



Bandwidths of Micro Twisted-Pair Cables and Fusion Spliced SIMM-GRIN Fibers and Radiation Hardness of PIN/VCSEL

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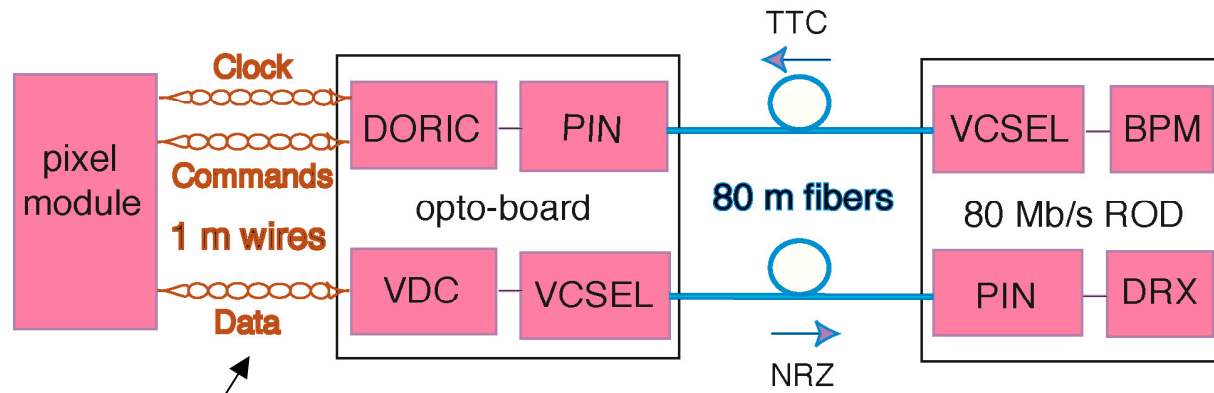
Outline



- Introduction
- Bandwidth of micro twisted-pair cables
- Bandwidth of fusion spliced SIMM-GRIN fibers
- Radiation hardness of PIN/VCSEL arrays
- Summary



ATLAS Pixel Opto-Link Architecture



micro twisted pairs decouple
pixel and opto module production
⇒ simplify both production

8 m of rad-hard/low-bandwidth
SIMM fiber fusion spliced to 70 m
rad-tolerant/medium-bandwidth
GRIN fiber

- upgrade based on current pixel opto-link architecture to take advantage of R&D effort and production experience?
⇒ can current pixel link infrastructure be operated at higher speed?



R&D Issues for SLHC



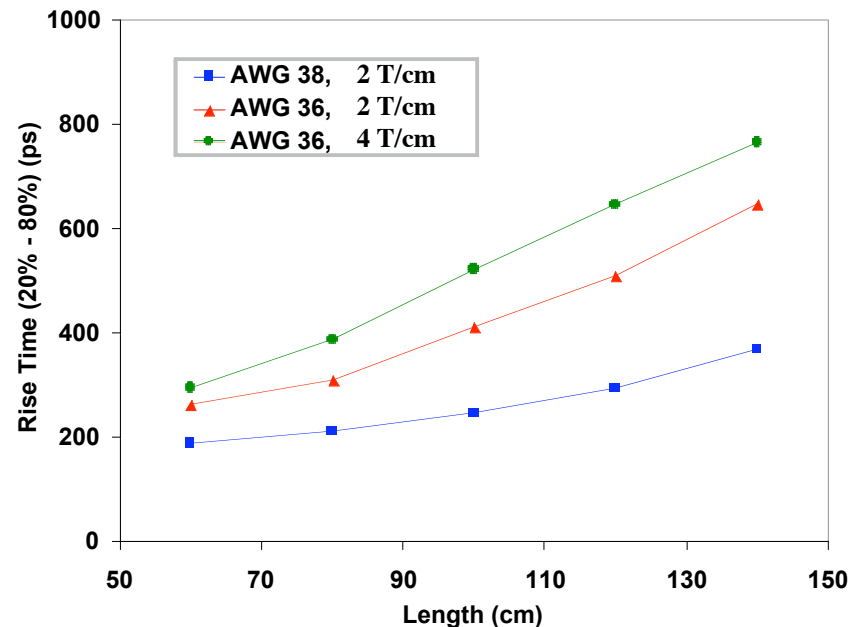
- bandwidth of ~ 640 Mb/s ($= 8 \times 80$ Mb/s) is needed
 - ◆ can micro twisted pair transmit at this speed?
 - ◆ can fusion spliced SIMM/GRIN fiber transmit at this speed?
- can PIN/VCSEL arrays survive SLHC radiation dosage?
- upgraded version of driver/receiver chips are needed



Bandwidth of Micro Twisted Pairs



- bandwidth of 3 micro twisted-pair wires were compared:
 - ◆ 38 AWG/100 μm , 2 turns/cm (current pixel cable)
 - ◆ 36 AWG/127 μm , 2 turns/cm
 - ◆ 36 AWG/127 μm , 4 turns/cm



- current pixel cable is the best!



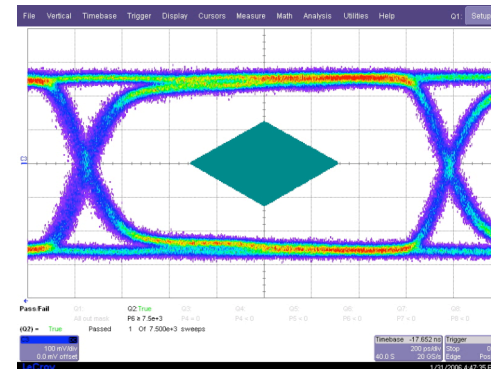
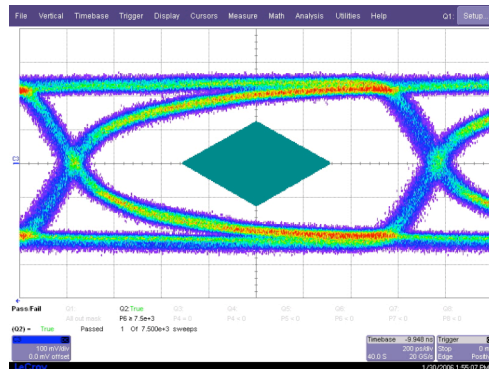
Eye Diagrams



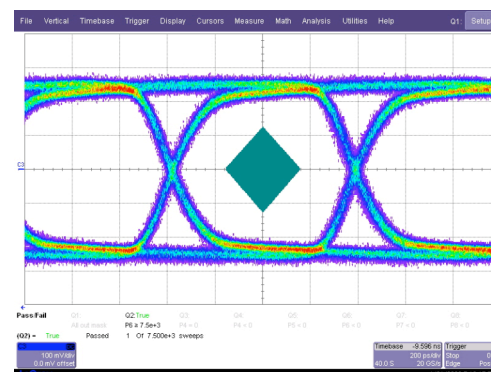
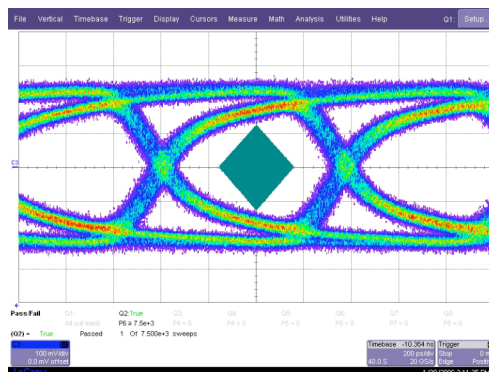
140 cm pixel cable

60 cm pixel cable

650 Mb/s



1.3 Gb/s



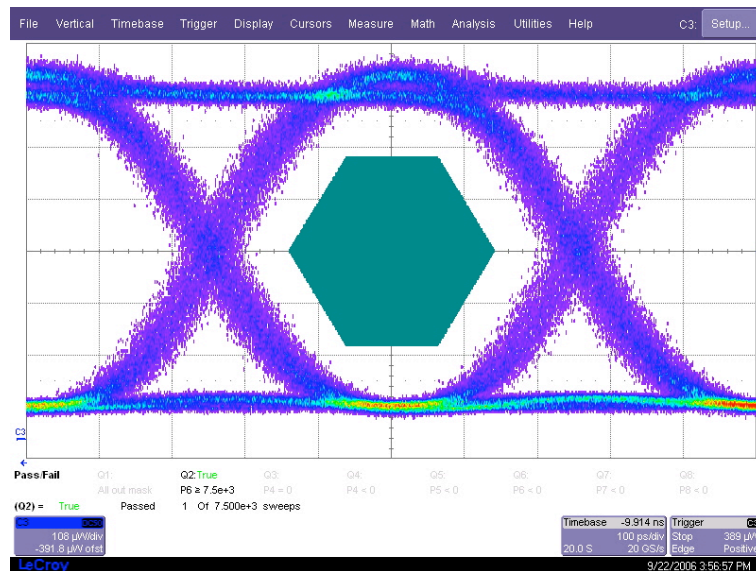
- transmission at 650 Mb/s is adequate
- transmission at 1.3 Gb/s may be acceptable



Bandwidth of Fusion Spliced Fiber

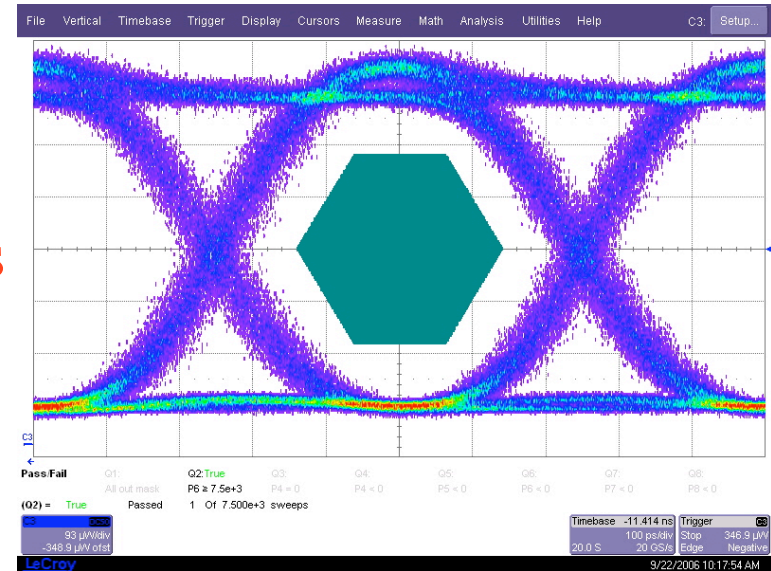


1 m GRIN fiber



2 Gb/s

8 + 80 m spliced SIMM/GRIN fiber



- transmission up to 2 Gb/s looks adequate



Radiation Level at SLHC



- Optical link of current pixel detector is mounted on patch panel:
 - ⇒ much reduced radiation level:
 - ◆ Si (PIN) @ SLHC:
 - 2.5×10^{15} 1-MeV n_{eq}/cm^2
 - 4.3×10^{15} p/cm² or 114 Mrad for 24 GeV protons
 - ◆ GaAs (VCSEL) @ SLHC:
 - 14×10^{15} 1-MeV n_{eq}/cm^2
 - 2.7×10^{15} p/cm² or 71 Mrad for 24 GeV protons
 - ◆ above estimates include 50% safety margin



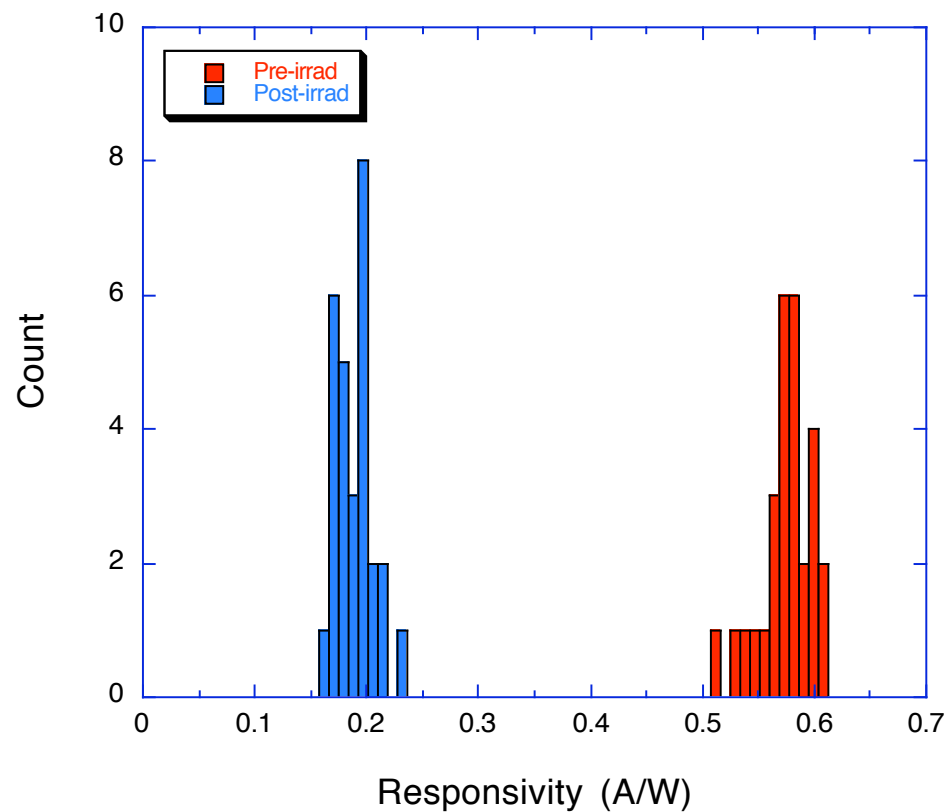
Requirements for PIN/VCSEL



- PIN:
 - ◆ What is responsivity after irradiation?
 - ◆ What is rise/fall time after irradiation?
- VCSEL:
 - ◆ driver chip most likely be fabricated with 0.13 μm process
 - operating voltage is 1.2 V
 - thick oxide option can operate at 2.5 V
 - ⇒ VCSEL must need < 2.3 V to produce 10 mA or more
 - ◆ What is rise/fall time after irradiation?
 - ◆ What is optical power after irradiation?
 - ◆ What current is needed for annealing?



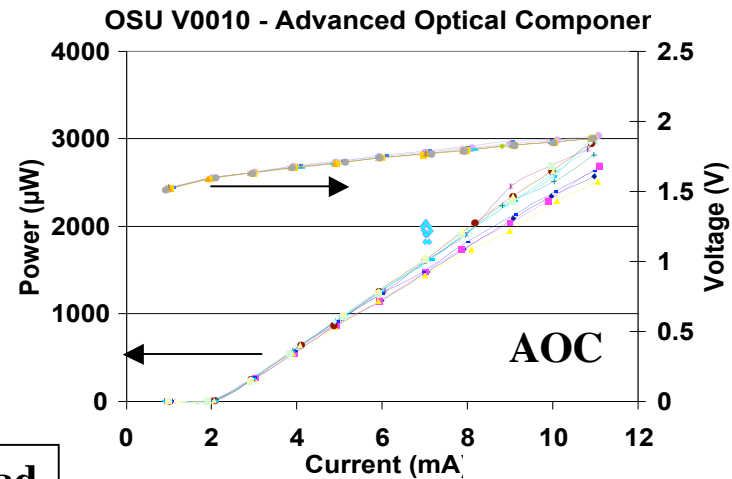
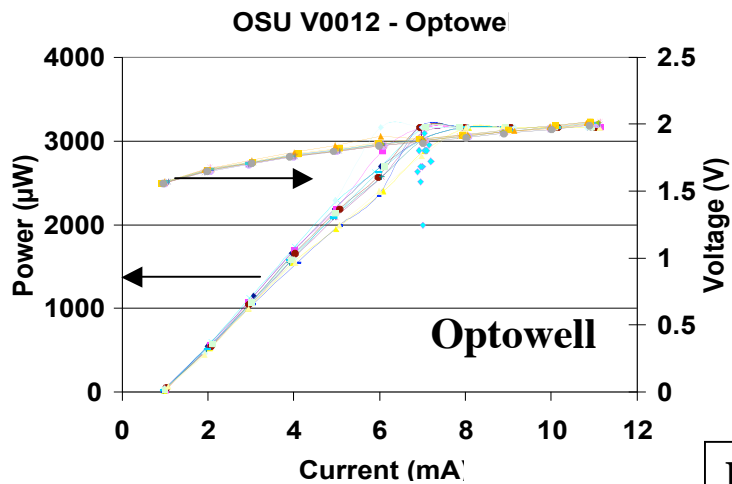
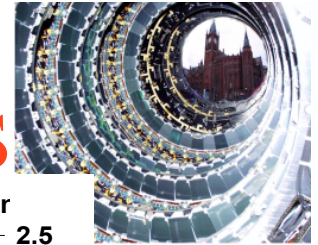
PIN Responsivity



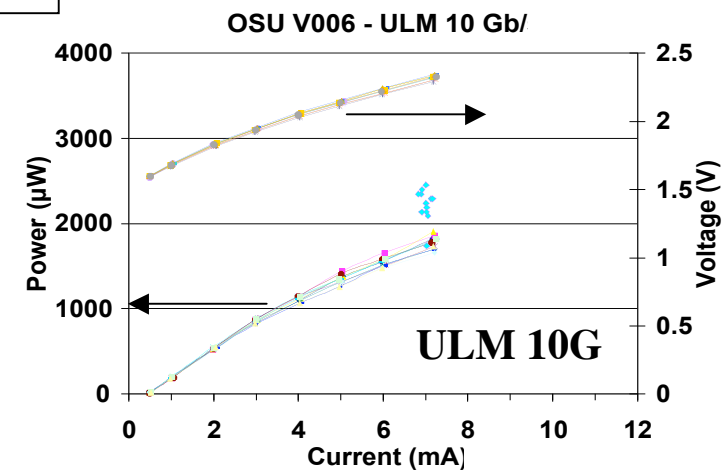
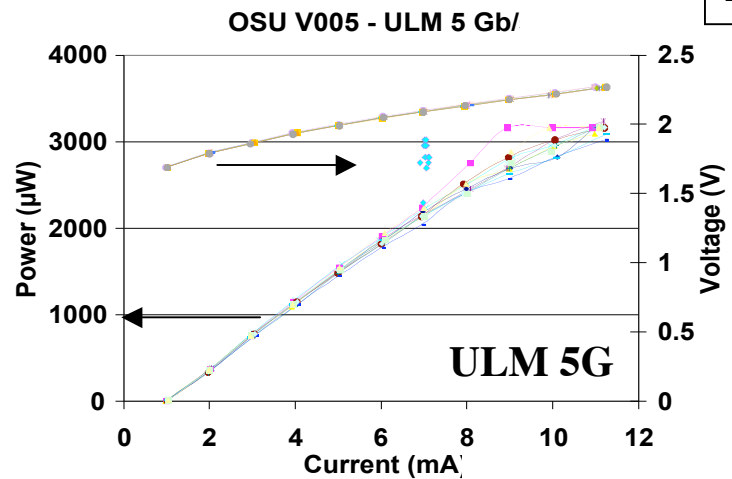
- responsivity decreases by $\sim 65\%$ after SLHC dosage



VCSEL LIV Characteristics



Pre-irrad

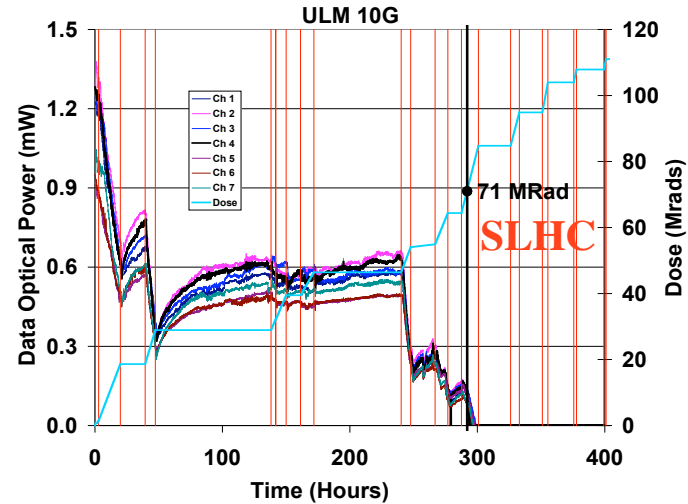
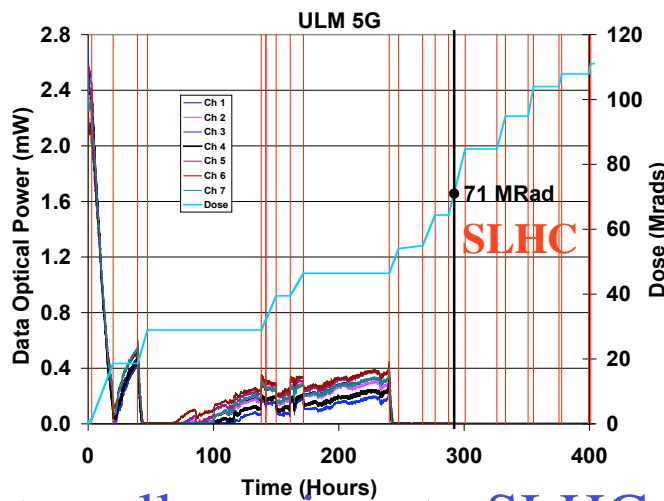
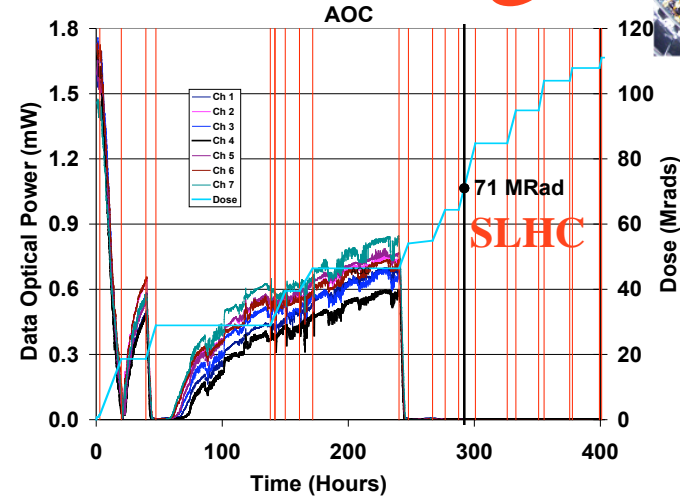
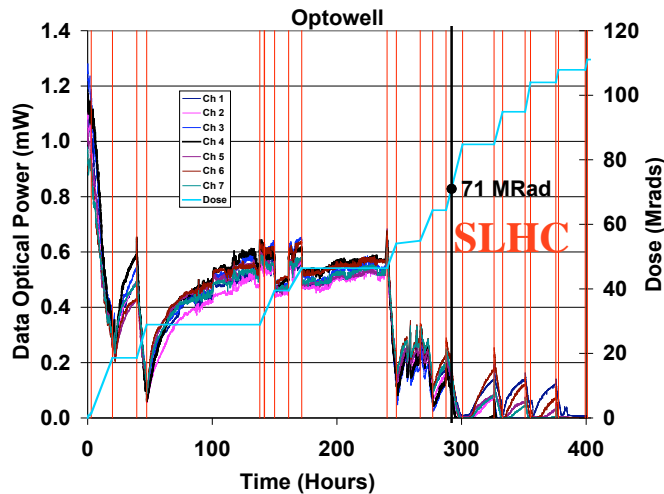


✗ ULM requires higher voltage to operate

● all arrays have very good optical power



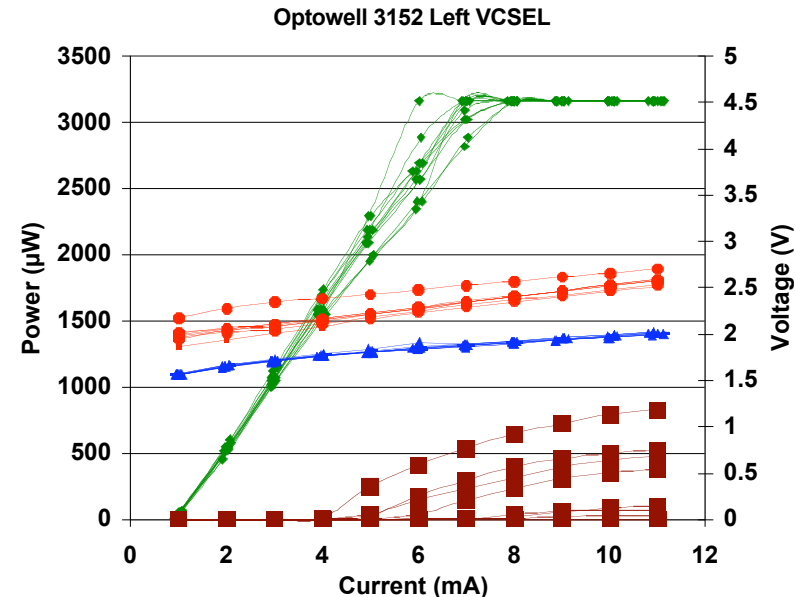
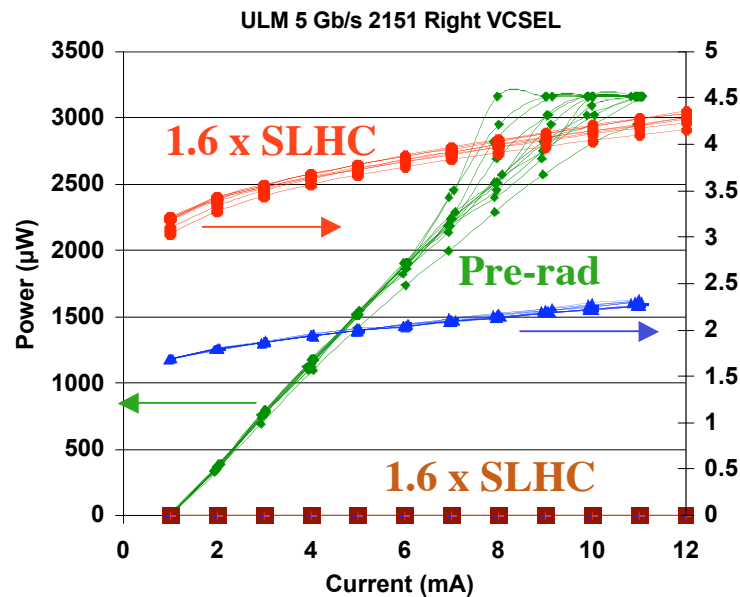
VCSEL Power vs Dosage



- Optowell survives to SLHC dosage
- more VCSEL might survive with more annealing during irradiation



VCSEL LIV Characteristics



- large shift in IV after 1.6 x SLHC dosage
 - SLHC dosage already includes 50% safety margin
- some optowell VCSEL still producing optical power
 - ⇒ will irradiate to SLHC dosage only in 2007



Summary

- micro twisted-pair cable of current ATLAS pixel detector can be used for transmission up to 1 Gb/s
- fusion spliced SIMM/GRIN fiber can transmit up to 2 Gb/s
- PIN responsivity decreases by 65% after SLHC dosage
- Optowell VCSEL survives SLHC dosage
- ⇒ current opto-link architecture satisfies SLHC requirements as a possible upgrade option