Experiences with the ATLAS Pixel Detector Optolink and Researches for Future Links

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Outline

• Introduction to ATLAS Pixel Optolinks
  – Components
  – Variables
• Lessons learned from Layout, Production and Operation
• Future Plans
• Conclusions
ATLAS

- General purpose LHC experiment
- 40 MHz BC rate
- Innermost detectors are silicon pixel and strip systems
Pixel Detector

- Min. 3 space points per track, up to $\eta = 2.5$
- $\sim 14 \, \mu m$ resolution in $R\phi$, $\sim 112 \, \mu m$ in $z$
- Triggered readout at 75 kHz
- 1744 detector modules in total
The ATLAS Pixel optical Readout Requirements

- Speed: 80 MBit/s at max. per link
- Timing: < 1 ns adjustable phase shift between modules to optimize physics performance
- Low Latency command line:
  - Readout buffers in modules can only keep 255 clock-cycles (~6.4 us)
- Stable operation:
  - Parameters should “at least” not need adjustment during one run
The ATLAS Pixel optical Readout

- Per-module Readout (1744 links)
- Bundled per half-stave (6 / 7 modules) or disc-sector (6 modules) for electro-optical conv.
- 1 / 2 data links per module, depending on the geographical position (occupancy)
The ATLAS Pixel Optical Readout

Off-Detector optical components

On-Detector optical components

80m Fibre

ROD → BOC

TX-Plugin
BPM-12
DRX-12
RX-Plugin

TTC-Data

OPTO BOARD
2 x DORIC
2 x VDC

MCC Module

5-6 add. Modules

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TWEPP 08
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Off-Detector TTC transmitter: The TX-plugin

- 8 Channels
- Encodes Clock & Data per module into a single stream using BiPhase Mark encoding (Latency about 65ns)
On-Detector Receiver and Transmitter: Optoboard

- Receives up to 8 BPM-encoded optical streams and decodes them into clock and data per mod.
- Transmits data of at max. 8 modules back to the off-detector electronics
- Up to 16 return links, depending on the geographical position of the corresponding modules
- One common power control per Optoboard
Off-detector Receiver: RX-plugin

- 8 PiN channels receiving data
- No active decoding needed
- Threshold PiN current adjustable: 0 – 255 μA
Variables of the System
Need individual tuning...

- **TX-plugin, per chan.:**
  - Light power
  - *Mark-to-Space Ratio*
  - Coarse delay (25ns/step)
  - *Fine phase* (~300ps/Step)

- **Optoboard:**
  - $V_{iset}$ (*light Power*) per Optoboard (!)

- **RX-path, per Chan.:**
  - Threshold current
  - *Delay (phase)* (0-24ns, 1ns/step)
Small Intro to BocScans...

- Take an “eyepattern”
- Apply white to the inside, something else to the outside
- Select one clock cycle of phase space and a fixed range in signal height
- Phase needs to be inverted as the scans shift data instead of sampling clock
And the resulting BocScan...

- Threshold: 26 Steps (10 uA)
- Delay: 25 Steps (1 ns)
- Signal is stable and delivers sub-ns resolution if wanted
- Signal height corresponds to signal amplitude (power)
- Works and delivers good results...
Problems (Layout):
Lack of DC-balancing

- RX-links have unbalanced transmission
- Thresholds and phases need to “manually” be adjusted off-detector
- Software exists, but keeps struggling with “special” links
Problems (Layout):
RX-plugins designed for lower P

- Light powers incoming are very high, compared to the maximum threshold
- Optoboards thus need to be operated near laser threshold
  - Unstable
  - Gives large differences for individual channels
- Irradiation “heals” this...
Problems (Layout): “Freezing” LASERs

- Optoboard lasers were optimized for operation at ~20C
- Typical operation point without additional heating at ~5C (Heating was added…)

![Graph showing optical power versus channel for different temperatures]
Problems (Layout): Control of thermal conditions

- Cooling lasers down to 5°C most of them still have an appropriate light power
  - Tuning the links using a clock-like return pattern works out beautifully
- Using real data (not 50% on) a significant change in the tuned operational parameters is observed: Slow TurnOn
Problems (Production)

- TX-plugins suffer from ESD damage, which can only be observed by measuring the IV characteristics of the laserdiode (dismounted):
  - Significantly lower knee voltage
  - Different slope in conducting region
- Affected plugins show no light output after running for a while (where “while” depends on the ESD voltage)
- Parts of the system were exchanged so far (~30 channels in a total of ~15 plugins died)
IV-Curves

Dead Channel

Healthy Channel
Weak Points: What we learned...

• Concerning the layout:
  – Data link not DC-balanced
  – RX-plugins designed for lower input power
  – Optoboard lasers “freeze” (Solution: Heating)
  – Thermal conditions on-detector are not consistent with design and hardware constraints

• Concerning production:
  – TX-plugins suffer from ESD damage
Future Plans

• Lessons learned to be taken into account:
  – Next link to be fully DC-balanced
  – Single High-Speed links per multiple modules (?)
  – On-detector clock generation and fine-phase adjustment (?)
  – In-system IV-curve measurement possible

• First components for setting up a laser test setup arrived
  – Thermal properties of lasers including packaging to be characterized
Conclusions

● The ATLAS Pixel Optolink generally works, even though it sometimes makes life hard...

● An update would be appreciated, and is needed for SLHC anyways
  – Maybe used for the ATLAS ID upgrade ~2013
Backup ahead...