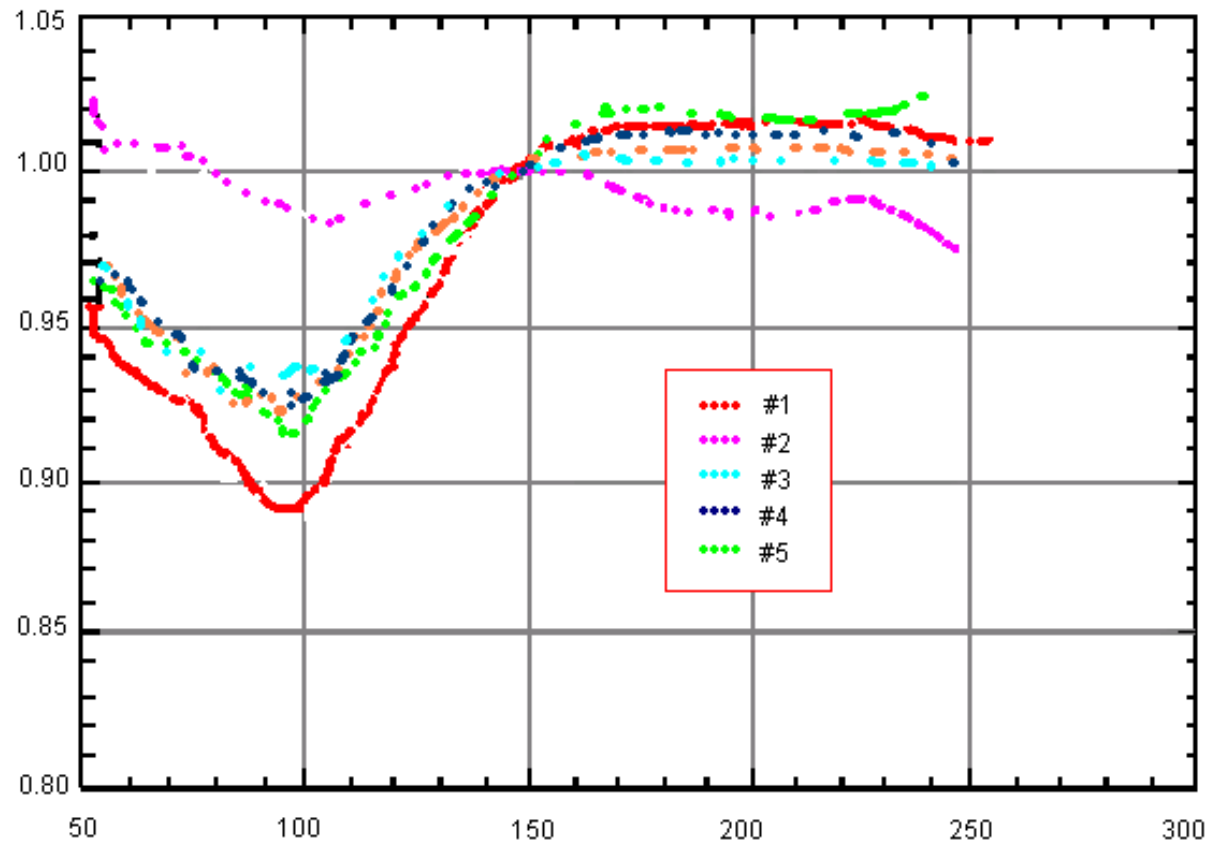


Figure: Relative quantum efficiency of five Au/GaP Schottky photodiodes after 11 months of storage

# Responsivity to Pulse Radiation

$$A/W = C/J$$

$$Q = (1/R) \int V dt$$

		Responsivity for 193 nm Pulsed Radiation					
		100 V Reverse Bias			120 V Reverse Bias		
Device	CW Responsivity @ 193 nm	100 nJ	1 μJ	2.5 μJ	100 nJ	1 μJ	2.5 μJ
UVG-100 00-26	.137 A/W	.127 C/J	.122 C/J	sat	.129 C/J	.123 C/J	sat
SXUV-100 02-2	.0104 A/W	.0101 C/J	.0108 C/J	.0105 C/J	.0102 C/J	.0108 C/J	.0105 C/J

Table: Comparison of cw and pulsed responsivity of UVG series (70 nm silicon dioxide entrance window) and SXUV series photodiodes when exposed to 100 nJ, 1 μJ and 2.5 μJ pulses with a 3 mm diameter beam. Because of the high responsivity, the UVG diode was saturated at the 2.5 μJ pulse energy level



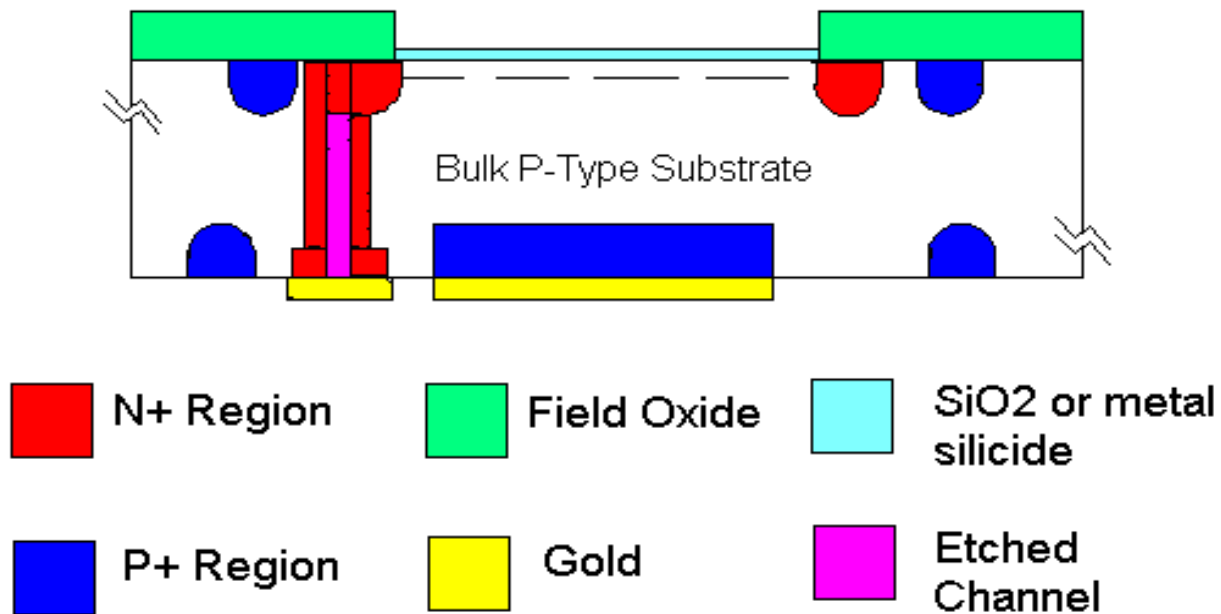


Figure: Structure of AXUV photodiode with back contacts  
(Patent pending)

# Conclusions

1. Owing to their quantum efficiency uniformity and stability, only silicon photodiodes are suitable to make precise EUVL source characterization
2. It appears that narrow EUV passband can be achieved by direct deposition of a thin metallic filter only on the surface of the silicon photodiodes
3. Silicon photodiodes are expected to survive billions of 13 nm pulses with 1 mJ/cm<sup>2</sup> pulse energy density

