Radiation-Hard/High-Speed Parallel Optical Links

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September 5, 2012
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

3 cm

VCSEL opto-pack

PIN opto-pack

MPO connector
New 12-Channel VCSEL Driver

- New ASIC designed using 130 nm CMOS
- Incorporate improvements taking advantage of experience from 1\textsuperscript{st} 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

4.5 mm
High-Speed Test Configuration

10 Gb/s ULM
VCSEL array

VCSEL array driver

MPO connector
Optical Eye Diagram

- optical eye diagram @ 5 Gb/s is quite acceptable
  - special thanks to Alan Prosser @ Fermilab for use of equipment
SFP+ as Optical Probe

7 Gb/s BERT

13 GHz Oscilloscope

VCSEL array driver

Channel under test

Finisar 10 Gb/s Small Form Factor (SFP+) Transceiver

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Optical Probe vs. SFP+

- SFP+ gives artificially somewhat better looking signal

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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

VCSEL spare 1

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
Optical Eye Diagram of Steered Signal

- optical eye diagram of steered signal @ 5 Gb/s is quite acceptable

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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
- VCSEL array driver was irradiated with 24 GeV protons at CERN last August to test Radiation hardness
  - await return of irradiated ASICs for characterization
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 of driver stage completed (130 nm)

extracted driver/buffers with bond pad
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