Radiation-Hard Optical Link for SLHC

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Outline

- Introduction
- Bandwidth of micro twisted-pair cables
- Radiation hardness of PIN/VCSEL arrays
- Results on MT-style optical packages based on BeO
- 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

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

- Micro twisted pairs decouple pixel and opto module
  - Simplify both design/production

- 8 m of rad-hard/low-bandwidth SIMM fiber fusion spliced to 70 m rad-tolerant/medium-bandwidth GRIN fiber
R&D Issues for SLHC

- bandwidth of ~ 1 Gb/s is needed
  - can micro twisted pair transmit at this speed?
  - can fusion spliced SIMM/GRIN fiber transmit at this speed?
    - ✔ measured bandwidth ~ 2 Gb/s (see LECC06 talk)
- can PIN/VCSEL arrays survive SLHC radiation dosage?
Bandwidth of Micro Twisted Pairs

- 80 μm, 7.5 μm Ins, 2 turns/cm
- 127 μm, 9 μm Ins, 2 turns/cm
- 127 μm, 9 μm Ins, 4 turns/cm
- 100 μm, 12.5 μm Ins, 4 turns/cm
- 100 μm, 25 μm Ins, 2 turns/cm (current pixel cable)
- 100 μm, 25 μm Ins, 4 turns/cm
- 127 μm, 25 μm Ins, 2 turns/cm

current pixel cable with thick insulation is quite optimum!

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Eye Diagrams

- Transmission at 640 Mb/s is adequate
- Transmission at 1280 Mb/s may be acceptable
- 127 µm cable is slightly better

127 µm cable
140 cm

100 µm current pixel cable
140 cm

60 cm

640 Mb/s

1280 Mb/s
Radiation Level at SLHC

- Optical link of current pixel detector is mounted on patch panels:
  - much reduced radiation level:
    - Si (PIN) @ SLHC (5,000 fb\(^{-1}\)):
      - 2.5 \times 10^{15} \text{ 1-MeV } \text{n}_{eq}/\text{cm}^2
      - 4.3 \times 10^{15} \text{ p/cm}^2 \text{ or 114 Mrad for 24 GeV protons}
    - GaAs (VCSEL) @ SLHC:
      - 14 \times 10^{15} \text{ 1-MeV } \text{n}_{eq}/\text{cm}^2
      - 2.7 \times 10^{15} \text{ p/cm}^2 \text{ or 59 Mrad for 24 GeV protons}
  - above estimates include 50% safety margin
PIN Responsivity

- Si PIN responsivity decreases by 65% after SLHC dosage
- completed irradiation of GaAs PIN from 3 vendors:
  - Optowell, AOC, ULM
  - responsivities will be measured next month
VCSEL LIV Characteristics

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

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VCSEL LIV Characteristics

- both arrays have very good optical power
VCSEL Power vs Dosage

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

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2006: Two arrays each (2 x 7 channels)
VCSEL Power vs Dosage

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

1st irradiation period

2007 preliminary
Two arrays each
(2 x 7 channels)

2nd irradiation period
VCSEL Power vs Dosage

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

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Opto-Pack Development

- Current pixel detector uses Taiwan optical packages
  - VCSEL mounted on PCB with poor heat conduction
  - Micro soldering of 250 µm leads is difficult
- Ohio State develops new opto-pack for SLHC
  - Uses BeO base with 3D traces for efficient heat removal
  - Wire bond to driver/receiver chip
Results on Opto-Packs

- 35 VCSEL & 6 PIN opto-packs have been fabricated
  - all VCSEL opto-packs except one have good coupled power
  - principle of new opto-pack has been demonstrated

1 cm

MT ferrule

VCSEL array

Ceramic guide pin

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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
- Si PIN responsivity decreases by 65% after SLHC dosage
- VCSEL from 3 vendors might survive to SLHC dosage
  ⇒ current opto-link architecture satisfies SLHC requirements
- compact MT-style opto-pack based on BeO has been developed