



Study of the Radiation Hardness of VCSEL and PIN Arrays

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Outline



- Introduction
- Radiation hardness of VCSEL arrays
- Radiation hardness of PIN arrays
- Summary



ATLAS Pixel Opto-Link



- ATLAS is a detector studying pp collisions of 14 TeV at CERN
 - ◆ pixel detector is innermost tracker
 - ◆ inner most layer replacement planned in 2012
 - ◆ detector upgrade planned for Super-LHC in 2015
 - ⇒ study radiation-hardness of VCSEL and PIN arrays for the opto-link upgrades



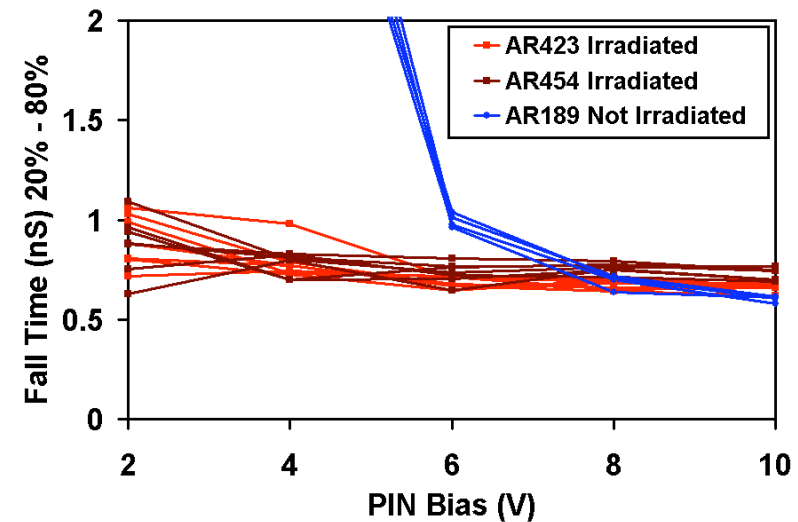
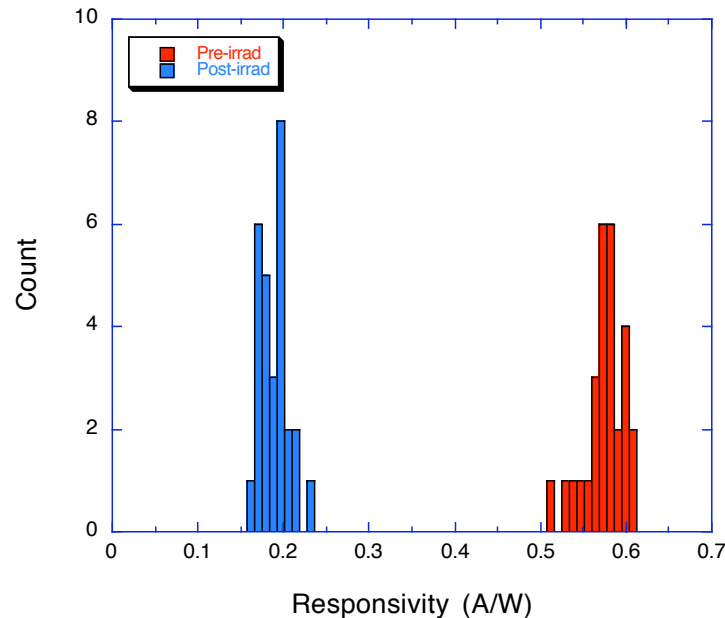
Radiation Level at SLHC



- Optical link of current pixel detector is mounted on patch panels:
 - ⇒ much reduced radiation level:
 - ◆ Si (PIN) @ SLHC ($3,000 \text{ fb}^{-1}$):
 - $1.5 \times 10^{15} \text{ 1-MeV } n_{\text{eq}}/\text{cm}^2$
 - $2.6 \times 10^{15} \text{ p/cm}^2$ or 69 Mrad for 24 GeV protons
 - ◆ GaAs (VCSEL) @ SLHC:
 - $8.2 \times 10^{15} \text{ 1-MeV } n_{\text{eq}}/\text{cm}^2$
 - $1.6 \times 10^{15} \text{ p/cm}^2$ or 34 Mrad for 24 GeV protons
 - ◆ above estimates include 50% safety margin



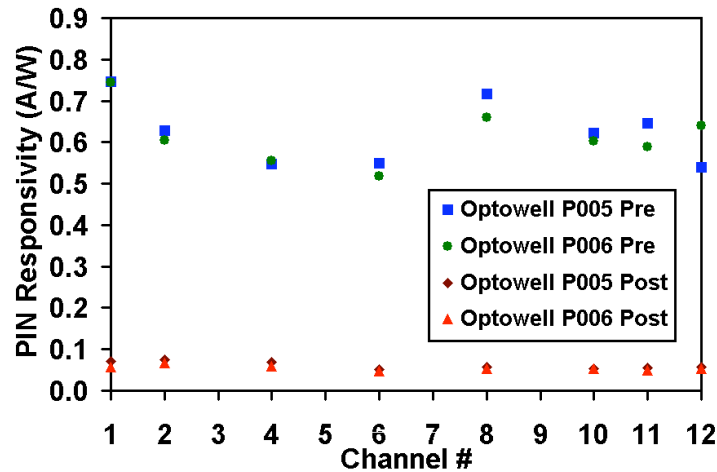
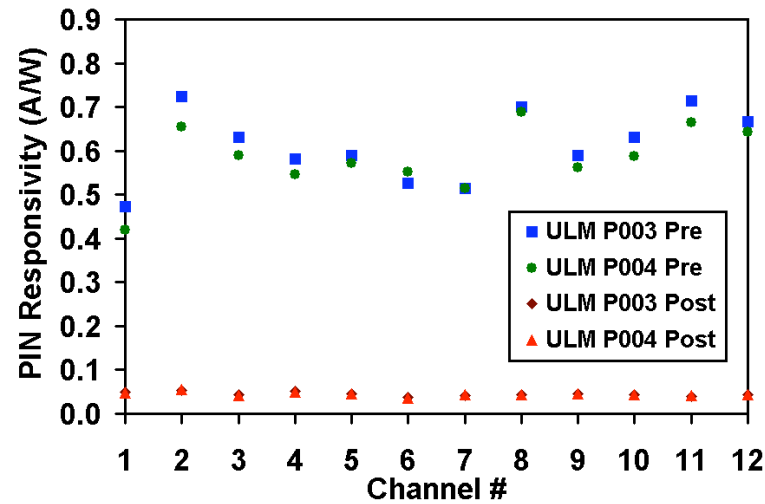
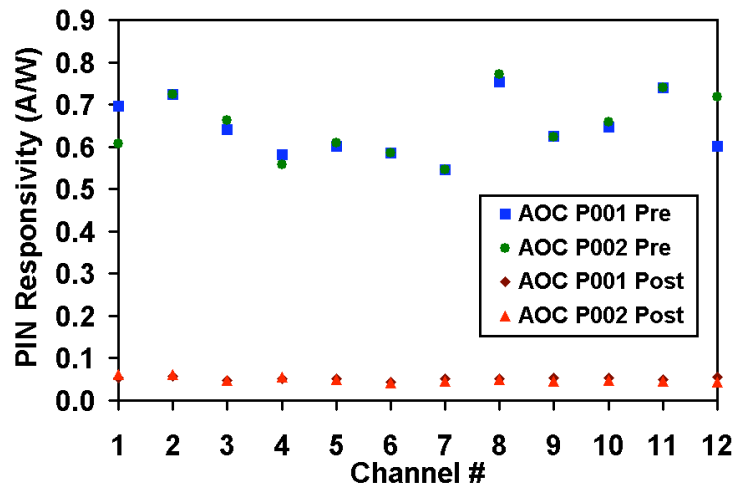
Radiation-Hardness of Silicon PIN



- PIN responsivity decreases by 65% after SLHC dosage
- no degradation of rise/fall time
 - ✓ operation at 160 MHz is OK



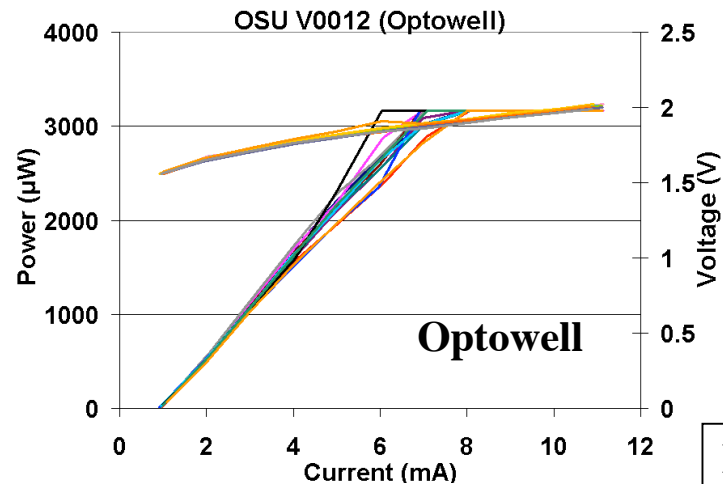
Radiation-Hardness of GaAs PIN



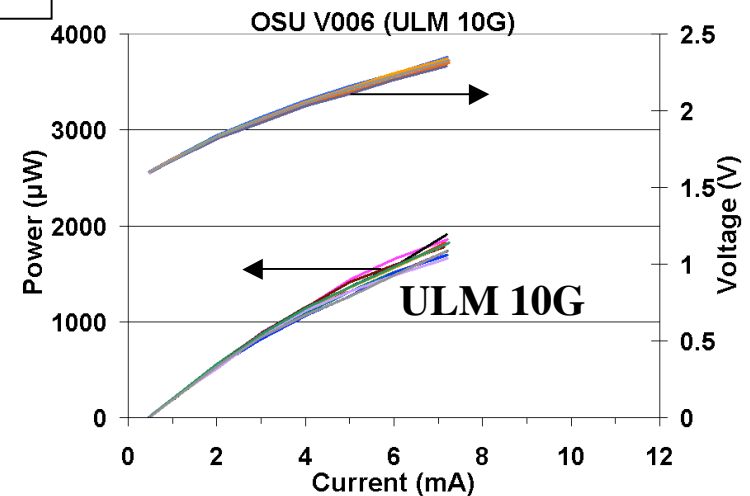
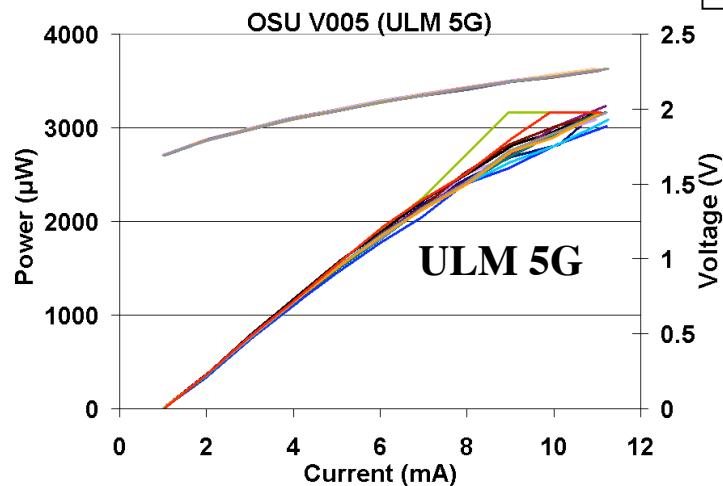
- all arrays are front side illuminated
- PIN responsivity decreases by ~10X



VCSEL LIV Characteristics



Pre-irrad

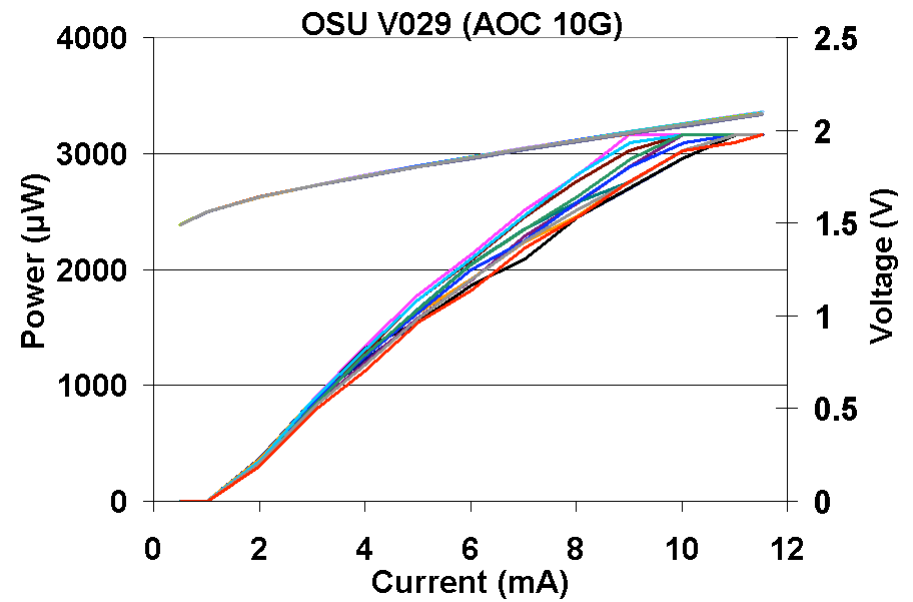
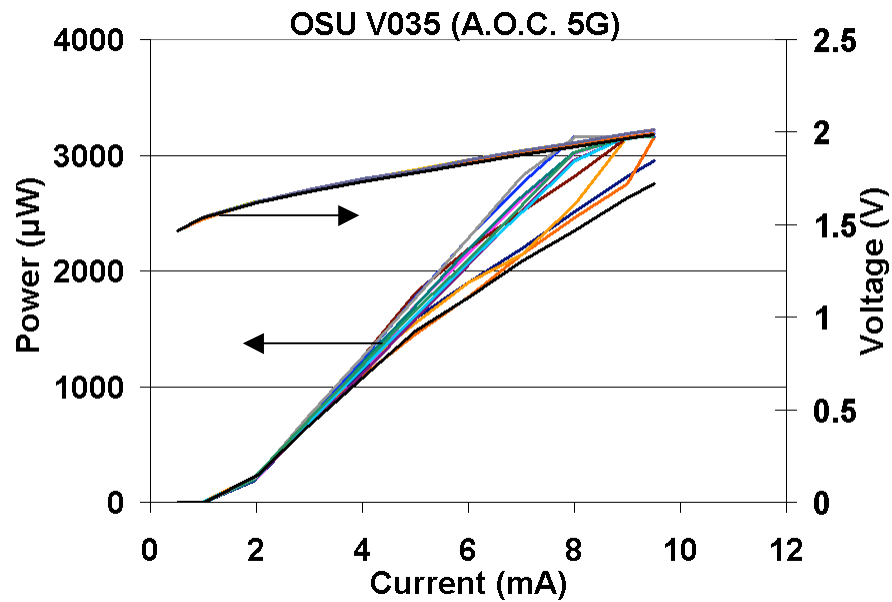


☹ ULM requires higher voltage to operate

● all arrays have very good optical power



VCSEL LIV Characteristics

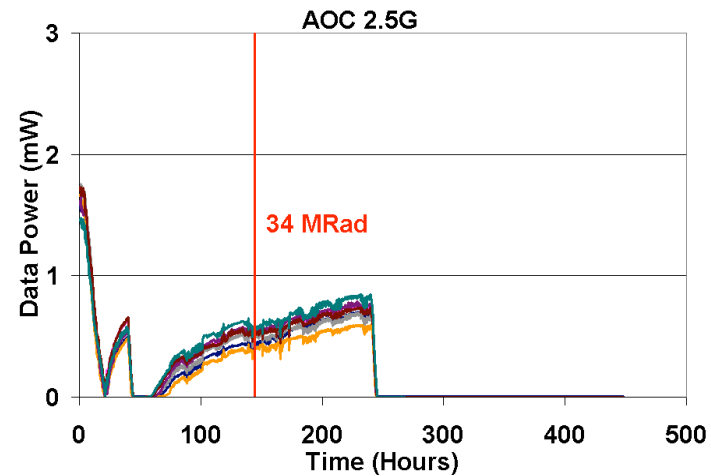
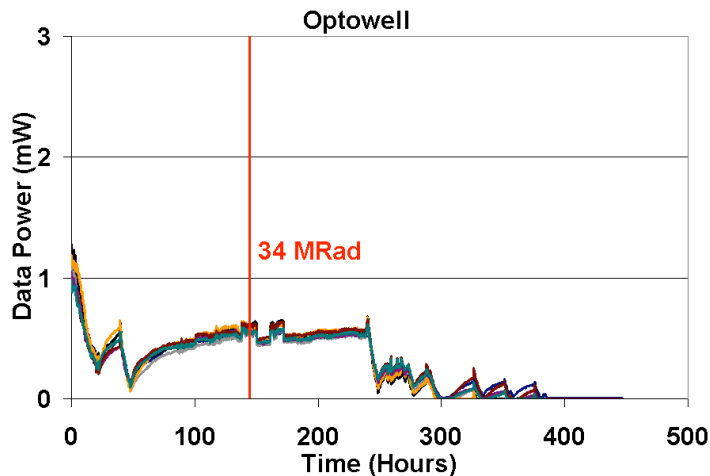


Pre-irrad

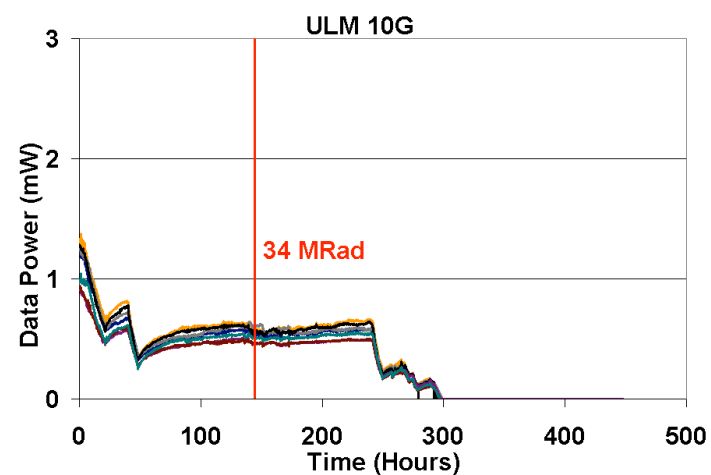
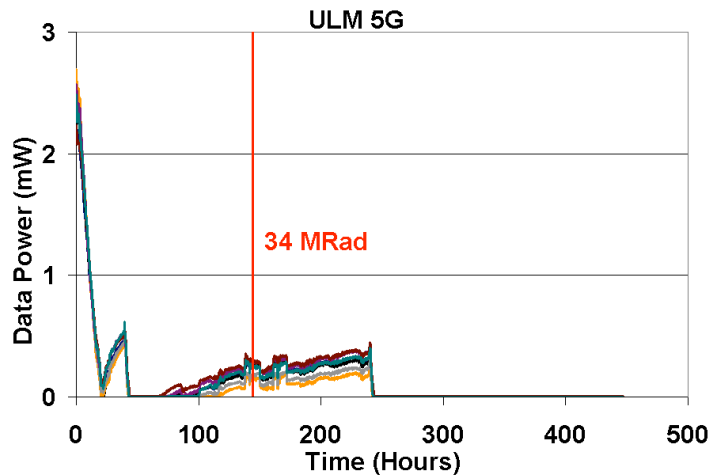
- both arrays have very good optical power



VCSEL Power vs Dosage



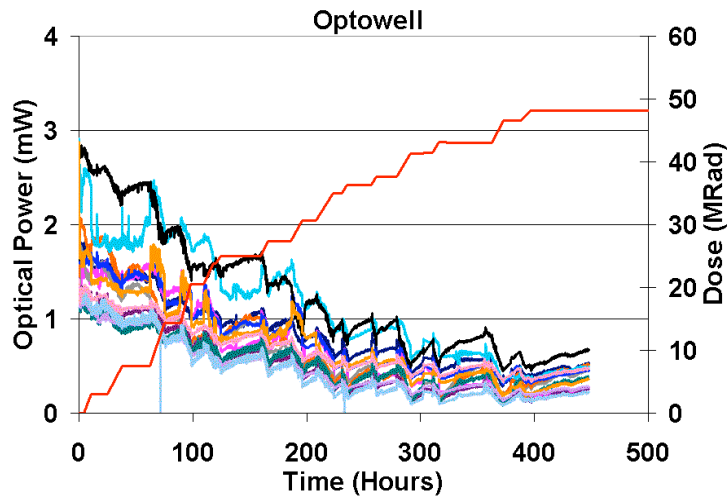
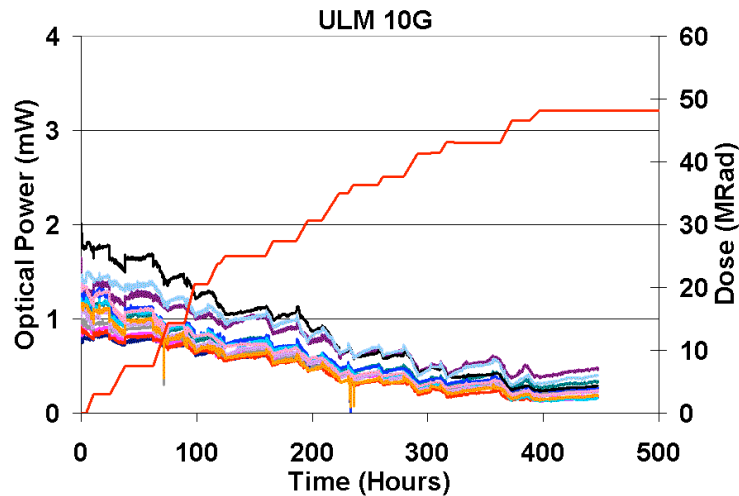
2006:
Two arrays each
(2 x 7 channels)



- Optowell & ULM (10 Gb/s) survive to SLHC dosage
- more VCSELs might survive with lower intensity/more annealing

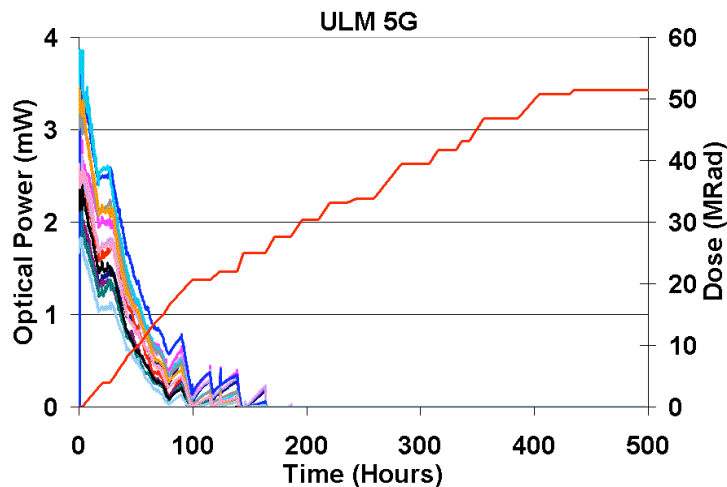
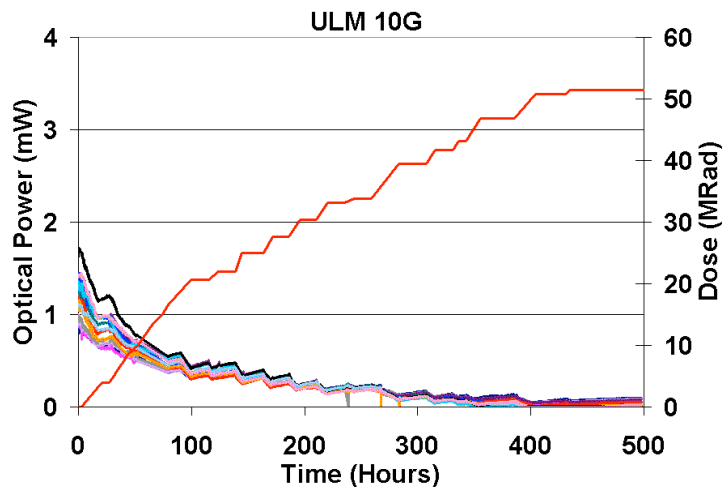


VCSEL Power vs Dosage



1st irradiation period

2007 preliminary
Two arrays each
(2 x 7 channels)

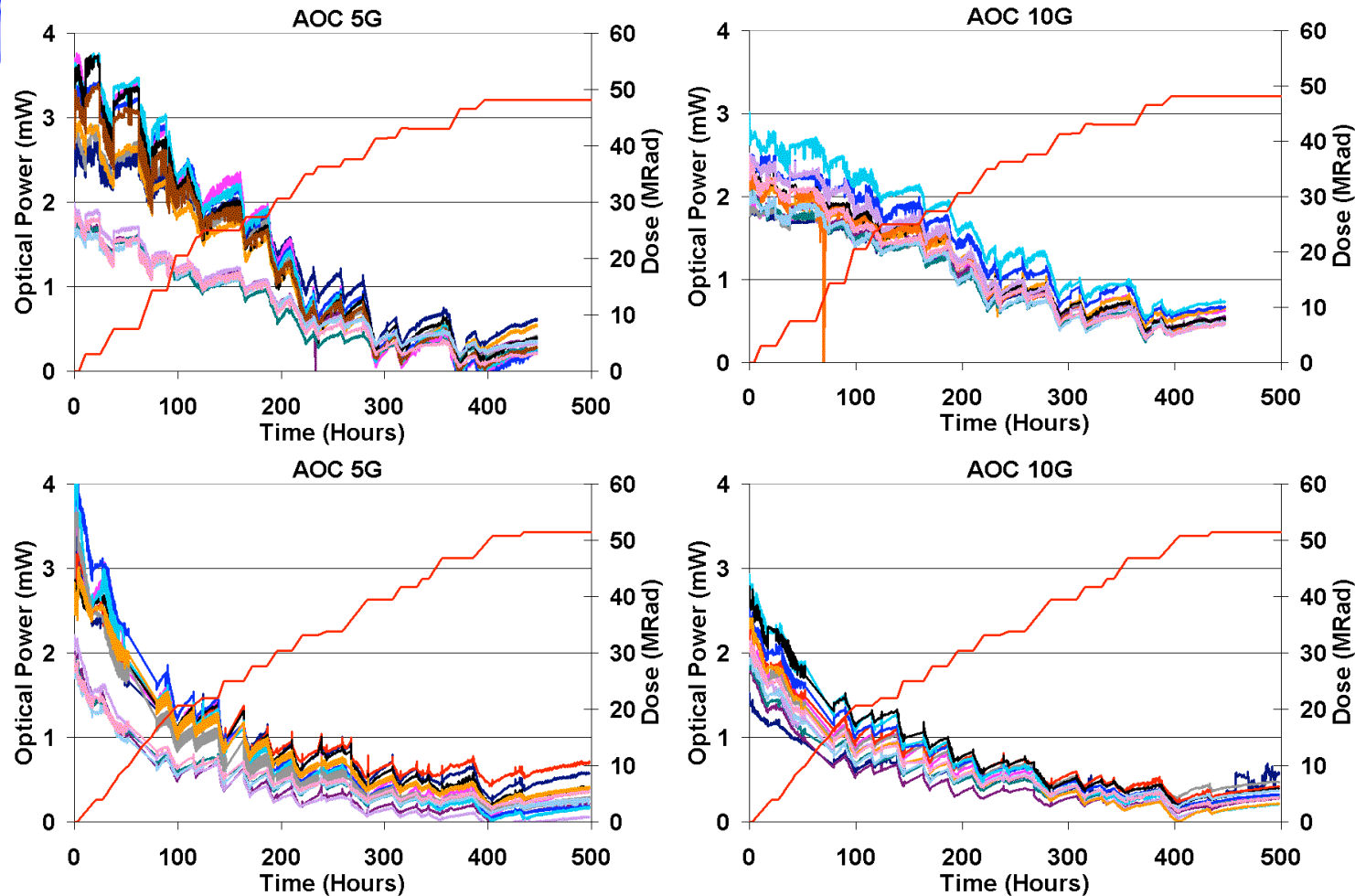


2nd irradiation period

- Optowell & ULM (10 Gb/s) survive to SLHC dosage



VCSEL Power vs Dosage



1st irradiation period

2007 preliminary
Two arrays each
(2 x 7 channels)

2nd irradiation period

- AOC (5 & 10 Gb/s) survive to SLHC dosage
- need further analysis after radiation cool down...



Summary

- Si PIN responsivity decreases by 65% after SLHC dosage
- GaAs PIN responsivity decreases by $\sim 10X$
- VCSEL from 3 vendors survive to SLHC dosage