Radiation-Hard/High-Speed Parallel Optical Links

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Outline

- Introduction to a compact solution
- Results with 5 Gb/s VCSEL array driver
- Summary
Use of VCSEL Arrays in ATLAS

- Widely used in off-detector data transmission
- First on-detector implementation in pixel detector
  - experience has been positive
    - VCSELs used are humidity sensitive but they are installed in very low humidity location
    - modern VCSELs are humidity tolerant
  - will use arrays for next pixel detector upgrade (IBL)
New Parallel Optical Engine

- Improved design for new pixel layer of ATLAS
  - use 12-channel VCSEL and PIN arrays
  - 36 optical channels

K.K. Gan
New 12-Channel VCSEL Driver

- New ASIC designed using 130 nm CMOS
- Incorporate improvements taking advantage of experience from 1st generation parallel optical engine:
  - redundancy to bypass a broken VCSEL
    - special thanks to FE-I4 group (Roberto Beccherle et al.) for command decoder circuit
  - power-on reset in case of communication failure:
    - no signal steering
    - 10 mA modulation current (on current)
    - 1 mA bias current (off current)
- Will only operate at 160 Mb/s for new pixel layer but designed ASIC to operate at much higher speed (5 Gb/s) to gain experience in designing high-speed parallel driver
New VCSEL Array Driver

- Only inner 8 channels connected to new pixel modules
- Future driver should reserve only one channel for redundancy

K.K. Gan

4.5 mm
High-Speed Test Configuration

10 Gb/s ULM
VCSEL array

VCSEL array driver

MPO connector
Optical Eye Diagram

- Difficult to judge eye diagram with 4.5 GHz optical probe…
SFP+ as Optical Probe

- 7 Gb/s BERT
- 13 GHz Oscilloscope
- SFP+ Channel under test
- VCSEL array driver
- Finisar 10 Gb/s Small Form Factor (SFP+) Transceiver
SFP+ Loopback vs VCSEL Driver

10 Gb/s SFP+ transceiver @ 5 Gb/s with optical loopback

VCSEL driver @ 5 Gb/s after 10 Gb/s SFP+ receiver
Eye with One/All Channels Active

- All channels work @ 5 Gb/s with bit error rate < $5 \times 10^{-13}$ for all channels active
- Jitter increases with all channels active but still passes the mask test
Effect of Steering on Eye

Receiving LVDS signal from channel 8, steering to VCSEL spare 1

LVDS in channel 8
Effect of Steering on Eye

- steered channel still passes the mask test
  - jitter increases with all channels active
Jitter Measurement

- measured on the spare channel with signal rerouted across die
  - should be the worse case scenario
- all other channels active

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<tr>
<td>Total Jitter @ BER 10^{-12}</td>
<td>65 ps</td>
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<tr>
<td>Random Jitter</td>
<td>3.1 ps</td>
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<tr>
<td>Total DJ</td>
<td>36.8 ps</td>
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Radiation Hardness

- 10 Gb/s VCSEL arrays have been proven to be radiation hard to tens of Mrad
  - send signal on ~1 m micro co-ax cables to less radiation and more serviceable location
- Radiation hardness of VCSEL array driver will be verified in the summer
Future Plan

- 10 Gb/s transmission needed for ATLAS inner pixel layer and LAr readout upgrades
  - joint ATLAS/CMS proposal funded via US DOE generic R&D program
- Layout array VCSEL driver/PIN receiver using GBLD and GBTIA with redundancy for possible pixel applications
Summary

- VCSEL array offers compact solution to data transmission
- 5 Gb/s VCSEL array driver successfully prototyped
- Currently designing 10 Gb/s VCSEL array driver