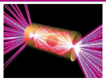
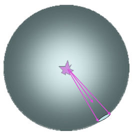
DOE/NV/25946--1507

Radiation Hard AlGaN Detectors and Imager

Ke-Xun (Kevin) Sun*
Department of Electrical and Computer Engineering, University of Nevada, Las Vegas, Ke-Xun.Sun@unlv.edu
National Security Technologies, LLC (NSTec), North Las Vegas, Nevada, *sunke@nv.doe.gov

Radiation Hardness Challenges for NIF Diagnostics





NIF Radiation Estimation

- Neutron emissions per ignition shot ~10^{15}
- Neutron energy ~15 MeV
- Detector placed at 1 m away from target
- Fluence at 1 m away

$$F = \frac{N}{4\pi R^2} \approx 8\times10^{9}\ 1/\mathrm{cm}^2$$

- One year fluence (700 shots)

$$F_{1year} \approx 5.6\times10^{12}\ \ 1/\mathrm{cm}^2$$

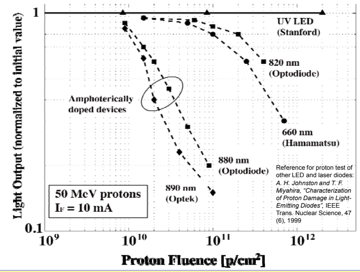
Facility	Particle & Energy	Total # Particles Per Shot (or beam brightness)	One Shot Total Fluence at 1 m away (1/cm²)	One Year Total Fluence at 1 m away (1/cm²)	1 mm² Detector Total Particle counts
NIF	neutrons 15 MeV	10^{15}	~8×10^{9}	~5.6×10^{12} (700 shots)	~5.6×10^{10}
LCLS	X-ray 8 keV	10^{12}	10^{12}	2×10^{20} (250 day operation)	~2×10^{18}

Radiation Hardness Requirements and Risk Mitigation

- **System and devices function properly after 1×10^{12} protons/cm² proton irradiation in one year**
- **Mitigation approaches:**
  - Films (non-electronic media)
  - Shielding (weighty)
  - Use devices with extreme radiation hardness, and use much less shielding (best)
- **GaN devices provide extreme radiation hardness:**

Functional after 1×10^{12} protons/cm² irradiation

Radiation Hardness of GaN Optoelectronics Demonstrated in UV LED Experiments

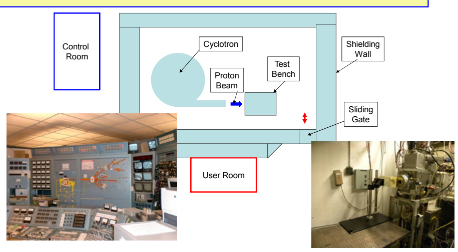


[2] K.-X. Sun, B. Allard, S. Williams, S. Buchman, and R. L. Byer, "LED Deep UV Source for Charge Management," presented at Amaldi 6 Conferences on Gravitational Waves, June 2005, Classical and Quantum Gravity, 23(8):S141-S150, 2006.

Experimental Setup at the University of California (Davis) Proton Facility

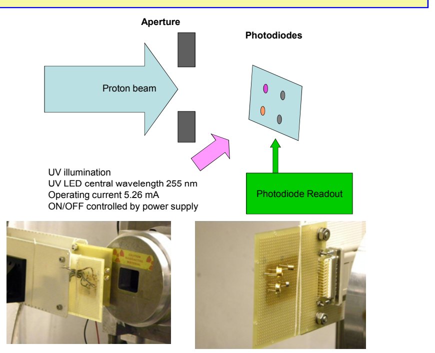
Proton Beam Parameter

- Proton beam energy 65 MeV
- Proton beam fluence increases mostly with step size 1×10^{11} ~2.5×10^{11} protons/cm²
- Total fluence 3×10^{12} protons/cm²



Proton Irradiation of the AlGaN Photodiodes

- Photodiodes are placed in the proton beam pass
- Photodiodes are illuminated by 255 nm UV light generated by UV LEDs mounted outside the proton beam



Radiation Hardness Test Results Using 65 MeV Protons up to Fluence of 3×10^{12} protons/cm²

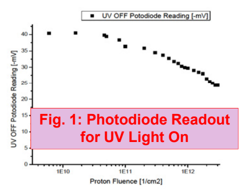


Fig. 1: Photodiode Readout for UV Light On

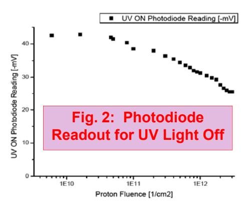


Fig. 2: Photodiode Readout for UV Light Off

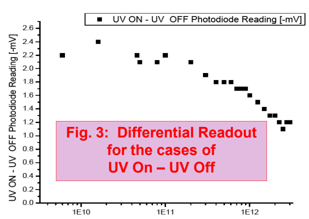


Fig. 3: Differential Readout for the cases of UV On – UV Off

Experimental Measurements

- Proton beam fluence increases
- Photodiode in photovoltaic mode
- For each fluence level, measure the photodiode readout for
  - UV light on: UV LED is powered on (Fig. 1)
  - UV light off: UV LED is turned off (Fig. 2)
- The differential reading is defined as the photodiode response to UV (Fig. 3).
- Normalized response is shown in Fig. 4

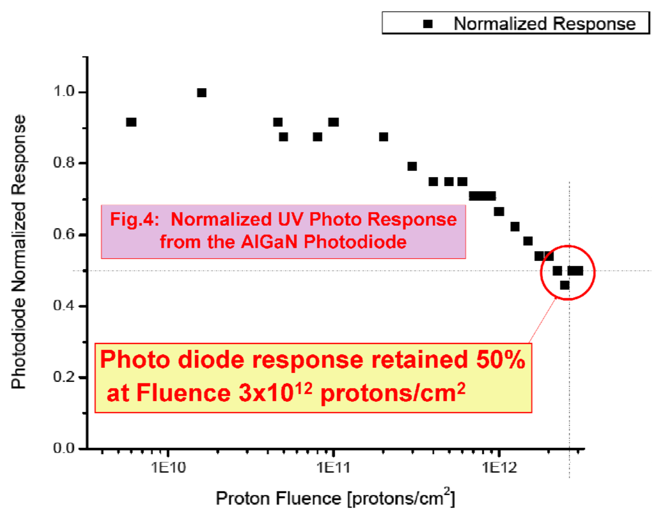


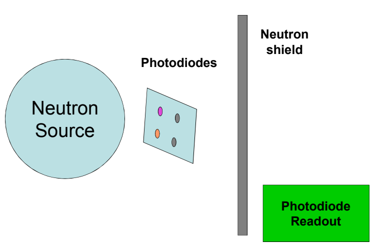
Fig.4: Normalized UV Photo Response from the AlGaN Photodiode

Photo diode response retained 50% at Fluence 3×10^{12} protons/cm²

Extreme Radiation Hardness Demonstrated

AlGaN Photodiodes demonstrate radiation hardness required by NIF, Z, LCLS

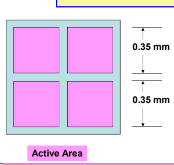
Neutron Test Underway

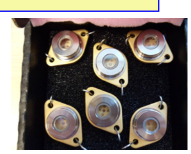


AlGaN Photodiode Arrays

AlGaN Photodiode Array Parameters

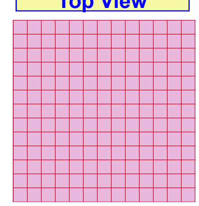
- 2x2 quad array for laser beam position detection near TCC
- 0.35 mm x 0.35 mm each quad size
- Center wavelength 254 nm, adjustable to 354 nm





AlGaN Imagers

AlGaN Imager Top View



AlGaN Imager Side View

AlGaN Pixel Layer

Readout GaN Electronics Layer

GaN/Sapphire Substrate

References

[1] K.-X. Sun et al. "LED Deep UV Source for Charge Management for Gravitational Reference Sensors," Class. Quantum Grav. 23 (2006) S141-S150
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Conclusions

- **AlGaN Deep UV Photodiode have extremely high radiation hardness**
- **These new devices have mission critical applications in high energy density physics (HEDP) and space explorations**
- **These new devices satisfy radiation hardness requirements by NIF**
- **NSTec is developing next generation AlGaN optoelectronics and imagers**

This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy and supported by the Site-Directed Research and Development Program.
Special thanks is given to the U.S. Department of Energy Livermore Complex for making this effort a success.