Opto-Link Options

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Acknowledgement
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Outline

- Architecture
- PIN/VCSEL arrays
- Opto-pack
- Opto-chips
- Fibers
- Cables
- Summary
Read Out Architect

- G. Darbo, P. Farthouat, A. Grillo, ATL-P-EN-0001

- Bypassed for inner pixel layers

- FE
  - 160 Mb/s
  - 160 MHz

- Module Controller
  - N links
  - 320 MHz
  - 320 Mb/s

- Super-Module Controller
  - M links
  - 3.2 Gb/s

- Opto Link
  - TTC fibers
  - Data
SLHC Opto-Link Channel Count

<table>
<thead>
<tr>
<th>R cm</th>
<th>staves</th>
<th>stave width</th>
<th>modules/stave</th>
<th>½ stave rate</th>
<th>SMC/stave</th>
<th>Links</th>
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<tbody>
<tr>
<td>3.7</td>
<td>12</td>
<td>2</td>
<td>24</td>
<td>6.9</td>
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<td>4</td>
<td>32</td>
<td>2.2</td>
<td>4</td>
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</table>

- Total number of SLHC barrel links: 548
- Current LHC barrel links: 1,458
- Number of links @ SLHC is manageable
- No need to transmit at higher rate (> 3.2 Gb/s)
Radiation-Hardness of Silicon PIN

- Irradiate PIN/VCSEL arrays with 24 GeV protons at CERN
- PIN responsivity decreases by 3x at 114 Mrad
  - SLHC at PP0: 69 Mrad or $1.5 \times 10^{15}$ 1-MeV $n_{eq}/cm^2$
    for 3,000$^{-1}$ fb with 50% safety factor
- 320 Mb/s transmission is 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 ($8.2 \times 10^{15}$ 1-MeV $n_{eq}/cm^2$)
Annealing of VCSEL Arrays

- Recovery is slow
- Optowell has the highest annealed power

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Pixel System Design Workshop
Annealing of VCSEL Arrays

- recovery is slow but adequate annealed power
Opto-Pack

- 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
  - New opto-packs have good coupled power
- Next: Modify MPO connector to replace current housing
Versatile Link

- CERN’s project to develop single-channel opto-link:
  - work with vendors to modify commercial opto-packs
  - evaluate radiation-hardness of opto components
  - institutions: CERN, Oxford, SMU
  - work on multiple-channel opto-links (arrays)
    by pixel group complements their effort
  - in close collaboration with VL to take advantage of their R&D
Opto-Chips

- 4 mm\(^2\) prototype chip:
  - PIN receiver/decoder operating at 40, 160 and 320 MHz
    - use bi-phase marked encoding due to the low speed
  - VCSEL drivers 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)
  - extracted simulations show full functionality
- layout was reviewed at CERN on March 11, 08
- submitted to IBM via CERN to MOSIS on March 24, 08
- delivery date: July 08
- irradiation: August 08
  - study radiation-hardness and SEU
Opto-Chips

640 Mb/s VCSEL Driver
3.2 Gb/s VCSEL Driver
640 MHz clock multipliers
(4 x and 16 x)
2.6 mm
PIN receiver/decoder

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Bandwidth of Fiber

- current opto-link: 11 + 80 m spliced SIMM/GRIN fiber
  - transmission at 3.2 Gb/s is adequate
  - current SLHC architecture calls for raw rate of 3.2 Gb/s plus 20% overhead for 8b/10b encoding
    - more efficient encoding will improve margin of operation
- new Corning fibers have higher bandwidth
  - will be irradiated by Oxford/SMU this summer
Eye Diagrams
100 µm current pixel cable

- Signals from modules can be sent to current PP0 location (1.4 m)
- Signals from modules (320 Mb/s):
  - can be transmitted up to ~ 3 m
  - can be transmitted up to ~ 4 m with pre-emphasis

Pre-emphasis
Eye Diagrams

1 mm TRT shield twisted pair (320 Mb/s, 100 Ω)

4 m

5 m

- Signals from modules (320 Mb/s) can be transmitted up to 4 m
Eye Diagrams

Pre-emphasis

- Use 4 m of Belden 1674A micro coax with 1.2 mm OD
  - transmit LVDS signals at 3.7 Gb/s on two coax
- Use Altera Stratix II GX to study pre-emphasis settings
  - use 8B/10B encoding
- pre-emphasis opens up the eye diagram
CMOS Driver with Pre-Emphasis

pre-emphasis tap supplies additional current as needed

nominal
set nominal drive current

preliminary 130 nm design
CMOS Driver Simulation

Preliminary test with RC transmission line:
- pre-emphasis opens the eye diagram

Pre-emphasis
Opto-Link Locations

- Use skinny cables to transmit 320 Mb/s signal
  - no further R&D needed for 3 m transmission
  - modest R&D on pre-emphasis needed up for 4 m transmission
  - minimum material (8 x 2 x 150 μm (0.28 mm²) cables)

- Use TRT micro cables to transmit 320 Mb/s to 4 m
  - no further R&D needed
  - significantly more material (8 x 2 x 127 μm cables + insulation)

- Use micro coax to transmit 3.7 Gb/s to 4 m
  - significant R&D needed:
    - connector, cable material, ASIC, radiation-hardness, SEU
  - significantly more material (2 x 1.2 mm (2.3 mm²) cables)
OSP bottom/ISP top

OSP top

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US ATLAS Pixel Upgrade Meeting

Figure 5.6 Annual doses (Gy/Year) assuming $10^7$ s at high luminosity.

- 320 Mb/s on skinny cable
- 320 Mb/s on TRT cable
- 3.7 Gb/s on coax cables

SLHC SCT fibers
Summary

● Basic components satisfy the SLHC needs:
  ◆ VCSEL/PIN, fibers, opto-pack

● proto-type chip will be evaluated in summer, including irradiation

● high-speed transmission in 4 m cable:
  ◆ 320 Mb/s transmission on skinny wires minimize material and requires modest R&D
  ◆ 3.2 Gb/s transmission on coax add significantly more material and requires significant R&D