



Pulsed and Steady-State Radiation Effects on Single Junction Si and Multiple Junction GaAs Photocells

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Radiation Test Facilities

- **Annular Core Research Reactor (ACRR)**
 - Mixed Neutron/Gamma
 - Passive and Active Tests



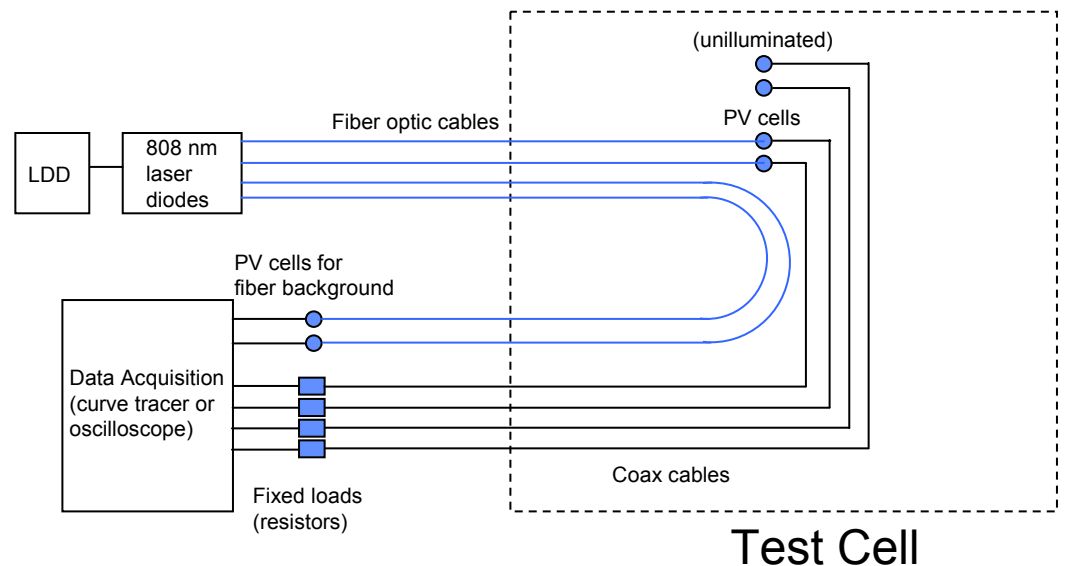
- **Gamma Irradiation Facility (GIF)**
 - Co⁶⁰ Array Gamma
 - Active Tests





Experimental Setup

- **Devices Tested**
 - Commercial 6 V GaAs Devices
 - Sandia Si Single Junction Cells
 - » Multiple Sizes
 - Largest 120 x 550 μm
 - Smallest 20 x 20 μm
- **Illumination**
 - 808 nm Laser Diodes
 - 150 mW
 - 100 μm 0.22 NA Fiber Cable
- **Data Acquisition**
 - I-V Curve
 - PV Response Across Fixed Load
- **Active and Passive Dosimetry**





Passive ACRR Test Results

Manufacturer	P/N	S/N	Illumination (mW)	Pre I_{sc} (A)	Post I_{sc} (A)	I_{sc} Reduction (%)	Pre V_{oc} (V)	Post V_{oc} (V)	V_{oc} Reduction (%)
Photonic Power	PPC-6E	CN176	1010	6.30E-02	3.00E-02	52.3	6.42	5.32	17.1
Photonic Power	PPC-6E	CN177	1010	6.54E-02	3.02E-02	53.8	6.54	5.44	16.8
Sandia MDL	120X550	1	154	3.67E-03	1.10E-03	70.0	0.76	0.60	21.5
Sandia MDL	120X550	2	154	2.54E-03	1.00E-03	60.6	0.75	0.60	20.7
Sandia MDL	120X250	3	154	1.18E-03	3.05E-04	74.2	0.75	0.59	21.8
Sandia MDL	120X250	4	154	1.30E-03	4.95E-04	61.9	0.76	0.60	20.4
Sandia MDL	40X100	5	154	1.93E-04	6.00E-05	68.9	0.72	0.60	17.4
Sandia MDL	40X100	6	154	1.53E-04	5.90E-05	61.4	0.70	0.60	15.1
Sandia MDL	40X60	7	154	8.50E-05	3.50E-05	58.8	0.70	0.60	14.5
Sandia MDL	40X60	8	154	8.00E-05	2.80E-05	65.0	0.70	0.59	15.7
Sandia MDL	20X40	9	154	2.56E-05	1.15E-05	55.1	0.68	0.59	12.9
Sandia MDL	20X40	10	154	2.90E-05	1.18E-05	59.3	0.69	0.60	12.8
Sandia MDL	20X20	11	154	1.45E-05	8.80E-06	39.3	0.67	0.58	13.1
Sandia MDL	20X20	12	154	1.87E-05	6.30E-06	66.3	0.68	0.60	12.6

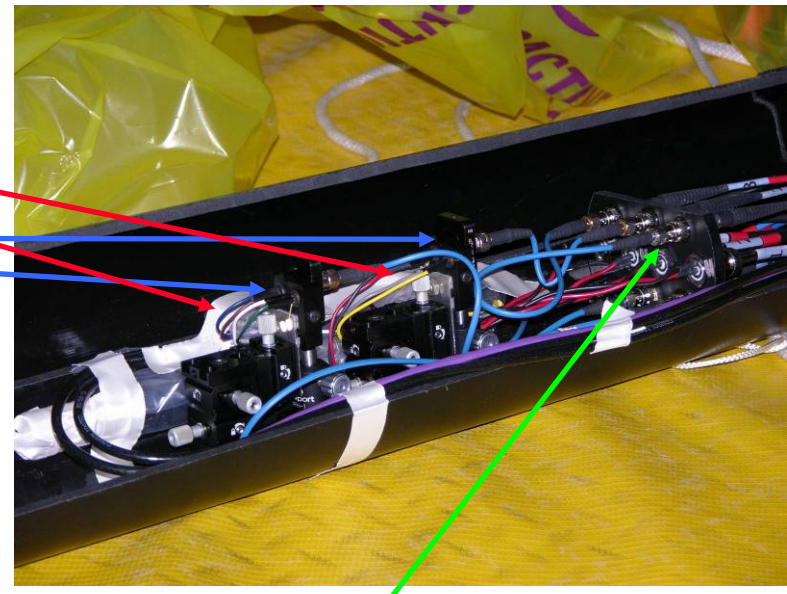
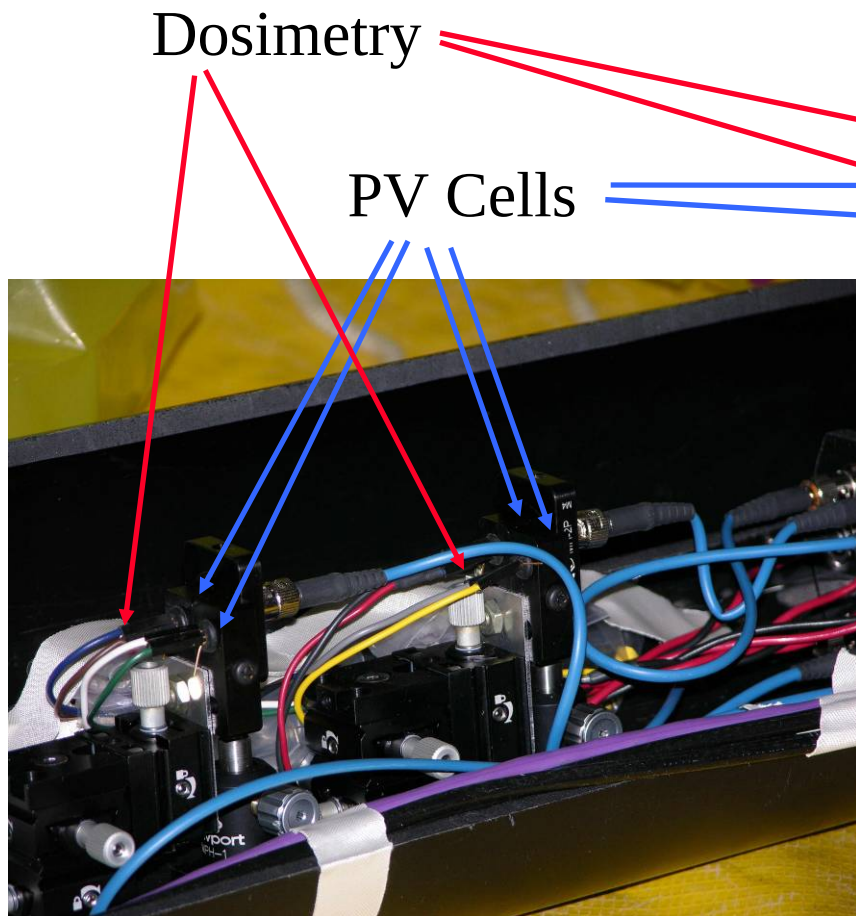
Dose: TLDs Saturated (hundreds of krad(Si)) and $4.1E14$ Neutrons/cm² (1 MeV(Si))

GaAs and Si PV Devices Show Comparable Degradation

Degradation Independent of Cell Size



ACRR Active Test Setup



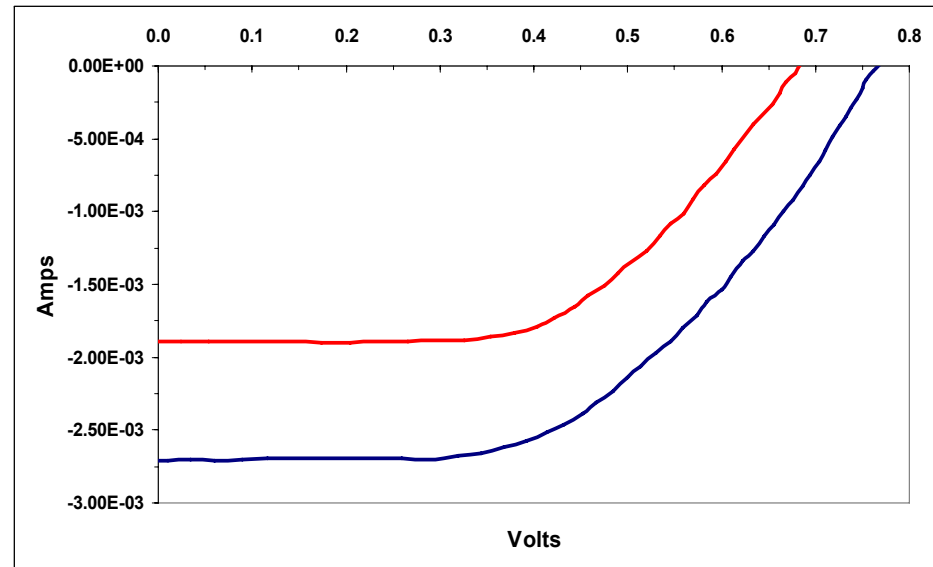
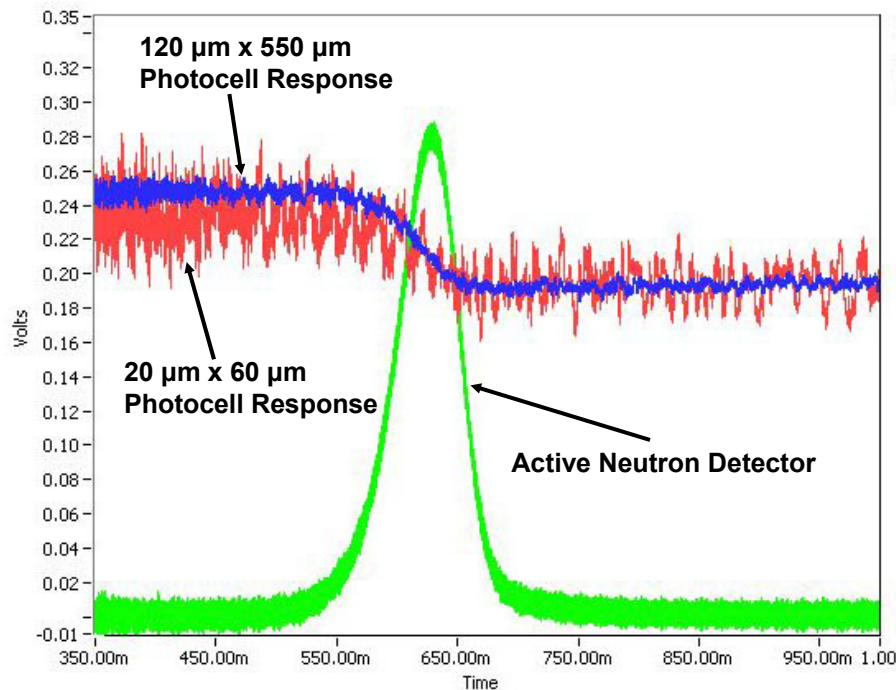
Optical and Electrical Header

- One Illuminated and One Unilluminated PV Cell Per Location
- Passive Dosimetry at Each Location
- Active Dosimetry Centered Between the Two Locations



3.8 MJ ACRR Shot

- ~30% Reduction in Current Output
- ~10% Reduction in voltage
- No Annealing
- $8.8\text{E}3$ rad(Si) Gamma Dose
- $2.9\text{E}13$ Neutrons/cm² (1 MeV(Si))

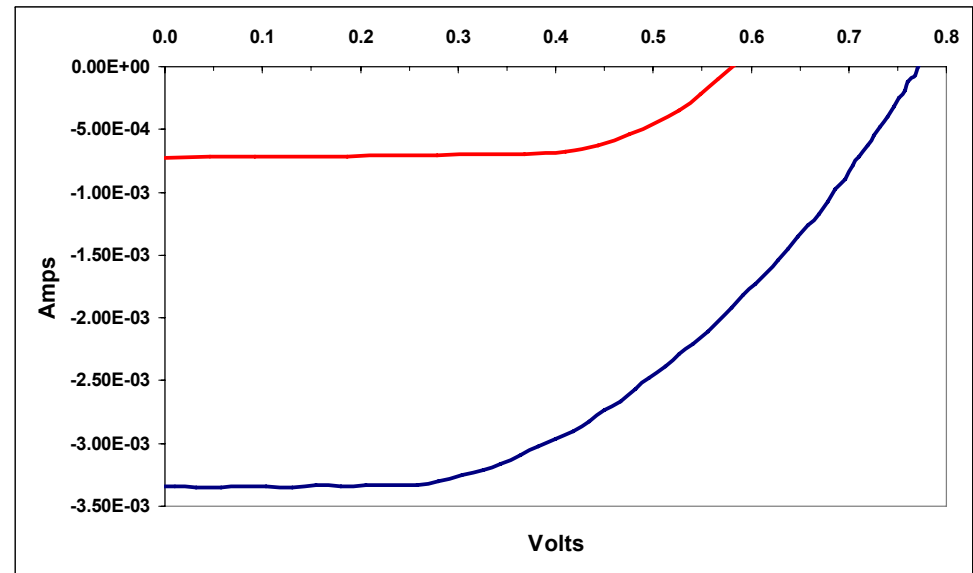
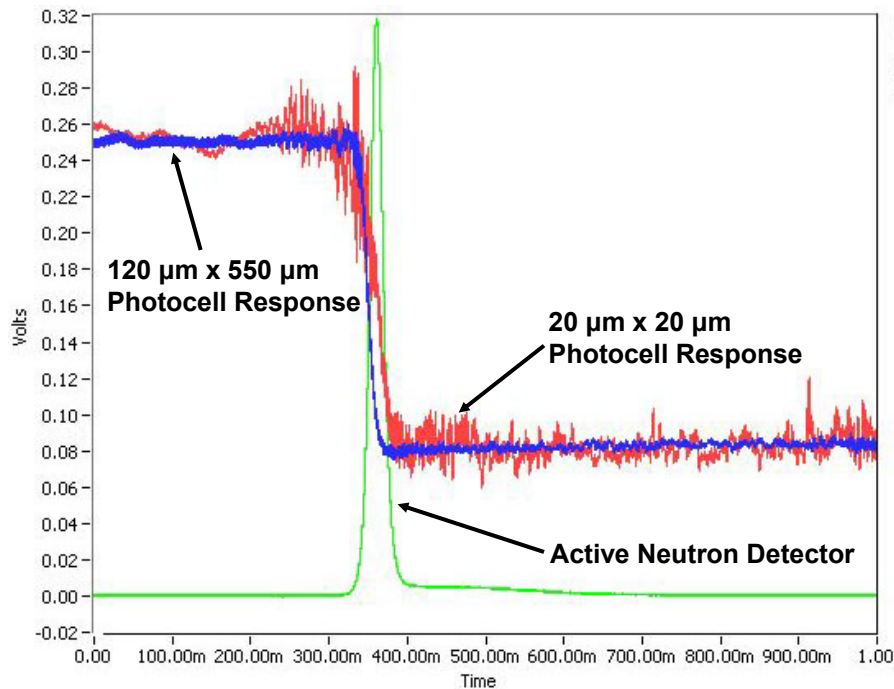


Blue Trace = 120x550 μm PV cell
Red Trace = 40x60 μm PV cell
Green Trace = Active Neutron Detector



85.4 MJ ACRR Shot

- ~70% Reduction in Current Output
- ~20% Reduction in Voltage
- No Annealing
- $1.7\text{E}5$ rad(Si) Gamma Dose
- $4.2\text{E}14$ Neutrons/cm² (1-MeV(Si))



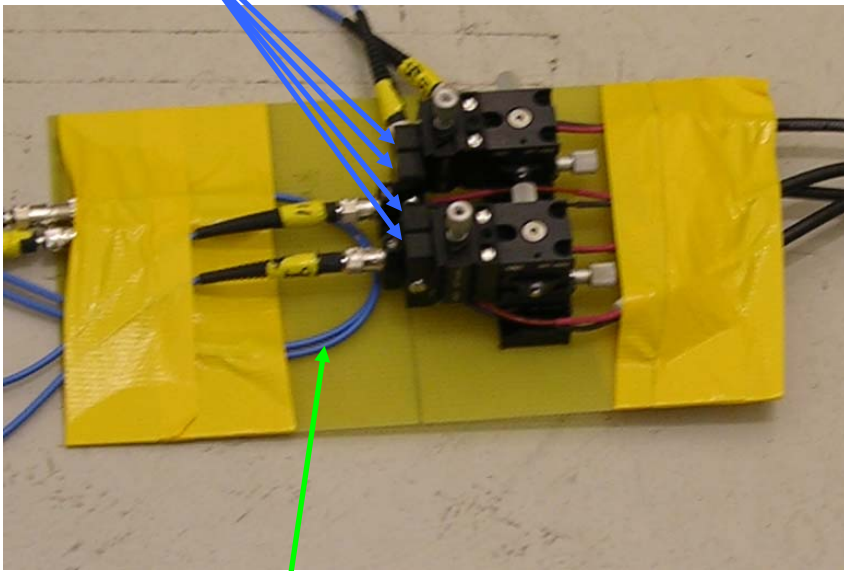
Blue Trace = 120x550 μm PV Cell
Red Trace = 20x20 μm PV Cell
Green Trace = Active Neutron Detector



GIF Test Setup

PV Cell Mounted on a Header

PV Cells

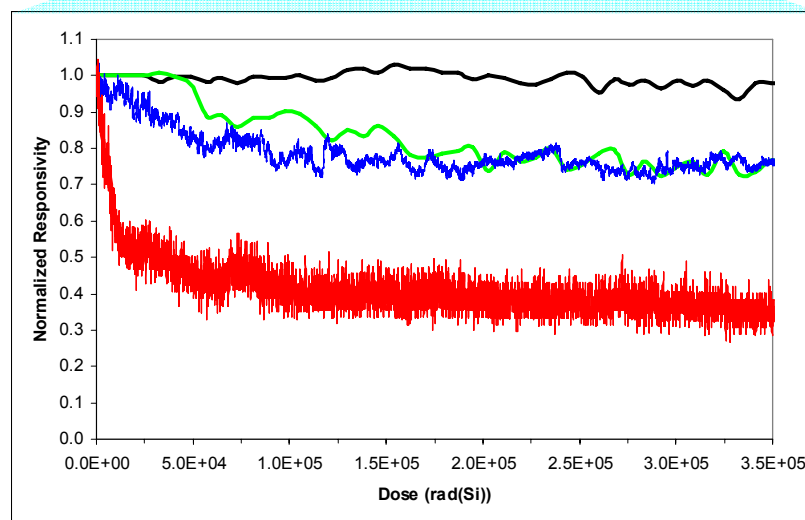
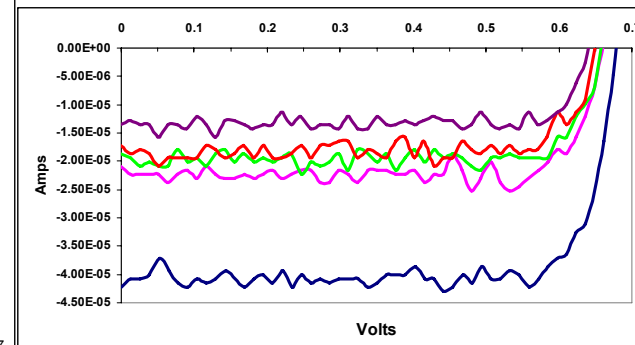
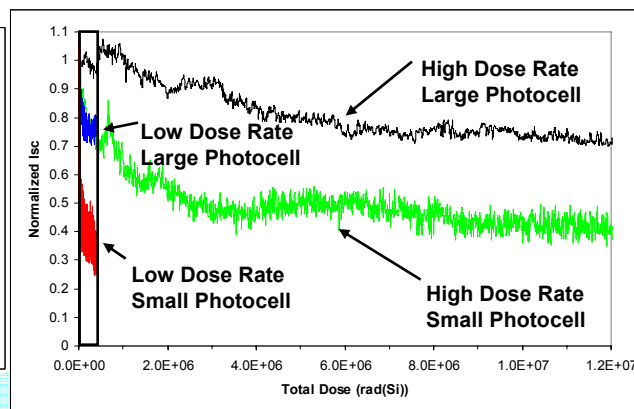
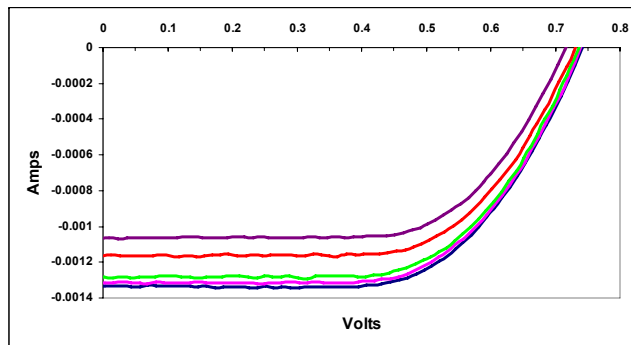


Background Fibers



- Dose Rate was Varied by Changing the Distance from the Source
 - Position 1 Dose Rate of 810 rad(Si)/s
 - Position 2 Dose Rate of 5.33 rad(Si)/s
- Device Sizes Tested
 - 550 x 120 μm
 - 40 x 60 μm
- Two Illuminated and Two Unilluminated PV cells Per Location
- Passive Dosimetry Placed Adjacent to PV Cells

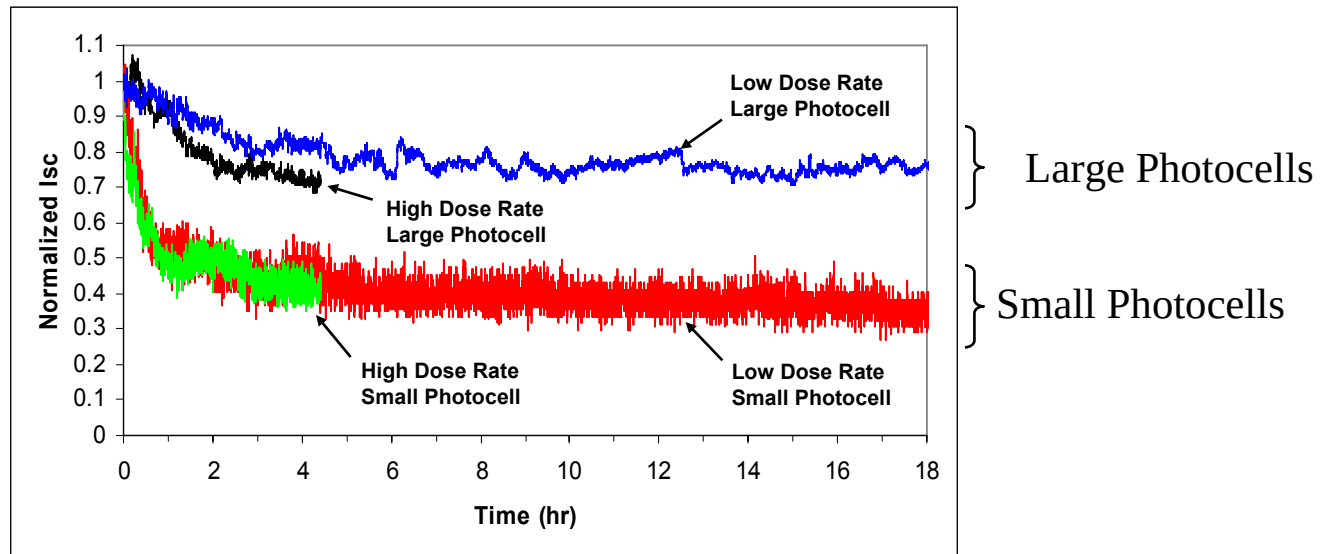
GIF Testing of Large PV Cells



Black Trace = 120x550 μm Cell High Dose
Green Trace = 20x20 μm Cell High Dose
Blue Trace = 120x550 μm Cell Low Dose
Red Trace = 20x20 μm Cell Low Dose



GIF Testing of Small PV Cells



- **Results Suggest Time Dependent Degradation Independent of Dose Rate**
 - Possible ELDRS Effect
- **Small Cells Exhibited Greater Degradation**



Conclusions

- **Radiation Testing of Photovoltaic Devices at ACRR and GIF**
- **Commercial GaAs 6 V Photocells and SNL Si Photocells Show Comparable Degradation in a Mixed Gamma-Neutron Environment**
- **I_{SC} Degradation is Independent of Photocell Size in a Mixed Gamma-Neutron Environment**
- **No Annealing Following Radiation Exposure**
- **1 MeV(Si) Neutron Fluence on the Order of $1E14$ neutrons/cm² Resulted in ~70% Reduction in the Short Circuit Current with ~20% Reduction in Output Voltage**
- **1 MeV(Si) Neutron Fluence on the Order of $1E13$ neutrons/cm² Resulted in ~30% Reduction in the Short Circuit Current with ~10% Reduction in Output Voltage**
- **Gamma Induced I_{SC} Degradation in Si Devices is a Function of Rate, Junction Area, and Total Dose Suggesting Photocells Exhibit**