Qualification of the CMS Digital Optohybrid

Outline:
- CMS optical digital control links
- DOH components
- DOH history and assembly
- Qualification programme
- Visual inspection
- Optical/Electrical tests
- System tests
- Environmental tests
- Radiation tests
- Pull tests
- Summary
CMS Control Link Digital Optohybrid (DOH)

CMS Tracker Optical Digital Control Links
- Bi-directional
- Extreme environment
  - High radiation levels
  - High magnetic field
  - Restricted access for repair
- Derived from analogue readout links
- Adopted by other CMS sub-detectors

<table>
<thead>
<tr>
<th>CMS Sub-detector</th>
<th>Rings</th>
<th>DOHs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixels</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>Tracker</td>
<td>350</td>
<td>700</td>
</tr>
<tr>
<td>ECAL</td>
<td>368</td>
<td>736</td>
</tr>
<tr>
<td>Preshower</td>
<td>52</td>
<td>104</td>
</tr>
<tr>
<td>RPCs</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>862</td>
<td>1696</td>
</tr>
</tbody>
</table>
DOH Components

- Optical fibres
- MU connectors
- DOH PCB
- 26-way NAIS
  - Electrical connector:
  - CK/DA to/from CCUMs
  - Reset to CCUM
  - I²C to/from CCUM
- LLD ASIC
- RX40 ASIC
- Laser diodes
- Pin photodiodes
- Fibre clamp
DOH Production History

- 2001-3  Preliminary specs/prototypes
- 10/03  Order placed with Kapsch
- 12/03  Specifications frozen
- 03/04  Pre-production batch (40 pcs)
- 04/04  Rejection
- 06/04  Re-qualification batch (37 pcs)
- 07/04  Acceptance
- 08/04  Start of final production
DOH Assembly Sequence

- **DOH PCB** → **Production**
- **SMD components** → **Assembly**
- **LLD and RX40 ASICs** → **Bump bond**
- **Pin photodiodes** → **Solder**
- **Lasers** → **Glue and wire bond**
- **Fibre clamp and laser cover** → **Glue**
Qualification Programme

Quality
- Visual inspection
- Geometrical measurements

Functionality
- Optical and electrical test

Environment and reliability
- Thermal cycling test
- Irradiation test
- Magnetic field test
- Fibre pull tests
- Mechanical shock and vibration test
Visual Inspection

<table>
<thead>
<tr>
<th>Inspection test</th>
<th># failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre clamp</td>
<td>10</td>
</tr>
<tr>
<td>Laser cover</td>
<td>20</td>
</tr>
<tr>
<td>QR code</td>
<td>2</td>
</tr>
<tr>
<td>Soldering</td>
<td>12</td>
</tr>
<tr>
<td>Fibre buffer rupture</td>
<td>5</td>
</tr>
</tbody>
</table>

Kapsch fibre clamp

CERN fibre clamp

Buffer rupture

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Optical/Electrical Test Setup

Rx Tests:
- Receiver sensitivity
- Receiver saturation
- Output voltage swing
- Reset generation

Tx Tests:
- Optical modulation amplitude (OMA)
- Average launch power (ALP)
- Input impedance
- I²C check
- L-I characteristics

System Tests:
- Power supply
- Eye pattern
- Skew
- Jitter

Pattern generator
Reference DOH
DOH under test
O/H Oscilloscope

Optical attenuators
Optical/Electrical Tests

**Sensitivity**

![Graph showing sensitivity versus frequency](image)

**OMA & ALP**

- **ALP Specification**
  - Default LLD input
  - Minimum LLD input

- **OMA Specification**

**LLD and LASERS**

- **Reset generation**
  - Graph showing 10 missing '1's
  - Data
  - Reset

**I2C check and L-I char.**

- Laser Output [µW] vs LLD Bias Setting
  - Default I2C = 48

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System Tests

- Power consumption within 350mW spec.
- Bit Error Rate, $<10^{-12}$
- Skew $<1\text{ns}$
- Jitter well within 250ps rms spec.
Environmental Tests

- Temperature cycling (CERN)
- B-field (CERN)
  - 2 DOHs, 3 orientations, 2.4 T
- Shock test (Kapsch)
  - 6 DOHs, 20G
- Vibration test (Kapsch)
  - 6 DOHs, 10Hz-500Hz
- All DOHs were functional after above tests
Radiation Tests

- Irradiation (6 DOHs)
  - 100kGy Co-60 gamma
  - Up to $9.4 \times 10^{14}$ n/cm$^2$ (UCL ~20MeV)
- Expected laser and photodiode damage
- Final system laser threshold shift should be less:
  - ~6mA (LLD bias shift =13)

**Lasers**

<table>
<thead>
<tr>
<th>Laser Output [$\mu$W]</th>
<th>Before irradiation</th>
<th>After neutron irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
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<tr>
<td>200</td>
<td>200</td>
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<tr>
<td>300</td>
<td>300</td>
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<tr>
<td>400</td>
<td>400</td>
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<td>500</td>
<td>500</td>
<td>500</td>
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<tr>
<td>600</td>
<td>600</td>
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</tr>
</tbody>
</table>

**Photodiodes**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Clock</th>
<th>Data</th>
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</thead>
<tbody>
<tr>
<td>Prerad avg. [$\mu$W]</td>
<td>8.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Prerad-gamma [%]</td>
<td>-5</td>
<td>-1</td>
</tr>
<tr>
<td>Prerad-neutron [%]</td>
<td>-29</td>
<td>-32</td>
</tr>
</tbody>
</table>
Non-destructive pull tests:
- Attach 700g to fibre
- 3/40 fibres failed (all lasers)

Destructive pull tests:
- Pull fibre until it fails
- 2/36 fibres below spec (all lasers 5.5N & 6.7N)

In Summary
- Fibre strength reasonably good
- Revise DOH pull strength specification
Summary

- DOH has undergone an extensive series of tests
  - Good functionality
  - Quality of assembly
    - 1st Pre-production failed visual inspection
    - 2nd Pre-production much better:
      - Redesigned fibre clamp
      - Redesigned assembly jig
- Remaining issues
  - Buffer ruptures on fibres
  - Soldering of photodiodes onto DOH pcb
- Production phase
  - 100 DOHs in August 04
  - Expect to reach production rate of ~200 DOHs/month