CD R&D on Optical Links for Detector Data Transmission

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Fermilab

All Experimenter’s Meeting

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CD R&D on Optical Links for Detector Data Transmission

Outline:

Versatile Link Common Project
Free Space Optical Transmission
New Optohybrids for CMS Pixel Detector Upgrade
U.S. Based R&D Program for Optical Links

Participants:

Fermilab Computing Division:

Mark Bowden
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Versatile Link Common Project

Versatile Link: CERN-organized common project for ATLAS and CMS

Goal: “Development of a general purpose optical link which can cover all envisioned transmission applications: a versatile link” @ data transfer rates of up to 5 Gbps.

Work Package 1.1 (Southern Methodist University)
Point to Point Architecture and System Engineering

Work Package 2.1 (CERN)
Front End Components (Versatile Transceiver)

Work Package 2.2 (Fermilab)
Back End Components (COTS, Off Detector Components)

Work Package 2.3 (Oxford University)
Passive Components

Source: “Versatile Link Status Report”
Jan Troska
CMS Tracker Upgrade Meeting
April 24, 2009
Optical Transceiver Test Measurements

Industry Standard Measurements and Apparatus

Eye Diagram Measurements:

- Optical Modulation Amplitude
- Extinction Ratio
- Rise/Fall Times

Jitter Analysis:

- Deterministic Jitter (including decomposition)
- Random Jitter (Gaussian, unbounded)
- Eye Opening @ $10^{-12}$ BER
Versatile Link SFP+ Transceiver Measurements

Transmitter Measurements
(each point is a different vendor or device)

Receiver Measurements
(each point is a different vendor or device)

Radar Plots
(each axis is a measurement, each color a device)

Data Collected at:

5 Gbps
6.25 Gbps
10 Gbps
Parallel Optics – Package Evolution

- Emerging Standards (100 GbE) Driven by Telecom and Storage
- Off the shelf and prototype devices evaluated
- High speed, parallel communications in multiple footprints
- For HEP: High Channel Count, Easier Cable Management Reduced Board Area (including connectors)
- Next Step: Develop μTCA Based Application Board (Q2, 2011)

- Parallel Optical Engine Transceiver (4 channels, 6.25 Gbps/channel) (Efficient PCB Applications, Lower Electromagnetic Noise)
- SNAP12 Transmitter (12 channels, 2.7 Gbps/channel)
- SFP+ Single Channel Transceiver (10 Gbps)
- Parallel Optical Engine Transmitter (12 channels, 12.5 Gbps/channel, 1 Qtr, 2011, BGA Reflow Assembly, Optics Included)
Cable-less Free Space Optical Data Transmission
(with Vega Wave Systems (T. Moretti, A. Sugg) and FNAL PPD (T. Liu))

- Motivation:
  - Reduce material budget
  - Work within rigid space constraints

Measured Transmission Spectrum of Silicon (IC grade doped)

- Optical fibers removed from detector volume
- Transmission through free space or silicon

10Gb/s Optical Receivers

Silicon Detectors

10 Gb/s Optical Transmitters at different wavelengths

Beam Line Center

~100-150 cm
~50-100 cm
~10-50 cm
CWDM/Free Space Bit Error Rate Testing
Proof Of Concept

CWDM: Coarse Wavelength Division Multiplexing

CWDM DeMux

Lens

~2 mm Si

21 cm

8 cm

Lens

~2 mm Si

CWDM Mux

FPGA-Based BERT

Rx LVDS Electrical Bit Streams

Tx LVDS Electrical Bit Streams

λ₁ = 1470 nm
λ₂ = 1490 nm
λ₃ = 1510 nm
λ₄ = 1530 nm

Next Step: Evolve the Optical Design for Detector Applications
CWDM/Free Space Optics Lab Test
Proof of Concept

Free-Space Optics Lab Test Bench

- Silicon Slices
- Multi-mode Fiber
- Mode Converter
- Single-mode Fiber (Rx DeMux Side)

Free-Space Optics TRx Group

- JDSU CWDM Mux and DeMux Units
- Altera Stratix II Signal Integrity Kit
- TRx Group (4 SFP Devices)

Operating error free for over 48 hours at 1 Gbps on all 4 four channels

9/13/2010
CMS Pixels Phase One OptoHybrid Approach

Moving towards new Pixel OH

- Profit from work within Versatile Link project to identify a sufficiently radiation resistant packaged Laser (TOSA)
  - Present Laser die no longer produced and not available

- Design and build a prototype OH to check signal integrity, matching of new laser to existing laser driver (LLD)
  - Dimensionally compatible with current mechanical design
  - Include ALT?

- Fully characterize design inc. system test, thermal management
- Produce, Test, QA

1310 nm Receiver Array (SNAP12)
Tested at 2.5 Gbps at FNAL
CERN testing at 800 Mbps indicates device will work at these rates for FED

Next Steps:
- System Performance Testing of CERN-designed OH with FED Array Receiver
- Develop Qualification Test Plan

Need:
- Current Laser No Longer Available
- Upgrades Will Require New Devices to Be Identified

Requirements:
- Rad tolerant
- Digital Transmission at Rates Up To 640 Mbps
U.S. Based R&D Program on Optical Data Links

Optical Data Transmission Workshop (hosted by CD, Aug. 19, 2010):

Participants:
National Labs (ANL, FNAL)
Universities (UChicago, UMinnesota, Ohio State, SMU)
Industry (Tyco, Altera)

Summary:
Activities were presented and discussed
Vendors described current products and roadmaps

Next Steps:
Identify Common Areas of Interest
Define Scope and Focus of the Collaboration
Working Group Meeting to be Held During Detector R&D Workshop at Fermilab (1st Week of October, 2010)