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Extreme Radiation Hardness and Space Qualification of AlGaN Optoelectronic Devices

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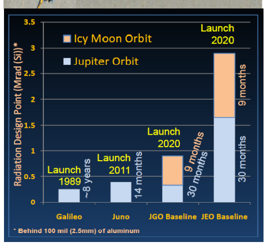
Radiation Challenges for Europa and Jovan Jupiter Missions



- EJSM is the flagship mission for NASA/ESA outer planet exploration programs
- JEO to fly over Europa
- JGO to fly over Jovian
- Total 1×10^{12} protons/cm^2 fluence expected for mission lifetime
- Radiation challenge unprecedented for NASA missions

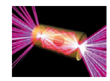
Graph from T. Y. Yan presentation "Risk Mitigation Effort Overview" at EJSM Workshop 2009, Baltimore

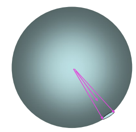
Radiation Hardness Requirements And Risk Mitigation

- System and devices function properly after 1×10^{12} protons/cm^2 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 3×10^{12} protons/cm^2 irradiation

Radiation Hardness Challenges for NIF Diagnostics





NIF Radiation Estimation

- Ignition shot: N~1015 neutrons
- Neutron energy ~15 MeV
- Detector placed at 1 m away from target
- Neutron emission per ignition shot ~10^{15}
- Fluence at 1 m away

$$F = \frac{N}{4\pi R^2} \approx 8 \times 10^9 \ 1/\text{cm}^2$$

- One year fluence (700 shots)

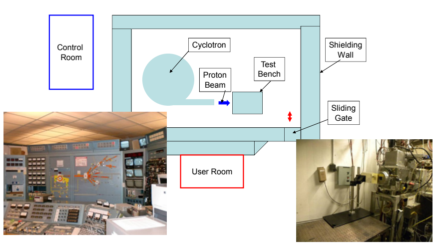
$$F_{1\text{year}} \approx 5.6 \times 10^{12} \ 1/\text{cm}^2$$

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}

Experimental Setup at the UC Davis Proton Facility

Proton Beam Parameter

- UC Davis Crocker Proton Facility
- Proton beam energy 65 MeV
- Proton beam fluence increases mostly with step size 1×10^{11} ~2.5×10^{11} protons/cm^2
- Total fluence 3×10^{12} protons/cm^2



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

Extreme Radiation Hardness of AlGaN Photodiodes Tested with 65 MeV, 3×10^{12} protons/cm^2

Experimental Measurements

- Photodiode in photovoltaic mode
- For each fluence level, measure the photodiode readout for UV light on and UV light off
- The differential reading is defined as the photodiode response to UV
- Normalized response is shown

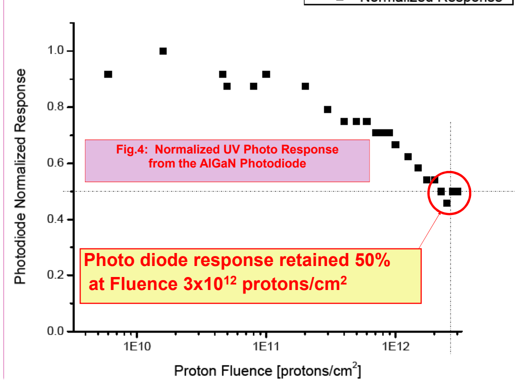
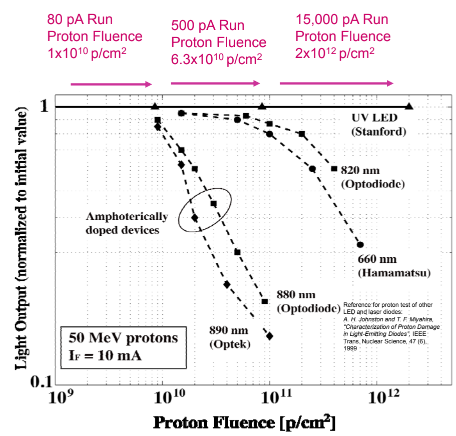
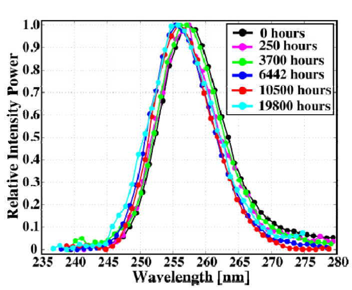


Fig.4: Normalized UV Photo Response from the AlGaN Photodiode

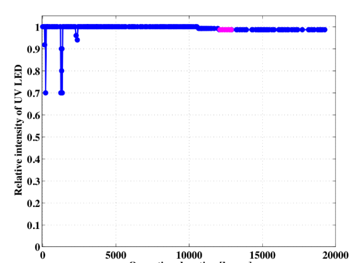
Extreme Radiation Hardness of AlGaN Deep UV LED



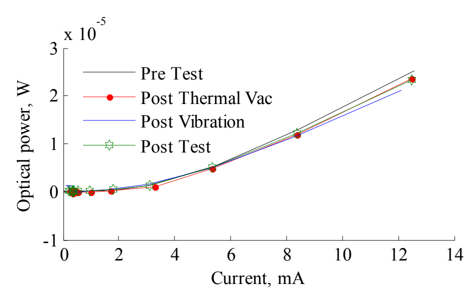
Emission Spectral Stability After 19,800 Hours Spectral Shift < -2 nm



Power Stability After 20,000 Hours Operation Power Level Stable within ~2%



Optical Power vs Driving Current Curves after Shake and Bake Test



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
[2] K.-X. Sun et al "UV LED Operation Lifetime and Radiation Hardness Qualification for Space Flights," Journal of Physics CS, doi: 10.1088/1742-6596/154/1/012028
[3] K.-X. Sun et al. "Space Qualification for Radiation Hard UV LED," 3rd NASA EJSM Workshop, Applied Physics Lab, John Hopkins University, July 7-9, 2009
[4] K.-X. Sun and L. MacNeil, "Radiation Hardness of AlGaN Photodiodes," 4th NASA EJSM Workshop, Jet Propulsion Laboratory, July 26-29, 2010
[5] K.-X. Sun and L. MacNeil, "GaN Radiation Hard Properties and Detectors," SPIE Hard X-ray, Gamma Ray, and Neutron Detection, San Diego, August 1-5, 2010

Conclusions

- AlGaN Photodiodes are demonstrated to have extreme radiation hardness
- AlGaN UV LED radiation hardness has been demonstrated earlier
- These new devices deserve further considerations for NIF diagnostics
- NSTec has capabilities to contribute to NIF, LCLS, and Z

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