Results of Opto-Link R&D

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Outline

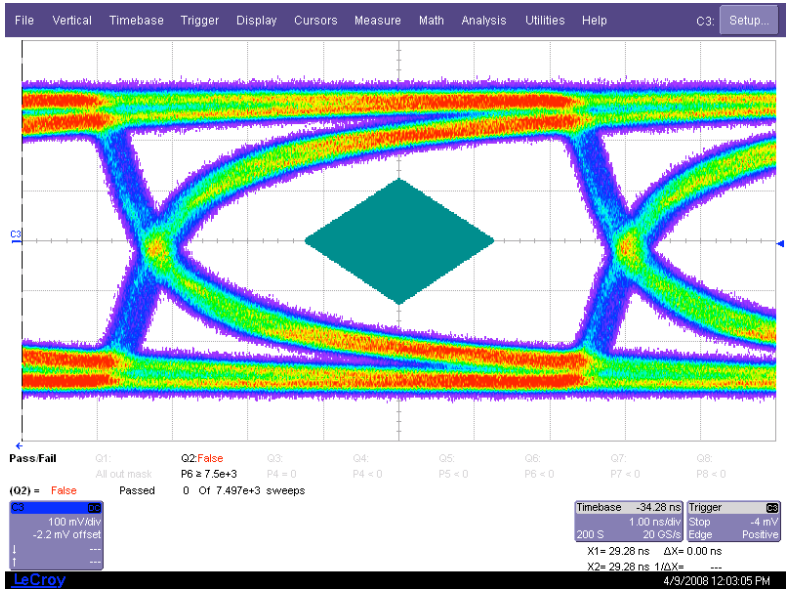
- Transmission on micro-cables
- Radiation hardness of PIN arrays
- Radiation hardness of VCSEL arrays
- Status of opto-chips
- Summary

Transmission on Micro-Cables

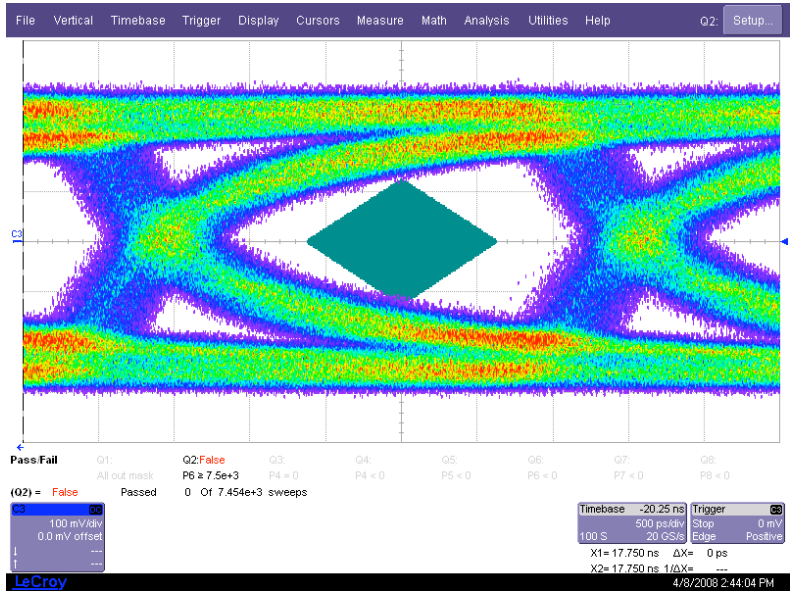
- optical link of current pixel detector is mounted on patch panels:
  - ⇨ much reduced radiation level
- use micro-twisted pairs for transmission between pixel and opto modules
  - ⇨ simplified the design/production of both types of modules
- pixel twisted pair:
  - OD: 0.3 mm (100 μm wire + 25 μm insulation)
  - can transmit at 640 Mb/s up to 1.4 m
- TRT shielded twisted pair:
  - OD: 1 mm
  - what is the bandwidth if the opto-link is moved out to 5 m?

Eye Diagrams

160 Mb/s

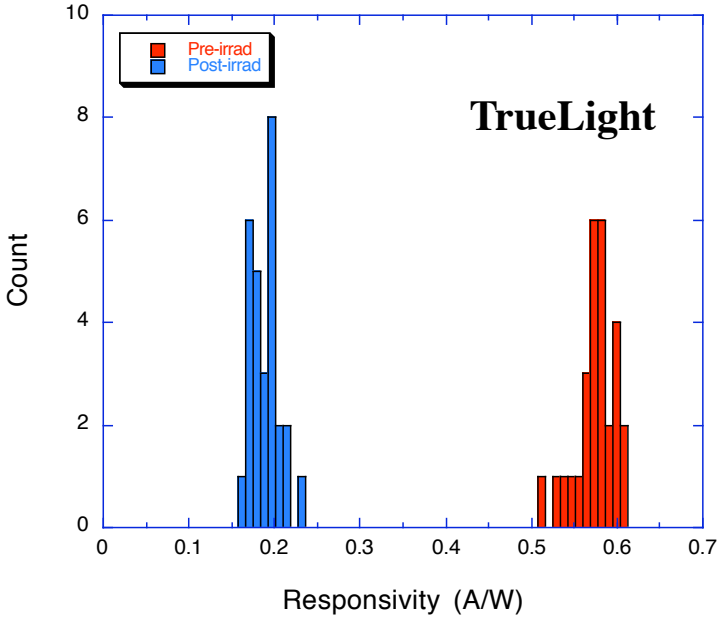


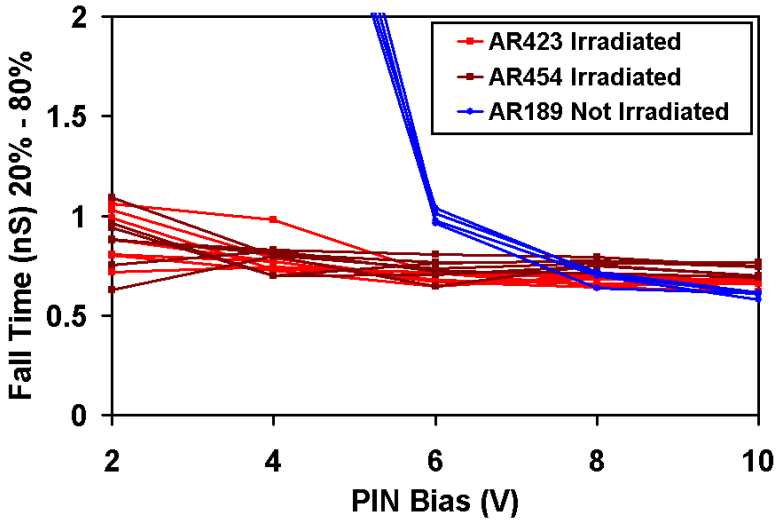
320 Mb/s



- transmission at 160 Mb/s is adequate

Radiation-Hardness of Silicon PIN

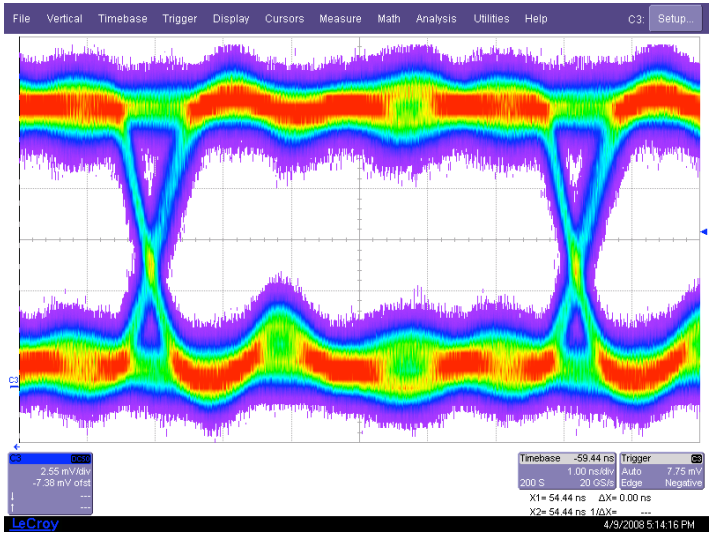




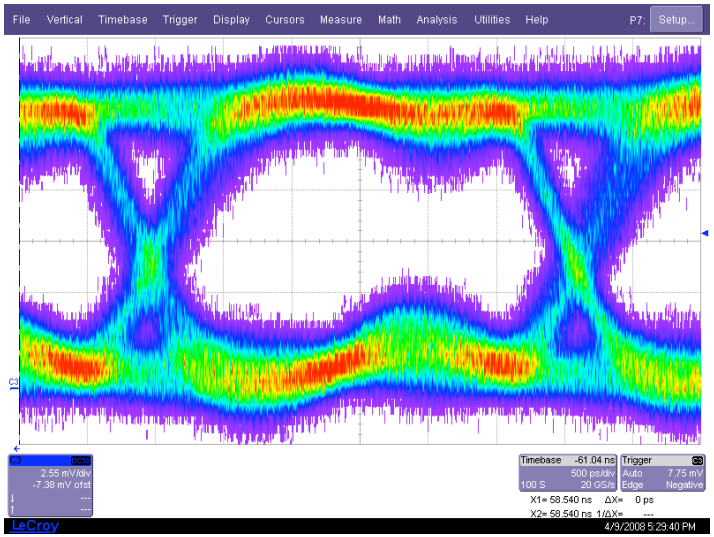
- irradiate PIN/VCSEL arrays with 24 GeV protons at CERN
- PIN responsivity decreases by 3x at 114 Mrad (SLHC: 69 Mrad)
- no degradation of rise/fall time

Eye Diagrams

160 Mb/s

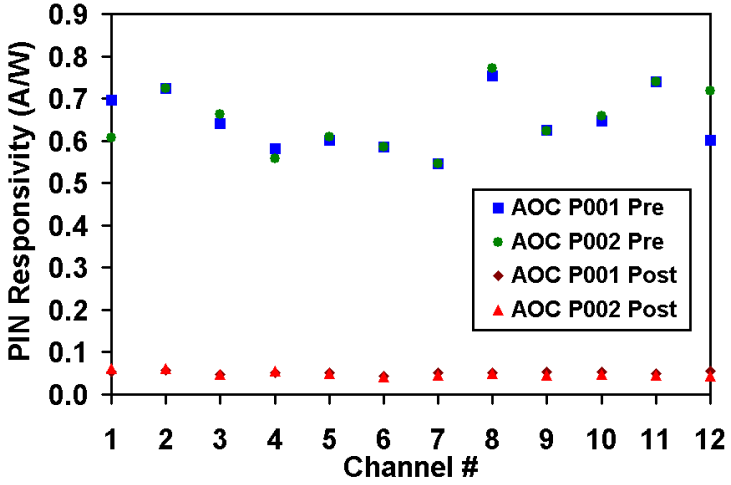


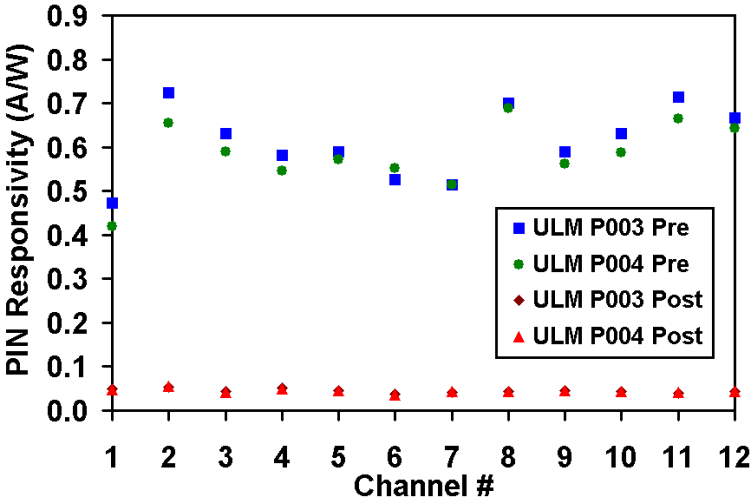
320 Mb/s

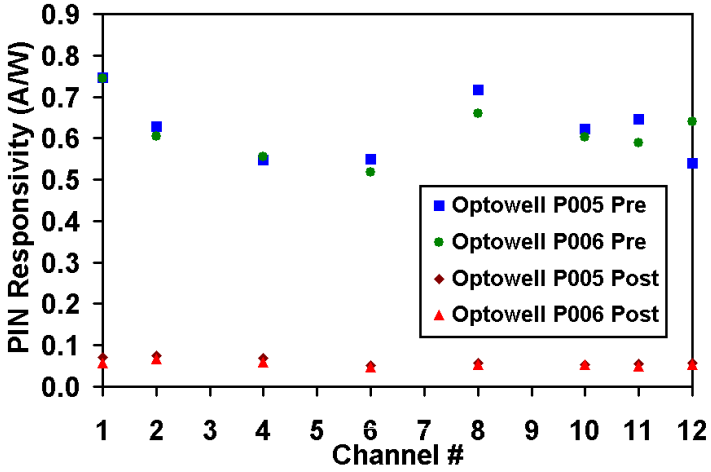


- measured using coax terminated with 50 Ω
  - plan to reduce noise with TIA
- operating at 320 Mb/s is probably adequate

Radiation-Hardness of GaAs PIN

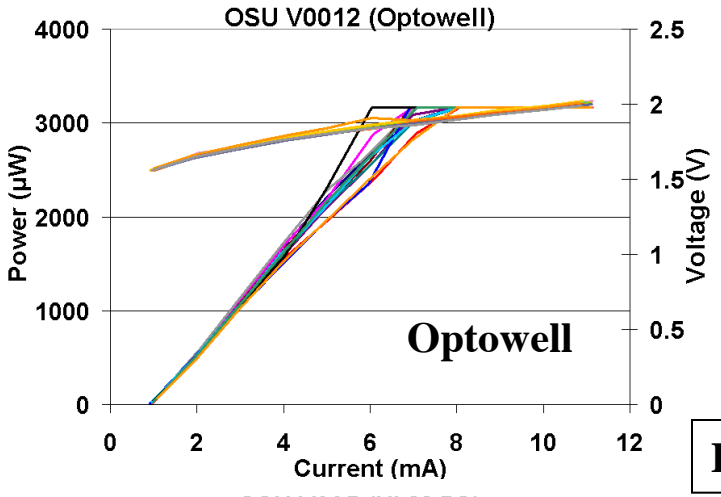




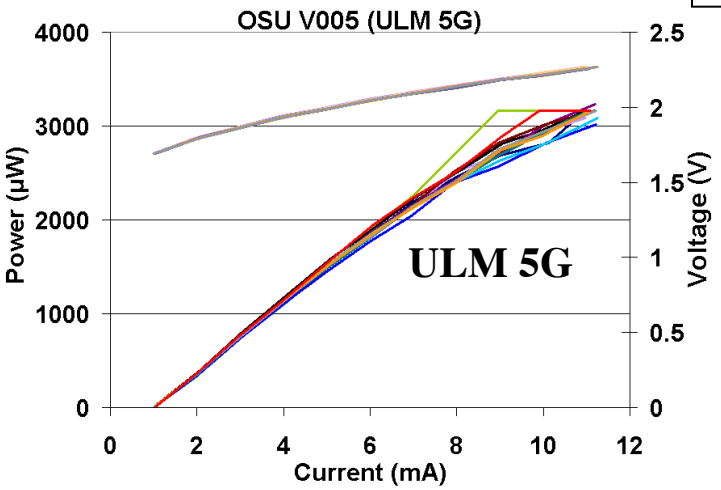


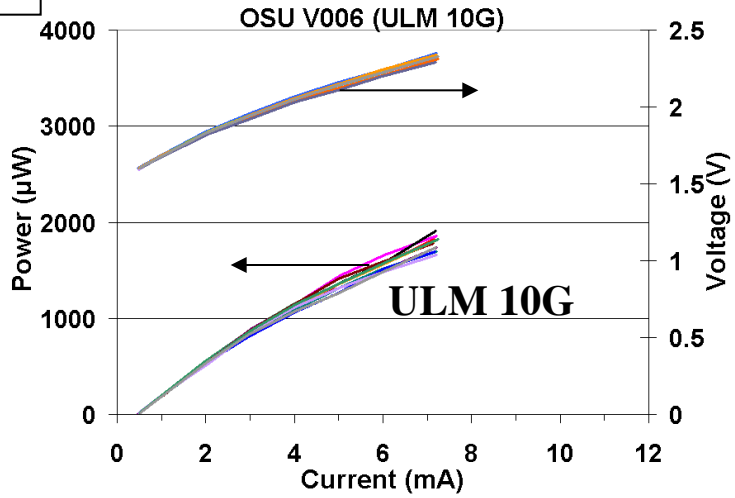
- all arrays are front side illuminated
- PIN responsivities decrease by ~10x at 53 Mrad
- should repeat irradiation to SLHC dosage of 34 Mrad

VCSEL LIV Characteristics



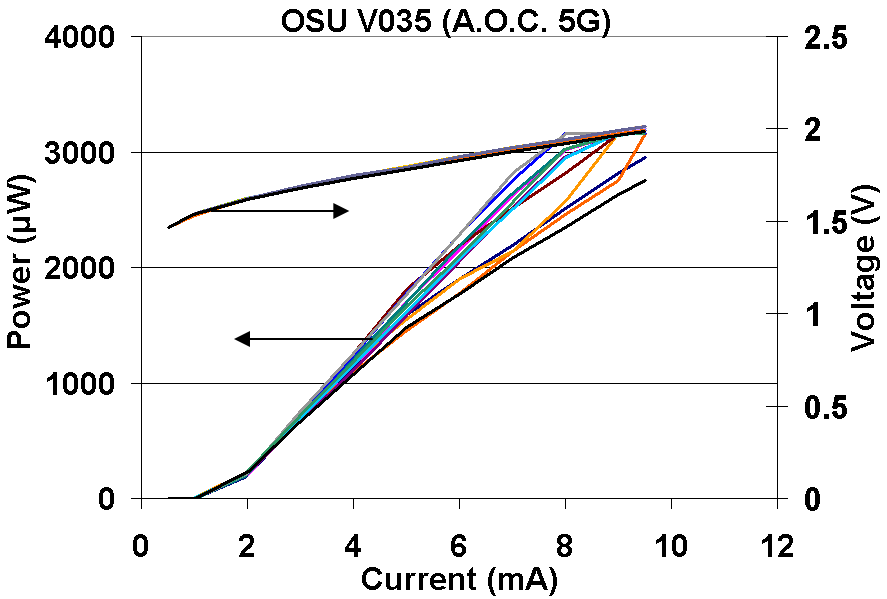
Pre-irrad

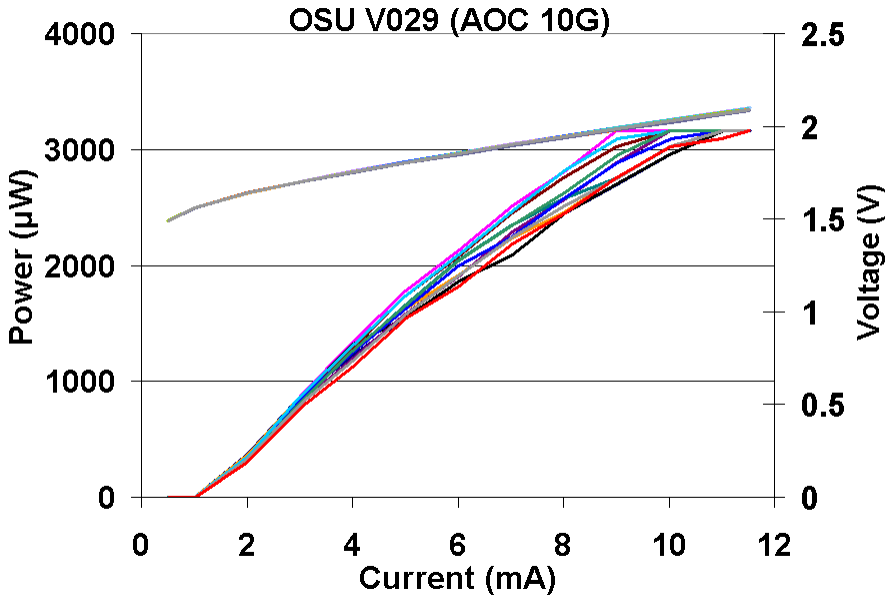




- ☹ ULM requires higher voltage to operate
- ● all arrays have very good optical power

VCSEL LIV Characteristics

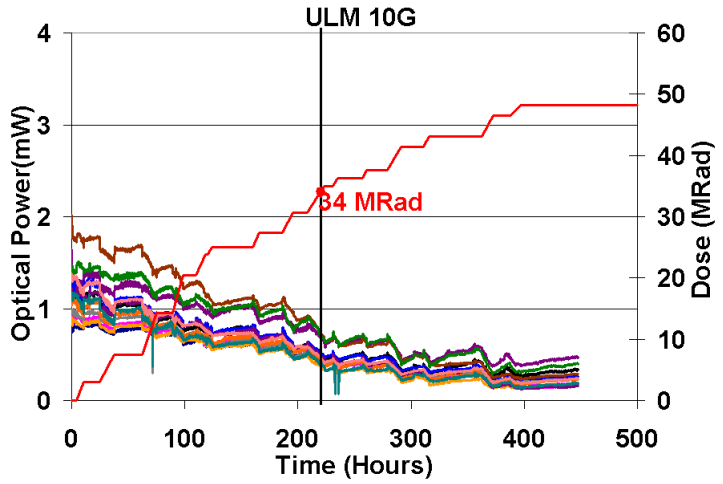


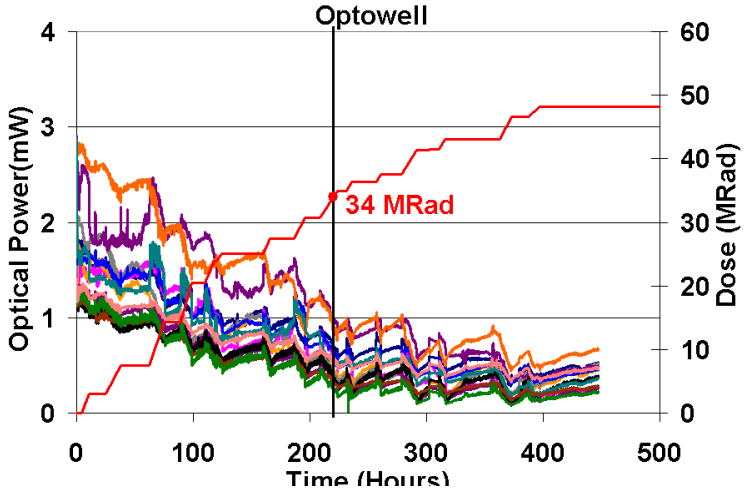


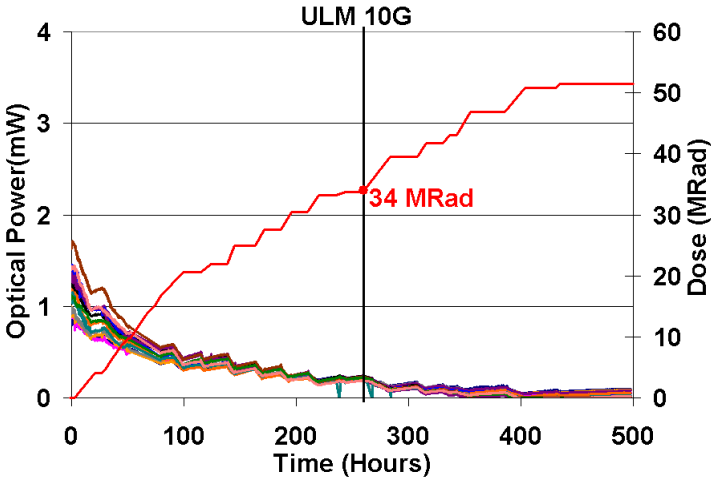
Pre-irrad

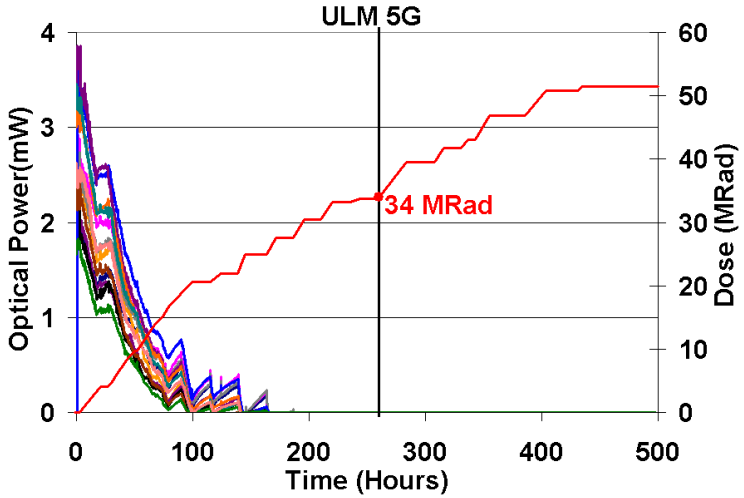
- both arrays have very good optical power

VCSEL Power vs Dosage









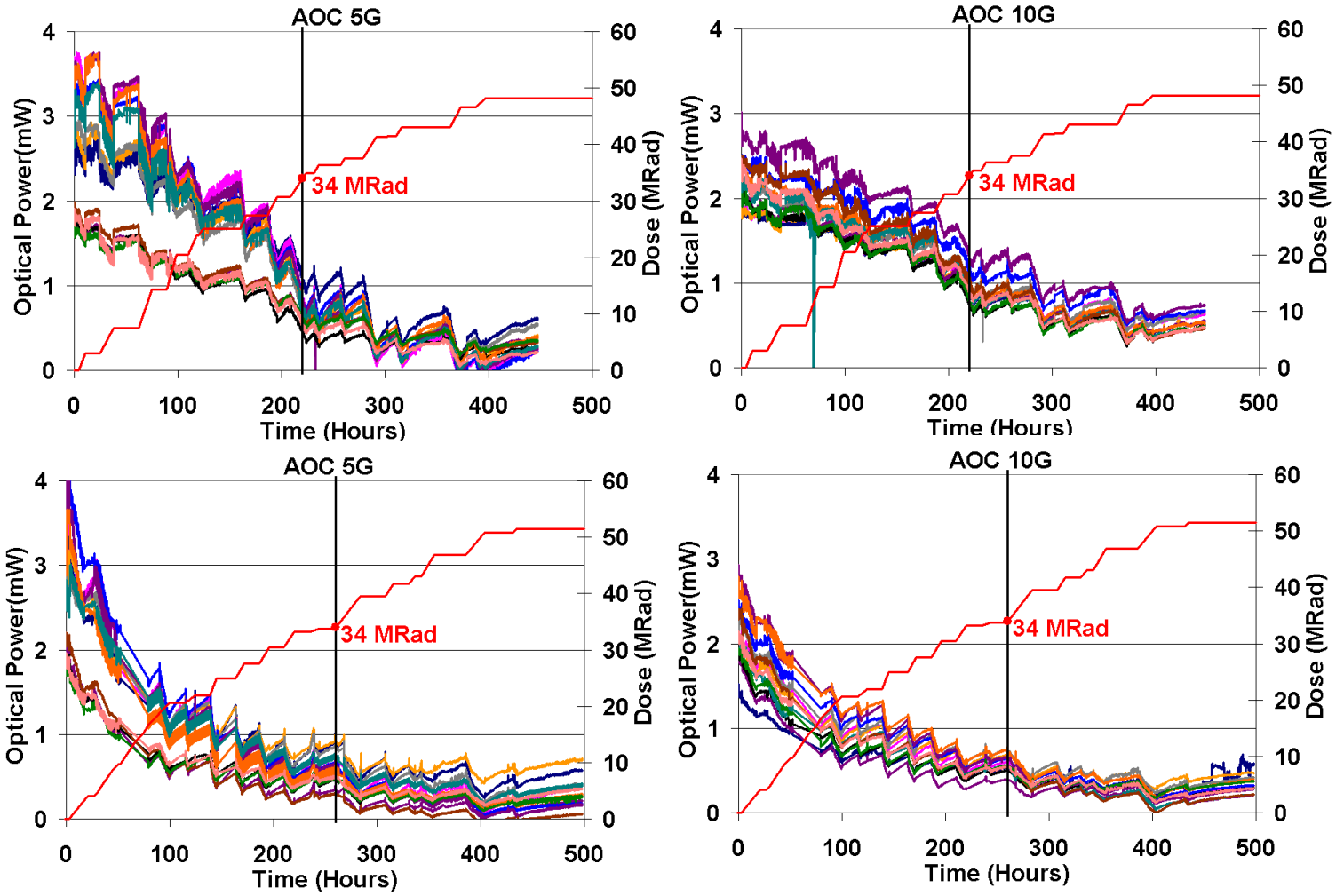
1st irradiation period

2007: Two arrays each (2 x 7 channels)

2nd irradiation period

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

VCSEL Power vs Dosage



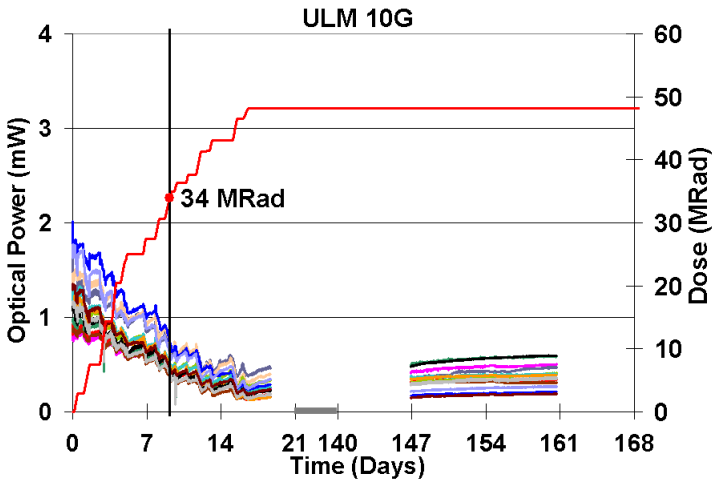
1st irradiation period

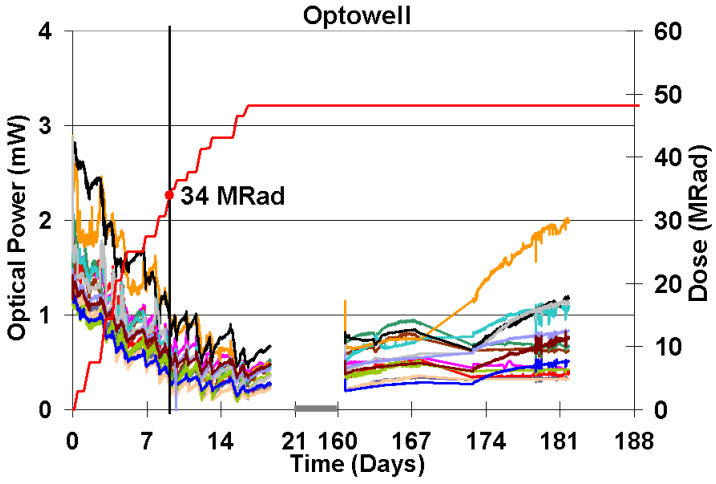
2007: Two arrays each (2 x 7 channels)

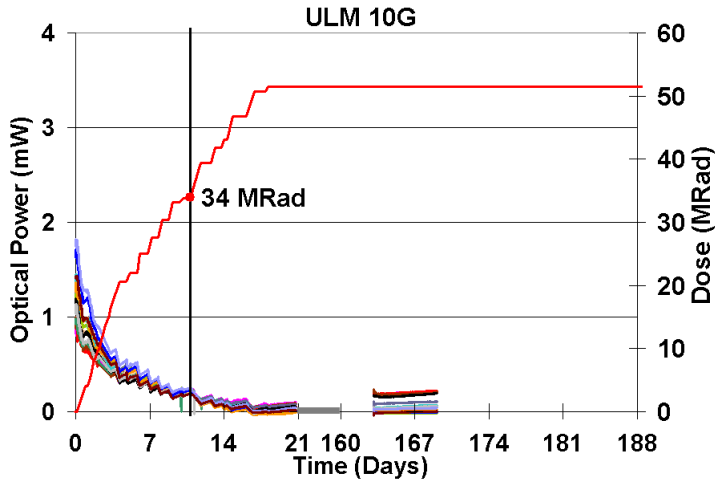
2nd irradiation period

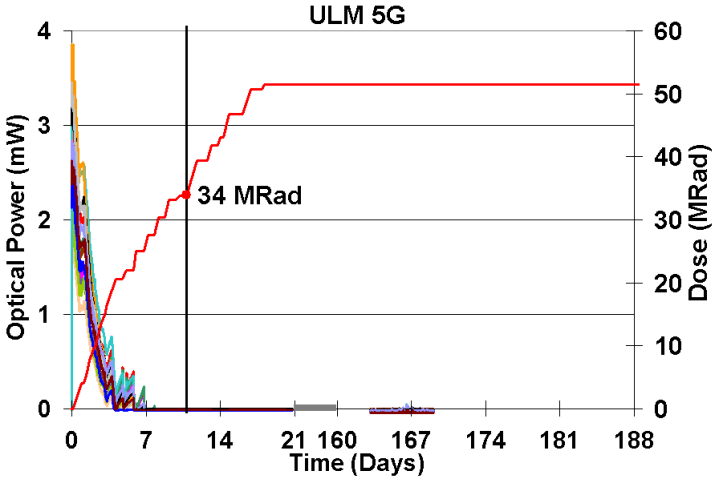
- AOC (5 & 10 Gb/s) survive to SLHC dosage

Annealing of VCSEL Arrays



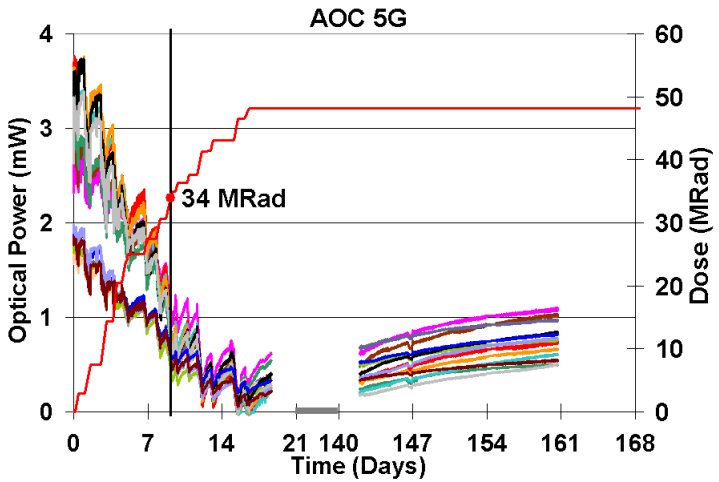


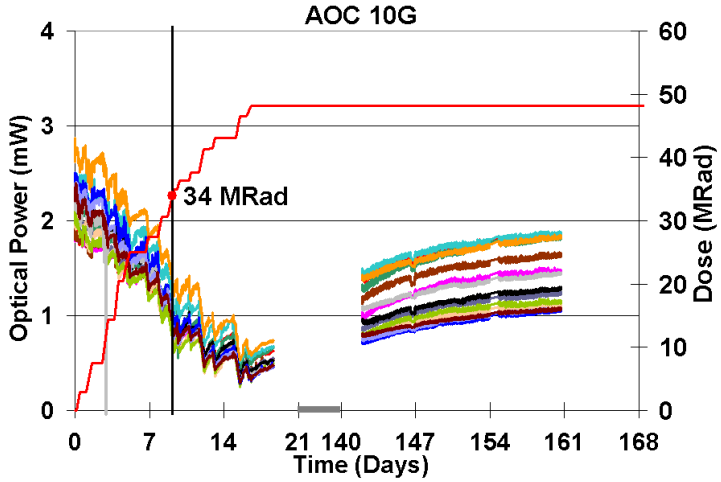


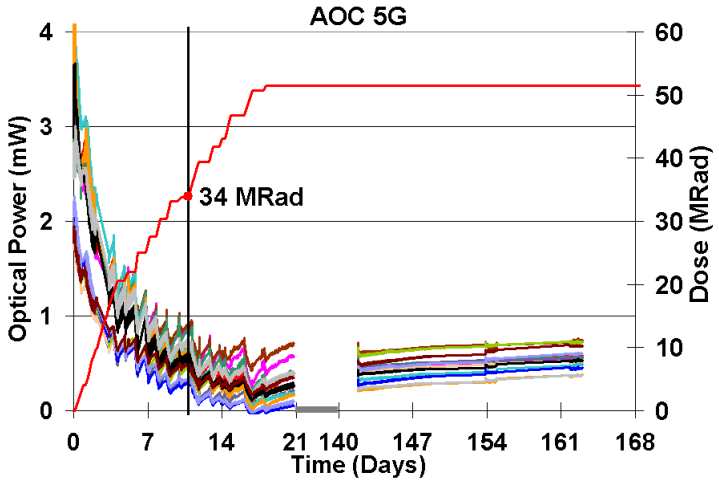


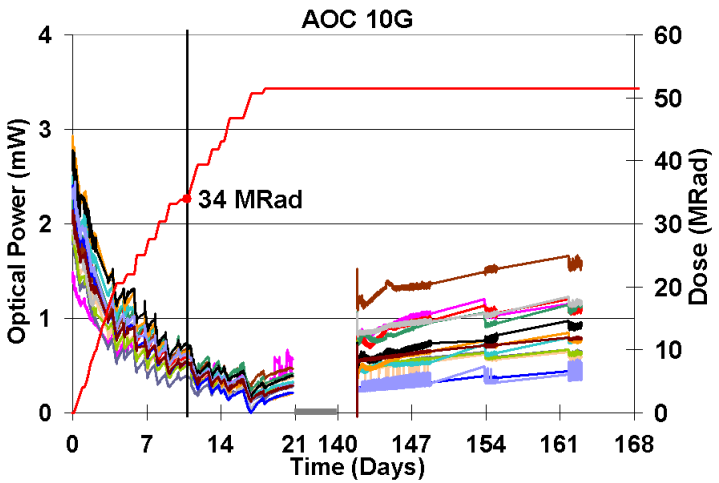
- recovery is slow
- Optowell has the highest annealed power

Annealing of VCSEL Arrays



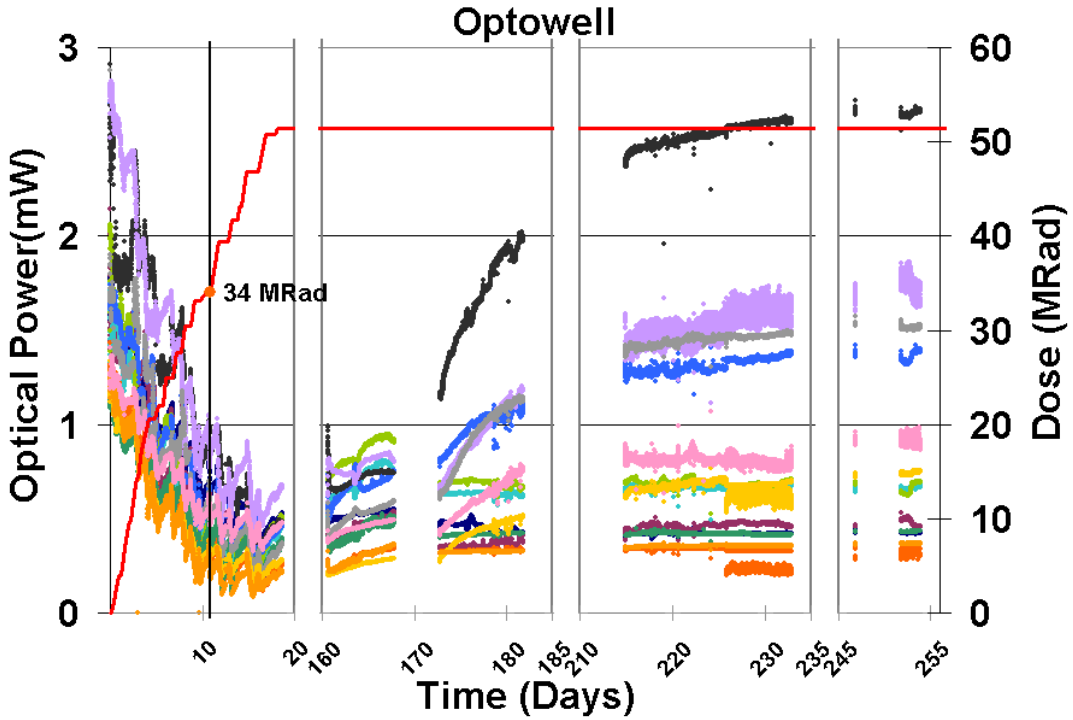






- recovery is slow but adequate annealed power

More Annealing of VCSEL



- VCSEL might not fully recover after SLHC dosage

Irradiation Plan

- should repeat irradiation to dosage for 3,000 fb^{-1} instead of 5,000 fb^{-1}
  - PIN:
    - Si: TrueLight, Hamamatsu
    - GaAs: AOC, ULM, Optowell
  - VCSEL:
    - AOC, Optowell, ~~ULM~~?
  - August 08 with 24 GeV/c p (CERN)

Opto-Chips

- 4 mm^2 prototype chip was submitted on March 24
  - receiver/decoder operating at 40, 160 and 320 MHz
    - use bi-phase marked encoding due to the low speed
  - VCSEL driver operating at 640 Mb/s and 3.2 Gb/s
  - both designs take advantage of LHC experience
  - SMC block: 640 MHz serialization clocks
    - SEU tolerant multipliers (16 x 40 MHz or 4 x 160 MHz)
- test radiation-hardness/SEU in August 2008

Summary

- TRT micro cable can transmit at 160 MHz up to 5 m
- Si PIN probably can transmit at 320 MHz @ SLHC dosage
- GaAs PIN responsivity decreases by 10X@ SLHC dosage
- AOC and Optowell are potential candidates for SLHC
- should repeat irradiation to dosage for 3,000 fb^{-1} instead of 5,000 fb^{-1}
- prototype chip submitted to test
  various upgrade scenario/radiation hardness