Evaluation of 1024 Channel VUV-Photo-Diodes for Soft X-Ray Diagnostic Applications

A. W. Molvik

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A. W. Molvik
Lawrence Livermore National Laboratory
University of California
Livermore, California 94550

We tested the operation of 1024 channel diode arrays (Model AXUV-1024, from IRD, Inc.) in subdued room light to establish that they worked and to determine the direction and speed of the scan of the 1024 channels. Further tests were performed in vacuum in the HAP, High-Average-Power Facility. There we found that the bare or glass covered diodes detected primarily visible light as expected, but diodes filtered by aluminized parylene, produced a signal consistent with soft x-rays. It is probable that the spectral response and sensitivity, as discussed below, reproduce that previously demonstrated by 1 to 16 channel VUV-photodiodes; however, significantly more effort would be required to establish that experimentally. These detectors appear to be worth further evaluation where 25 μm spatial resolution bolometers or spectrograph detectors of known sensitivity are required, and single-shot or 0.02-0.2 s time response is adequate. (Presumably, faster readout would be available with custom drive circuitry.)

Previous single channel VUV-Photo-Diodes from UDT, United Detector Technologies, Inc., and IRD International Radiation Detectors, Inc. and 16 channel arrays of VUV-Photo-Diodes from IRD, Inc. have found extensive use for measuring photon power, because of their near-bolometric response of 1 hole-electron pair for each 3.7 eV incident between 20 and 10,000 eV, and about 1 hole-electron pair for each 10 eV between ~1 and 20 eV. These had response times near 5 ns for 16 channel or for 3 mm diameter single channel diodes. Below we report measurements on the first versions of a new 1024 channel VUV-Photo-Diode, Model AXUV-1024, on a base that is compatible with a Reticon SB series. These were developed by IRD, Inc. under a Phase II, Small Business Grant from DOE.

Two IRD, Inc. detectors, #44 and #21, of Model AXUV-1024 were tested. No. 44 was used for initial setup, then No. 21 was tested in greater detail. The detectors were mounted on and read out with an EG&G Reticon RC1030LNN General purpose evaluation board. It provided a Sync out trigger to a digital scope and a Video out that gave an up to 10V signal. It functioned only with high impedance loads. It did not function if either the Sync or Video out drove a 50 ohm load. It operated in a free-running mode with 1 pulse/190 ms.

The array was first tested in air, in room light. The 1024 channels were output sequentially at 20 μs per channel for a total readout time of 20.48 ms. The individual channels were clearly seen when the digital scope provided several samples per channel.
Even subdued room light saturated the system at +10 V. The maximum darkening that we achieved yielded signals of 1-2 V. The first channel appeared 65 µs after the leading edge of the Sync trigger out. By covering various portions of the detector, we found that the leading edge was at the end nearest Pin 1, i.e., the end with the semicircle cutout in the base. When we covered the detector with a mask that had several open areas, a corresponding pattern appeared in the video out, establishing that the system was operating in a reasonable fashion.

Detector #44 had 4 bad channels as reported by IRD, each bad channel produced a +10 V signal out under all conditions. All the air tests were performed with #44, as well as the first 6 vacuum shots discussed below.

The detectors were exposed to VUV on the High-Average-Power Facility (HAP). HAP uses a 10 Hz glass laser, with up to 300 mJ per 10 ns pulse, frequency doubled to green, focused to ~10 µm at near 45° incidence on a tantalum target. This system produces a power density of up to $4 \times 10^{13} \text{W/cm}^2$ per pulse at full power. We operated 2-3 orders of magnitude lower in power, from 0.075 to 0.77 mJ, to avoid saturating the detectors, measuring the laser energy with a Molecron JD20000. The target was rotated by a stepping motor between each shot, so that the laser was incident on a fresh unused spot on the target every shot. The detector was located about 10° off of the normal to the Tantulum target at a distance of 25 cm and was oriented with the 1024 channels distributed horizontally.

The Reticon RC103OLNN board was mounted inside the HAP vacuum system, with no rf shielding. The vacuum ranged between $8.5 \times 10^{-5}$ Torr on shot 9 to $1.5 \times 10^{-5}$ Torr after shot 24 and $7.5 \times 10^{-6}$ Torr after shot 6, when it had been under vacuum for the longest time. The data were collected on a Tektronix digital scope. For the data shown here, 5000 samples were recorded on each shot at 10 µs/channel, which gave 1-3 samples per detector channel, averaging 2 samples/channel. We manually synchronized a push-button, to direct the next laser pulse to the target chamber, with arming the scope to save the next video out signal from the detector. We estimate that the synchronizing was repeatable to about 0.25-0.5 sec, which appeared to be adequate, except on shots 14, 15, 17, and 18 where the laser apparently fired part way through the detector read cycle, so only the last part of the detector measured signal above background.

Detector #21 was installed after we had adjusted the laser attenuation to produce signals of about twice the background level, and well below the 10 V saturation level. We covered the first 45% of the channels with a clear glass microscope slide to pass visible light but block UV and x-rays, left the middle 24% bare, and covered the last 31% of channels with aluminized parylene (75 nm Aluminum on 500 nm parylene) in a 3 mm wide aluminum frame that blocked about 12% of these channels. This filter passes ~5% near 100 eV, rising to 18% at 200 eV, and up to 40% at a narrow window at 250 eV, before dropping at the carbon k-edge to 10% at 300 eV. The transmission then ramps smoothly upwards to 90% at 1 keV.

Our measurements are summarized in Fig. 1, where the dark signal of 1.7 V was subtracted from each signal. We draw the following conclusions from Fig. 1:

1. The signal on bare or clear glass filtered channels was proportional to laser energy, consistent with detecting mostly scattered laser light (green).
2. The signal on channels filtered by aluminized parylene was also proportional to laser energy, but with a zero offset beginning at 0.2 mJ, consistent with detecting UV light, and inconsistent with scattered laser light.
   (a) We note that the zero power intercept for the parylene filtered channels is -3.3 V, about twice the dark signal, and incompatible with a hypothesis that the filtered signal without the dark-current subtraction would increase linearly from zero.
   (b) We estimate that the UV-spectrum from the laser target should decrease from the few hundred eV range at full laser energy of 300 mJ to a few tens of eV at 0.22 mJ laser energy.
   (c) The ratio for the UV to visible power was not determined, since for the 0.375 mJ shot, the bare and glass filtered channels were saturated, and for the 0.22 mJ shots, the parylene filtered signal was at the dark current level.
   (d) The rapid increase in the ratio of UV to visible, from 0 at 0.22 mJ to 0.33 at 0.375 mJ, is compatible with either or both of the UV power or energy per photon increasing rapidly with laser energy, which we would expect.
3. The clear glass filter passes ~80% as much signal as seen by bare channels, a reasonable value.
4. We estimate the energy emitted by the target from our measured signal as follows: Each element of 12.5 µm by 2.5 mm is integrated by a 3 pF capacitor. Electronics after that have unity gain. For a maximum signal of 10.0 V-1.7 V(background), Q=CV=2.49 × 10⁻¹¹ coul. Assuming the standard silicon diode sensitivity of 3.7 eV per hole-electron pair, this charge corresponds to 5.76 × 10⁸ eV incident on each channel. The detectors are 25 cm distant from the laser target and about 10° off of the normal to the
target. The energy will be spread over $2\pi$ steradians, and for a cosine distribution, will have twice the average intensity near normal. The total energy emitted by the target is then $3.62 \times 10^{15}$ eV or 0.58 mJ. This compares with incident laser energies of 0.38 mJ to saturate a bare detector, about a factor of 1.5 discrepancy.

Other conclusions are:

5. The background level was too high on our measurements to enable several orders of magnitude in signal level to be measured. This was not a problem with previous VUV photo-diodes, and can probably be eliminated with additional effort.

6. RF noise from the laser or laser target was not a significant problem, compare Shot 21, where the laser fired but was blocked from entering the chamber, with Shot 24 where the laser was off. (Or was the laser cycling at 10 Hz?)

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References


