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

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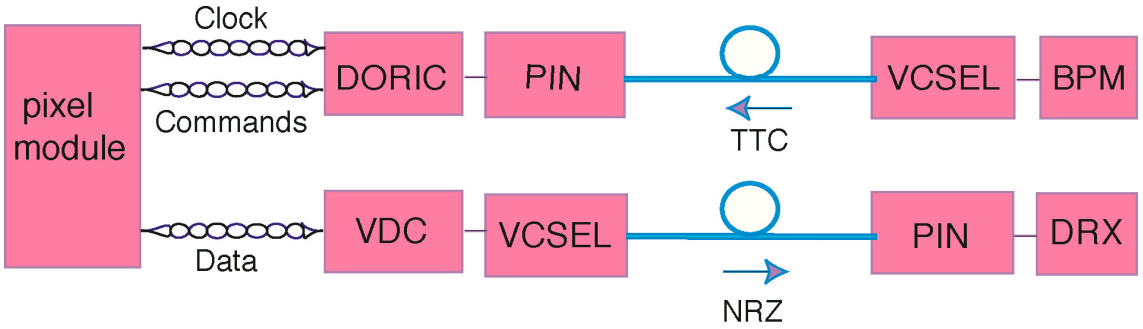
Outline

- 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

- ATLAS is a detector studying pp collisions of 14 TeV at CERN
  - pixel detector is innermost tracker
  - detector upgrade planned for Super-LHC in 2015



- opto-link production is decoupled from module production
  - transmit signal to/from modules with micro twisted pairs
- use 8 m of rad-hard/low-bandwidth SIMM fiber fusion spliced to 70 m rad-tolerant/medium-bandwidth GRIN fiber

⇨ simplify opto-board production

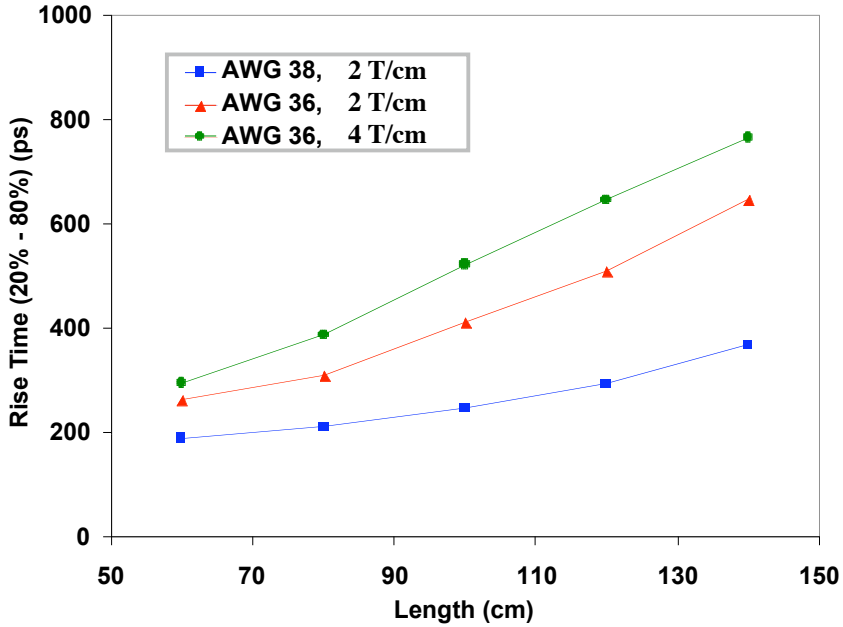
⇨ upgrade based on current pixel link architecture to take advantage of R&D effort and production experience?

R&D Issues for SLHC

- bandwidth of ~ 640 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?

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

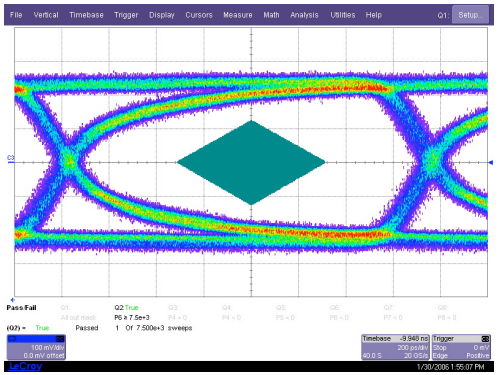


- current pixel cable is the best!

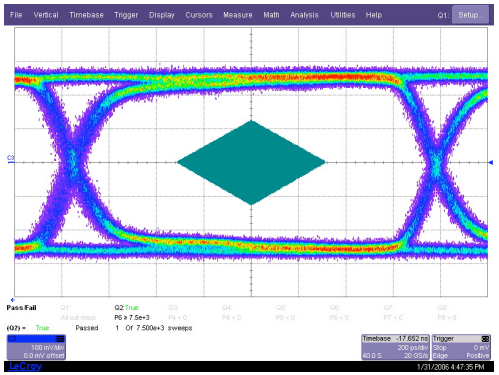
Eye Diagrams

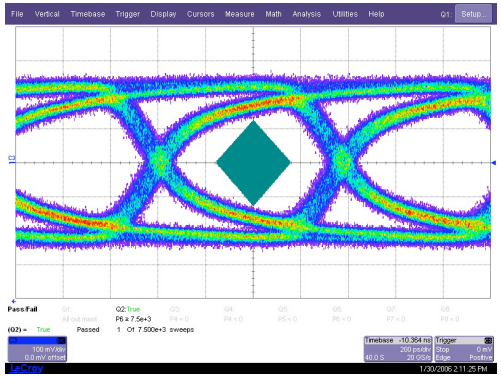
140 cm pixel cable

60 cm pixel cable

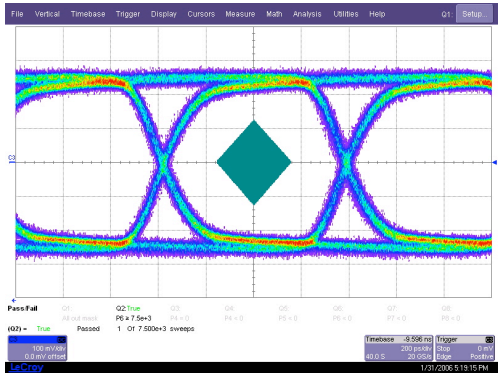


650 Mb/s





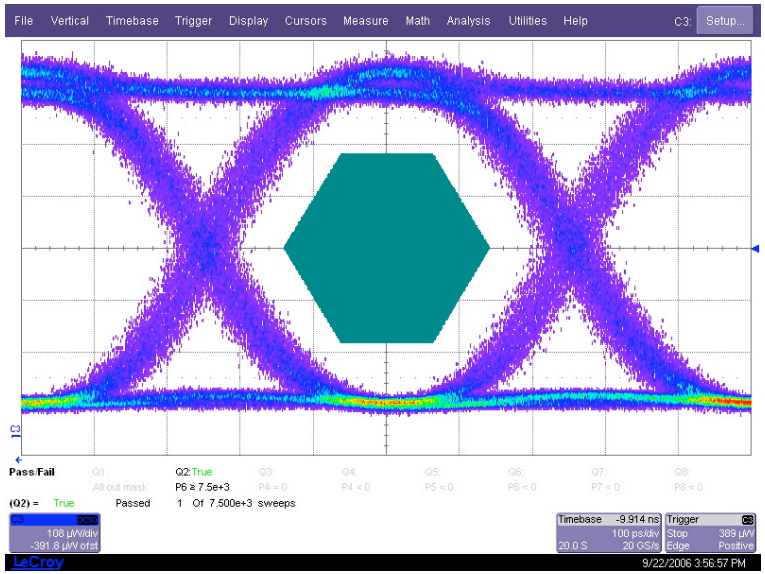
1.3 Gb/s



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

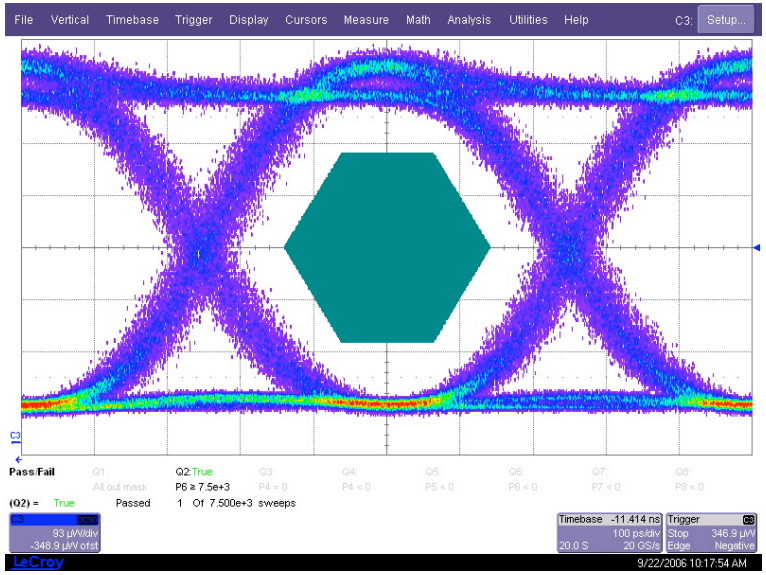
Bandwidth of Fusion Spliced Fiber

1 m GRIN fiber



2 Gb/s

8 + 80 m spliced SIMM/GRIN fiber



- transmission up to 2 Gb/s looks adequate

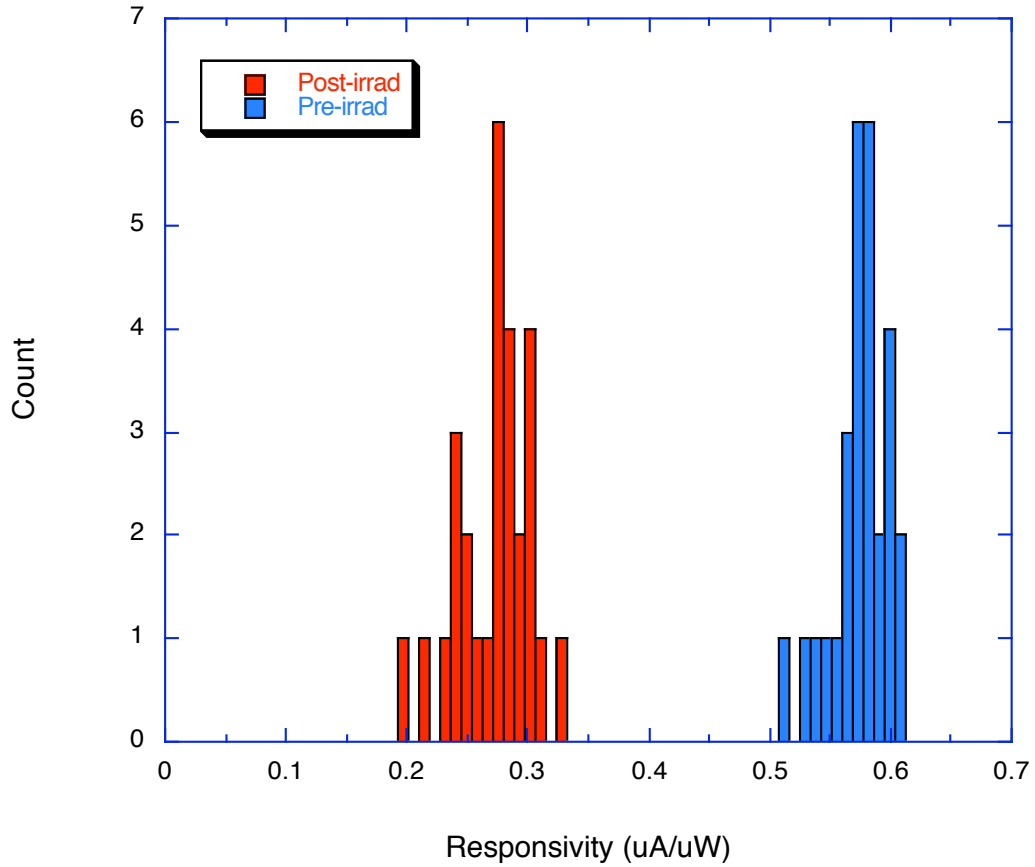
Radiation Level at SLHC

- Optical link of current pixel detector is mounted on patch panel:
  - ⇨ much reduced radiation level:
    - Si (PIN) @ SLHC:
      - 2.5 x 10^{15} 1-MeV n_{eq}/cm^2
      - 4.3 x 10^{15} p/cm^2 or 114 Mrad for 24 GeV protons
    - GaAs (VCSEL) @ SLHC:
      - 14 x 10^{15} 1-MeV n_{eq}/cm^2
      - 2.7 x 10^{15} p/cm^2 or 71 Mrad for 24 GeV protons

Requirements for PIN/VCSEL

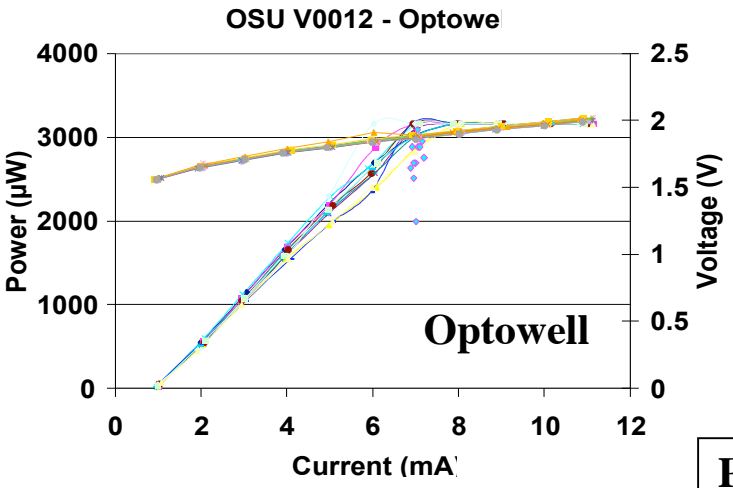
- PIN:
  - What is responsivity after irradiation?
  - What is rise/fall time after irradiation?
- VCSEL:
  - driver chip most likely be fabricated with 0.13 μm process
    - operating voltage is 1.2 V
    - thick oxide option can operate at 2.5 V
    - ⇨ VCSEL must need < 2.3 V to produce 10 mA or more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

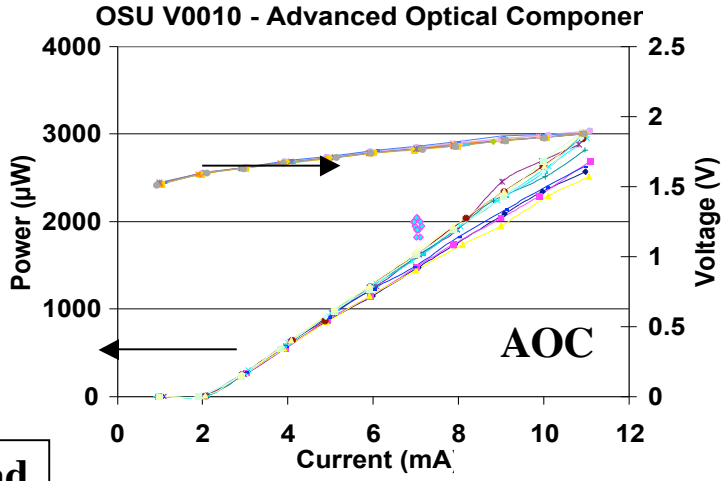
PIN Responsivity



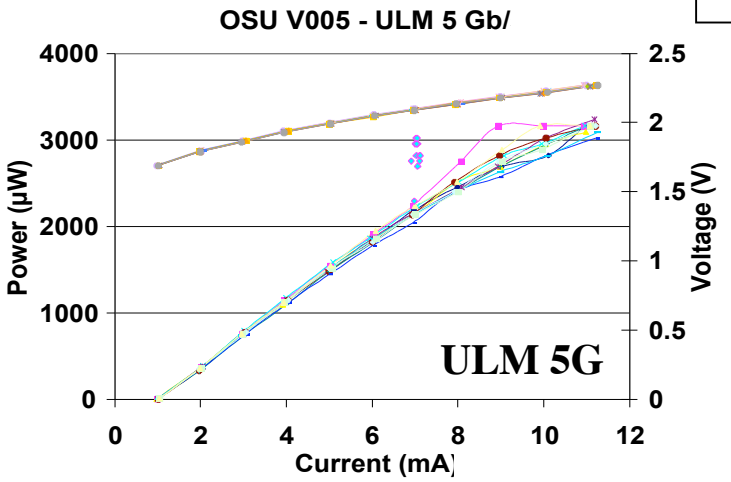
- responsivity decreases by ~50% after SLHC dosage

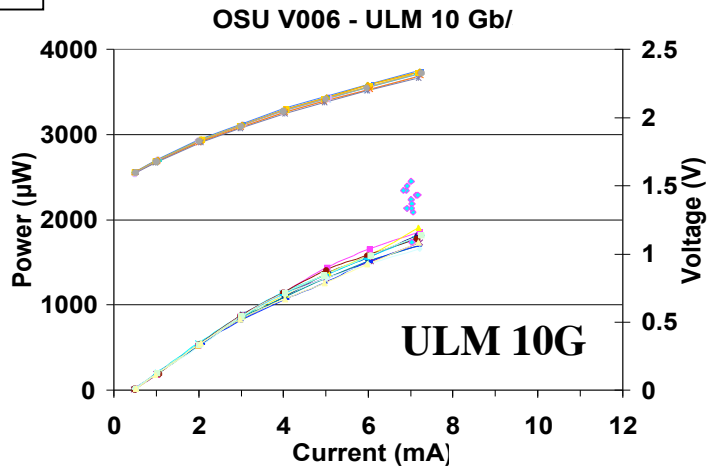
VCSEL LIV Characteristics





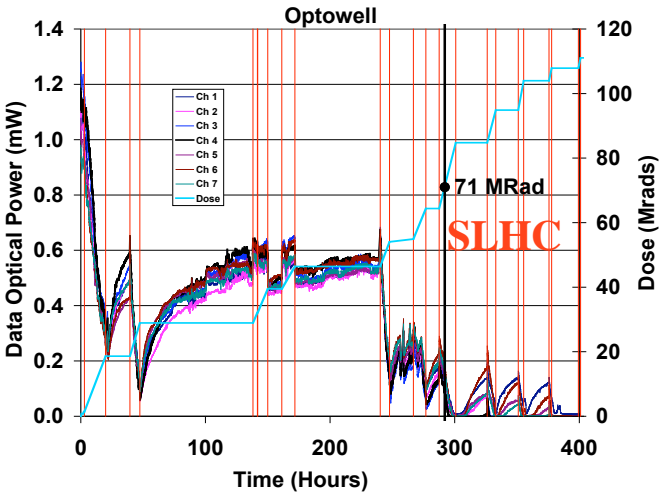
Pre-irrad

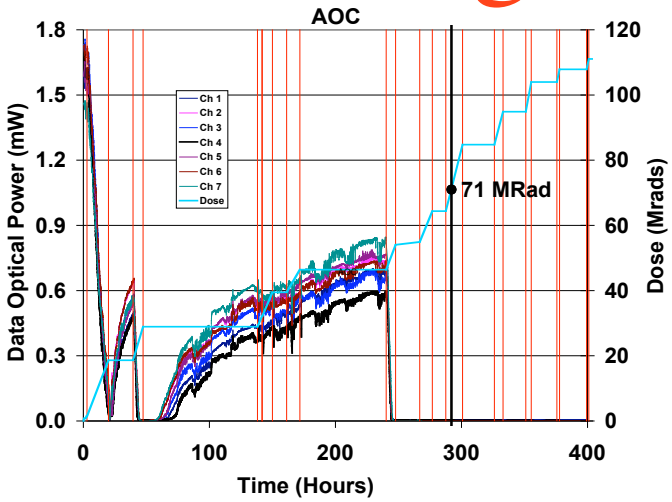


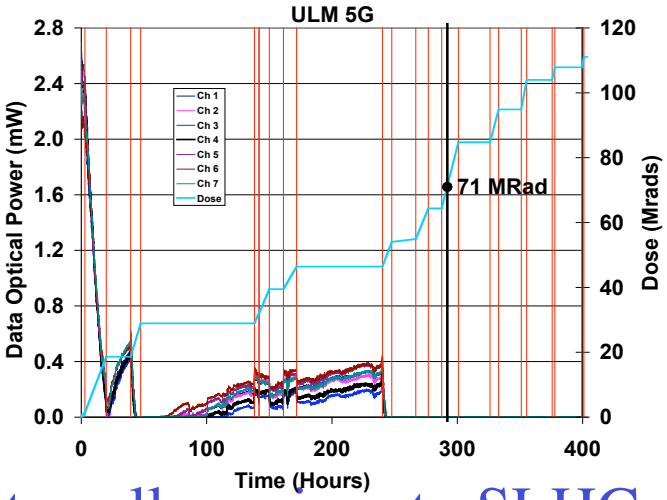


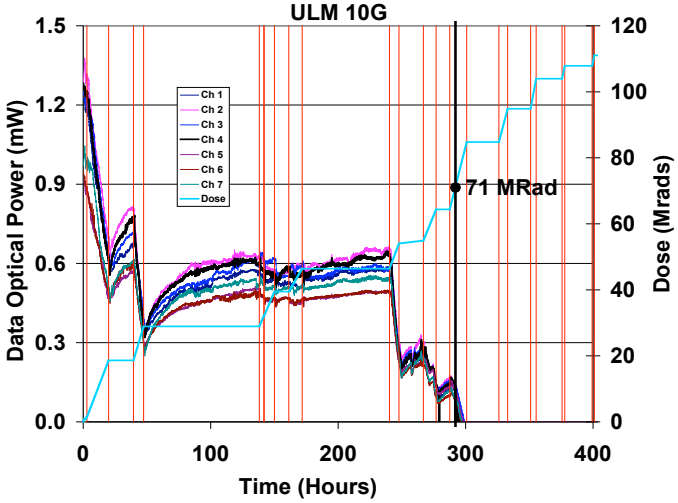
- ULM requires higher voltage to operate
- all arrays have very good optical power

VCSEL Power vs Dosage









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

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 50% after SLHC dosage
- Optowell VCSEL survives SLHC dosage
- ⇨ current opto-link architecture satisfies SLHC requirements