

**ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE  
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH**

Laboratoire Européen pour la Physique des Particules  
European Laboratory for Particle Physics

# **CMS Tracker Optical Control Link Specification**

## **Part 2: Front-end Digital Optohybrid**

**Version 2.2, 12 November, 2003.**

**CERN EP/CME**

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# 1. Introduction

## 1.1. General system description

This specification defines the design requirements for the digital optical link to be used in the control system of the various sub-detectors of the CMS detector [1.1] at the CERN [1.2] Large Hadron Collider (LHC). The system architecture is based on the token ring concept, with mixed optical and copper sections [1.3]. The system was originally developed for the Tracker subdetector [1.4], where the total number of redundant control rings is 320, corresponding to 2560 optical link fibre channels. Including the other subsystems: ECAL, preshower and pixels, the combined total number of digital control link fibre channels is expected to be 6808.

The CMS optical control link is embedded into the control ring, as shown in Fig 1.1 taking the Tracker system as an example. The optical link is highlighted on the left of the figure, starting and ending at the backend transceiver module which is mounted on the Front End Controller board (FEC). Specifications for the FEC, and communication control unit (CCU) ASICs can be found in [1.5] and [1.6] respectively.

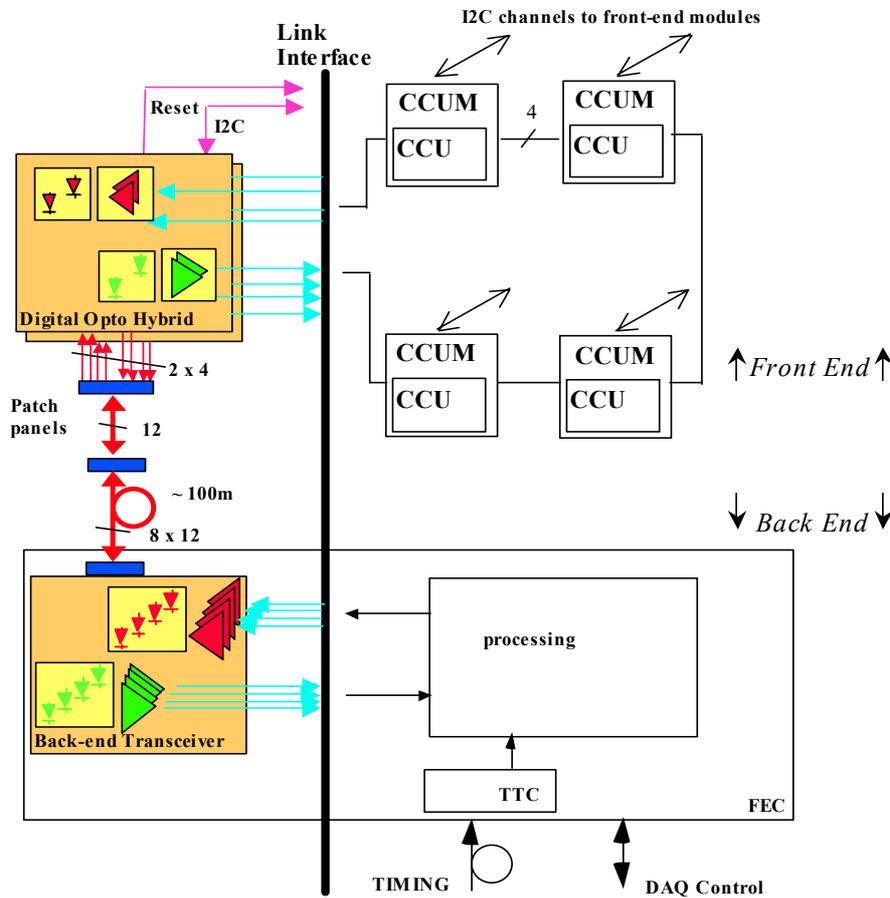


Fig. 1.1. Tracker control ring with optical link highlighted on the left.

The communication architecture proposed to control the embedded electronics is based on two layers. A more detailed description can be found for instance in [1.3]. The first layer (called the Ring) links the FEC and CCU modules (CCUMs) as well as connecting between CCUMs on the same ring. The protocol on this first layer is message-based and is implemented in a way similar to LAN networks. Four lines are required to transmit data (40Mb/s) and system clock (40MHz) with redundancy. Optical links are used to transmit data between the back-end (FEC) and the front-end digital optohybrid (DOH). The data is then communicated between CCUMs via electrical interconnections. The second layer of communication, between the CCUMs and the front-end chips, is entirely electrical and is based on the I<sup>2</sup>C standard protocol.

## 1.2. Document structure and convention

The optical link specification is broken down into eight independent parts, each describing and specifying a different level or function in the system:

- Part 1. System
- Part 2. Digital Opto-Hybrid
  - 2.1 Laser Driver ASIC
  - 2.2 Laser Transmitter
    - 2.2.1 Terminated Pigtail
      - 2.2.1.1 Buffered Fibre
  - 2.3 PIN Photodiode
  - 2.4 Digital Receiver ASIC
  - 2.5 Digital Optohybrid Substrate
- Part 3. Terminated Fibre Ribbon
  - 3.1 Ruggedized Ribbon Harness
    - 3.1.1 Ruggedized Ribbon
- Part 4. Terminated Multi-Ribbon Cable
  - 4.1 Dense Multi-Ribbon Cable
- Part 5. Back-End Opto-Transceiver Module
- Part 6. Distributed Patch Panel
  - 6.1 MU-sMU Adaptor
- Part 7. In Line Patch Panel
  - 7.1 MFS Adaptor
- Part 8. Backend Patch Panel

This particular specification has the following structure:

- |                         |                                   |             |               |
|-------------------------|-----------------------------------|-------------|---------------|
| 1. Introduction         | 2. Technical requirement          | 3. Glossary | 4. References |
| 1.1. System description | 2.1. Description                  |             |               |
| 1.2. Document structure | 2.2. Block diagram                |             |               |
| 1.3. Related WWW sites  | 2.3. Specification                |             |               |
| 1.4. Contact            | 2.4. Implementation               |             |               |
| 1.5. Document history   | 2.5. Manufacturing Specifications |             |               |
|                         | 2.6. Quality Assurance            |             |               |
|                         | 2.7. Specification Test Table     |             |               |

**Parameters still to be determined within the specification are labelled TBD.**

### 1.3. Related WWW sites

- CERN laboratory: <http://www.cern.ch/Public/>
- CMS project: <http://cmsinfo.cern.ch/Welcome.html>
- CMS Tracker Technical Design Report: <http://cmsdoc.cern.ch/ftp/TDR/TRACKER/tracker.html>
- CMS Tracker Electronic System: <http://cmstrackercontrol.web.cern.ch/CMSTrackerControl/docmain.htm>
- CMS Tracker Optical Links: <http://cms-tk-opto.web.cern.ch/>
- FED developments: [http://www.te.rl.ac.uk/esdg/cms\\_fed\\_pmc/index.html](http://www.te.rl.ac.uk/esdg/cms_fed_pmc/index.html)
- APV and MUX developments: <http://www.te.rl.ac.uk/med/>

### 1.4. Document history

|                         |  |
|-------------------------|--|
| Rev. 1.0, 13/11/02 (KG) | Draft  |
| Rev. 1.1, 17/12/02 (KG) | Decreased nominal laser efficiency to 16 $\mu$ W/mA.   |
| Rev. 1.2, 21/1/03 (KG)  | Number of pigtail lengths to 3. LVDS min spec.<br>Text labels for active components updated, but drawings still to be changed.<br>DOH area and thickness to be finalised and updated.  |
| Rev. 1.3, 7/3/03 (KG)   | DOH v4 (preliminary) design figures added.   |
| Rev. 1.4, 9/5/03 (KG)   | Manufacturing specs added. QA section added.<br>Number of control rings increased for new ECAL quantity.   |
| Rev. 1.5, 30/6/03 (KG)  | Manufacturing specs modified to include industrial standards.  |
| Rev. 2.0, 8/7/03 (KG)   | Photographs and schematics of v4 prototype included<br>CERN specs from Design Office included  |
| Rev. 2.1, 22/7/03 (KG)  | Minor corrections. Burn-in added.  |
| Rev. 2.2, 12/11/03 (KG) | Labels of LLD default bias settings corrected<br>Curing temperatures reduced to 50°C<br>Number of DOH with 2m pigtails corrected.<br>Position of QR code defined.<br>CERN job spec details added in implementation.<br>(Note - Additional 64 DOH for modified TEC are not yet included). |

### 1.5. Contacts

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## 2. Technical requirement: front-end digital optohybrid

### 2.1. Description

The digital optohybrid (DOH) is a compact radiation resistant transceiver assembly with two lasers and a laser driver ASIC (LLD[1.7]), and two photodiodes and a receiver ASIC (RX40[1.8]), all mounted on a 4-layer FR4 hybrid. The electrical interface is a 26pin NAI connector. The optical interface consists of 4 single-mode fibre pigtailed with individual MU connectors.

The two receiver channels on the DOH transmit the LHC 40MHz clock (CK) (as well as L1 trigger and resynchronisation signals) and control data (DA) at 40Mbit/s in the direction from the FEC to the ring of CCUMs. The two transmitter channels send clock and data to the FEC from the ring of CCUMs.

The hard-reset for the front-end ASICs is also generated by the RX40 on the DOH, following reception of a reset request (a signal of at least 10 consecutive '0' levels on the DA line) sent by the FEC over the DA optical link channel.

640 DOH will be required for the Tracker, 112 for the Pixels, 846 for ECAL and 104 for the Preshower (not including yield or spares), a total of 1702 hybrids. At least 1800 DOH will be manufactured.

There will be two versions of the optohybrid: DOH 056 and DOH 200. The first version has 56cm fibre pigtail and the second has 200cm long fibre pigtailed. Of the 1800 hybrids produced, 1448 will be DOH 056 and 352 will be DOH 200.

### 2.2. Block diagram

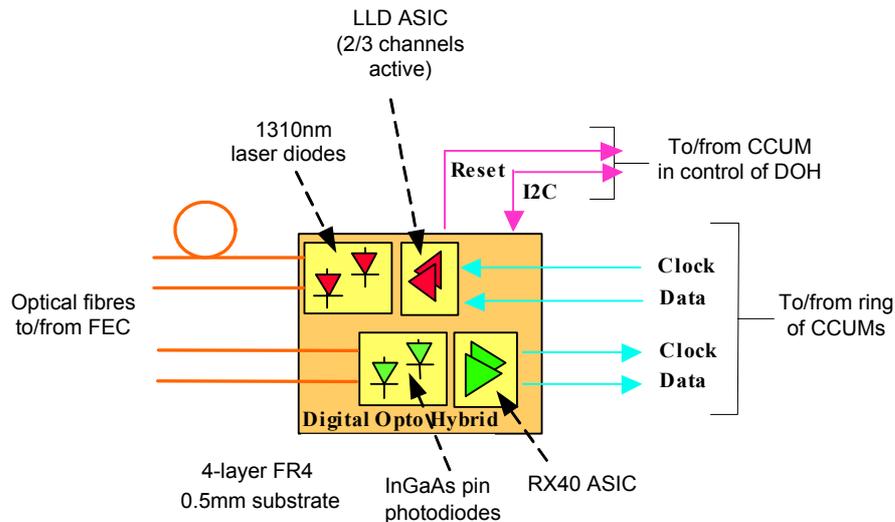


Fig. 2.1. Front-end digital optohybrid block diagram

### 2.3. Operational Specifications (@25°C unless otherwise noted)

| #   | Operational specifications | min | typ  | max        | unit     | note   |
|-----|----------------------------|-----|------|------------|----------|--|
| 2.1 | Bit Rate                   | 2   |      | 100        | Mb/s     | Balanced code  |
| 2.2 | Bit error rate             |     |      | $10^{-12}$ |          |  |
| 2.3 | Skew                       |     |      | 1          | ns       | Between the 2 fibres coming from the same hybrid, see glossary 3.1 |
| 2.4 | Jitter                     |     |      | 0.25       | ns       | Rms, see glossary 3.2  |
| 2.5 | Operation rate             |     | 4000 |            | hrs/year | Over lifetime of 10 years.   |
|     | Specs 2.6 to 2.10          |     |      |            |          | Reserved for future use  |

| #    | Physical specifications | min         | typ | max | unit | note  |
|------|-------------------------|-------------|-----|-----|------|---|
| 2.11 | Number of Tx channels   | 2           |     |     |      | LD0 on Fig. 2.3 = Clock<br>LD1 on Fig. 2.3 = Data |
| 2.12 | Number of Rx channels   | 2           |     |     |      | PD0 on Fig. 2.3 = Clock<br>PD1 on Fig. 2.3 = Data |
| 2.13 | Size                    | 21.5x35x4.5 |     |     | mm   | See Fig 2.3, Fig. 2.4.                            |
|      | Specs 2.14 to 2.20      |             |     |     |      | Reserved for future use                           |

| #    | Electrical specifications          | min   | typ  | max | unit | note   |
|------|------------------------------------|---|------|-----|------|--|
| 2.21 | Differential input voltage         | ±300  |      |     | mV   | Into 120Ω. Note that the LLD ASIC has an analogue transfer characteristic.   |
| 2.22 | Input impedance                    |   | 120  |     | Ω    | R1, R2, R3 and R4 = 56Ω (TBD)  |
| 2.23 | Differential output voltage        | ±250  | ±400 |     | mV   | LVDS. Should be terminated differentially with 100Ω.   |
| 2.24 | Reset Output                       | Active low  |      |     |      | Generated by RX40 upon reception of 10 consecutive '0' levels on DA channel (PD1 on Fig 2.3).  |
| 2.25 | Power supply                       | 2.25  |      | 2.7 | V    |  |
| 2.26 | Power dissipation                  |   | 350  |     | mW   | Tx contributes 220mW [1.7]<br>Rx contributes 125mW [1.8]   |
| 2.27 | I2C address                        | 11100   |      |     |      | Fixed  |
| 2.28 | Default LLD laser I2C bias setting | Preset via 3 hardwired input bits DRES4, DRES5, DRES6 corresponding to the 3 MSBs of the 7bit pre-bias register. 4 LSbs set to 0. |      |     |      | Common to all laser output channels. On the DOH:<br>DRES4=1<br>DRES5=1<br>DRES6=0<br>= 48 <sub>decimal</sub> or 22mA approx. pre-bias current to each laser. |
| 2.29 | Default LLD gain setting           | 12.5  |      |     | mS   | Hard-wired in LLD  |
| 2.30 | Electrical connector               | 26-way male NAIS  |      |     |      | See fig. 2.5 for connector pin assignment  |
|      | Specs 2.31 to 2.40                 |   |      |     |      | Reserved for future use  |

| #    | Optical specifications              | min   | typ  | max  | unit | note  |
|------|-------------------------------------|---|------|------|------|---|
| 2.41 | Wavelength                          | 1260  | 1310 | 1360 | nm   |   |
| 2.42 | Tx average output power at power up | -8  |      | -4   | dBm  | Assumes laser efficiency of $16\mu\text{W}/\text{mA}$ ( $\pm 20\%$ ), I2C default =48, $I_{\text{bias}} = 0.45\text{mA} \cdot \text{I2C step}$ ( $\pm 20\%$ ) and $I_{\text{threshold}} = 5\text{mA}$ .           |
| 2.43 | Tx optical modulation amplitude     | -11   |      | -5   | dBm  | Assumes voltage input of 800mV ( $\pm 20\%$ ), Gain = 12.5mS ( $\pm 20\%$ ) and laser efficiency of $16\mu\text{W}/\text{mA}$ ( $\pm 20\%$ ).<br>DOH biased such that amplitude not truncated by laser threshold. |
| 2.44 | Rx sensitivity                      |   |      | -18  | dBm  |   |
| 2.45 | Rx saturation (d.c.)                | -3  |      |      | dBm  | Maximum average input power.  |
| 2.46 | Rx saturation (a.c.)                | -3  |      |      | dBm  | Maximum optical modulation Amplitude into Rx.   |
| 2.47 | Optical fibre type                  | single mode tight-buffered<br>9/125/250/900 $\mu\text{m}$ |      |      |      |   |
| 2.48 | Pigtail length                      | 0.56  |      | 0.58 | m    | Short pigtail length laser  |
|      |                                     | 0.56  |      | 0.60 |      | Short pigtail length photodiode   |
|      |                                     | 2.00  |      | 2.04 |      | Long pigtail length laser and photodiode  |
| 2.49 | Optical connector                   | MU  |      |      |      |   |
| 2.50 | Tensile strain                      | 7.0   |      |      | N    | Fibre should not be bent smaller than bend radius of 30mm.<br>Fibre pigtails not yet protected by a fibre-clamp should not be twisted.  |
|      | Specs 2.51 to 2.60                  |   |      |      |      | Reserved for future use   |

| #    | environmental specifications  | min                                | typ | max   | unit              | note   |
|------|-------------------------------|------------------------------------|-----|-------|-------------------|--|
| 2.61 | Magnetic field resistance     | 4                                  |     |       | T                 | Parallel to particle beam axis   |
| 2.62 | Hadronic fluence <sup>1</sup> |                                    |     | 3e14  | 1/cm <sup>2</sup> | Integrated over lifetime <sup>2</sup> , 90% charged particles, 10% neutrons, see ref [2.1] |
| 2.63 | Gamma dose                    |                                    |     | 1.5e5 | Gy(Si)            | Integrated over lifetime <sup>2</sup> , see ref [2.1]                                      |
| 2.64 | Temperature                   | -20                                |     | 50    | °C                | Operation and storage  |
| 2.65 | Operating humidity            | Dry lab environment during testing |     |       |                   | Dry nitrogen flow during operation in Tracker.   |
|      | Specs 2.66 to 2.80            |                                    |     |       |                   | Reserved for future use  |

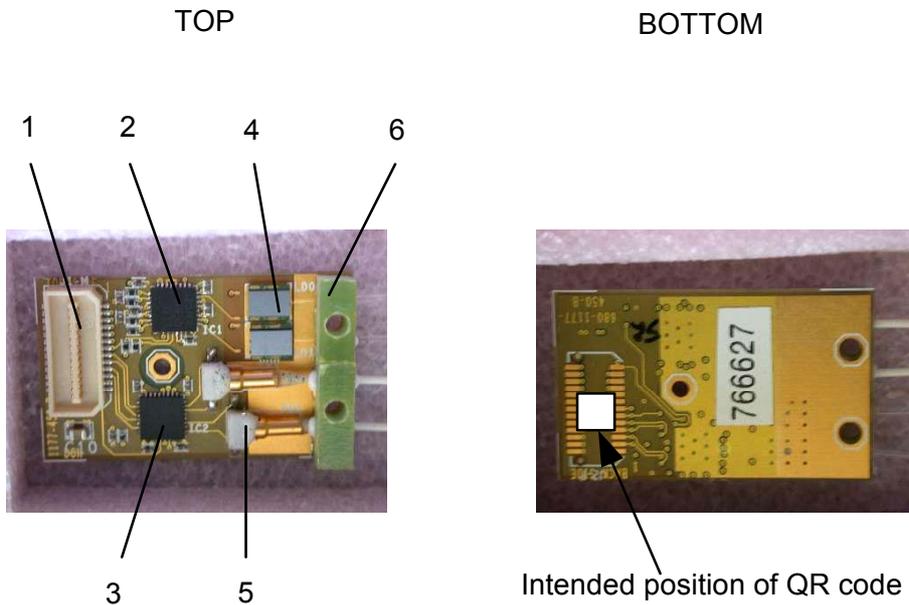
<sup>1</sup> Qualification of the parts for radiation resistance is the sole responsibility of CERN. No radiation testing is required of the optohybrid manufacturer.

<sup>2</sup> Foreseen operating lifetime: nominal 10 years.

| #    | safety specifications |   | note  |
|------|-----------------------|---|---|
| 2.81 | Optical               | laser system hazard level 1                 | IEC 825-1, 825-2,<br>See reference [2.2]    |
| 2.82 | Fire                  | CERN standards for<br>underground equipment | CERN IS23 and IS41, see reference<br>[2.3]. |
|      | Specs 2.83 to 2.99    |   | Reserved for future use                     |

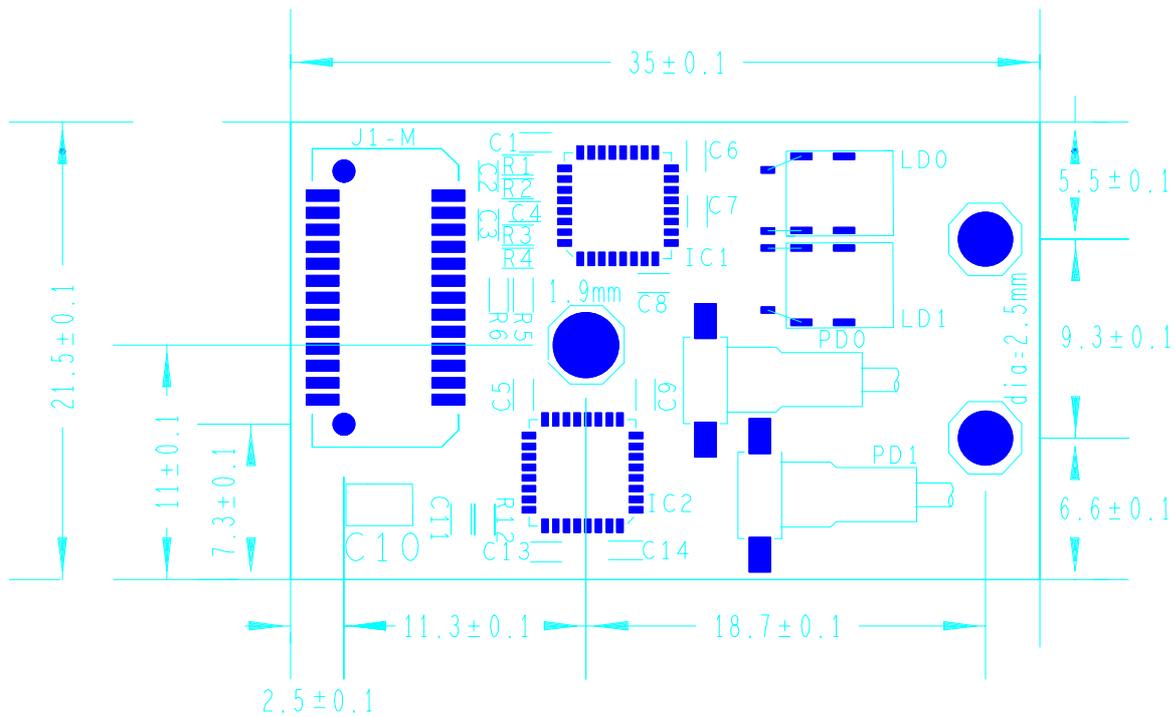
## 2.4. Implementation

Fig. 2.2: Photograph



1. NAI8 26-way Header connector. 2. LLD ASIC. 3. RX40 ASIC. 4. Lasers (ST Microelectronics, Fig. 2.6). 5. Photodiodes (Fermionics, Fig. 2.7). 6. Fibre clamp. 7. QR code label not shown. It will be attached as shown on the bottom side. 8. Laser protective cover not shown. The large label on the bottom side is not foreseen on the final DOH. Parts 2, 3, 4, 5 and 7 will be supplied by CERN.

Fig. 2.3: Mechanical drawing.





### 2.4.2. Component list

| Sub-component                         | Part Number on DOH                        | Part Type              | Supplier <sup>1</sup> | Value    | Tolerance | Package                                   | Voltage or Power rating | Quantity | Provided by CERN |
|---------------------------------------|---|------------------------|-----------------------|----------|-----------|---|-------------------------|----------|------------------|
| Optohybrid substrate                  |   |                        | Manufacturer          |          |           |   |                         | 1        | No               |
| Header connector                      | J1-M                                      | AXN426430S             | NaiS Matsushita       |          |           | 26-pin Header (male) (0.8mm) Height=4mm   |                         | 1        | No               |
| Laser Driver ASIC [see Reference 1.7] | IC1                                       | LLD2                   | CERN                  |          |           | LPCC 32                                   |                         | 1        | Yes              |
| Receiver ASIC [see Reference 1.8]     | IC2                                       | RX40_V1_2 <sup>2</sup> | CERN                  |          |           | LPCC 32                                   |                         | 1        | Yes              |
| Laser diode                           | LD0, LD1                                  |                        | ST Microelectronics   |          |           | Custom (see Fig. 2.5)                     |                         | 2        | Yes              |
| Photodiode                            | PD0, PD1                                  |                        | Fermionics            |          |           | Custom (see Fig. 2.6)                     |                         | 2        | Yes              |
| SMD Resistor                          | R1, R2, R3, R4                            | Any                    | Any                   | 56 ohms  | 5%        | R0402                                     | 1/16 W                  | 4        | No               |
| SMD Resistor                          | R5, R6                                    | Any                    | Any                   | 2k2 ohms | 5%        | R0402                                     | 1/16 W                  | 2        | No               |
| SMD Resistor                          | R12                                       | Any                    | Any                   | 10k ohms | 5%        | R0402                                     | 1/16 W                  | 1        | No               |
| SMD Ceramic Capacitor                 | C1, C4, C5, C6, C7, C8, C9, C11, C13, C14 | X5R                    | Kemet                 | 100nF    | 10%       | C0402                                     | 10V                     | 10       | No               |
| SMD Ceramic Capacitor                 | C2, C3                                    | X7R                    | Kemet                 | 1nF      | 10%       | C0402                                     | 10V                     | 2        | No               |
| SMD Ceramic Capacitor                 | C10                                       | X7R                    | Kemet                 | 1uF      | 10%       | C0805                                     | 10V                     | 1        | No               |
| QR Code Label                         | Not shown.                                |                        | NTT                   |          |           | 5.5x5.5x0.5mm <sup>3</sup> (see Fig. 2.7) |                         | 1        | Yes              |
| Fibre Clamp                           |   |                        | Manufacturer          |          |           |   |                         | 1        | No               |
| Laser cover                           |   |                        | Manufacturer          |          |           |   |                         | 1        | No               |

<sup>1</sup> The components where the supplier has been specified have been qualified as radiation resistant by CERN.

<sup>2</sup> For DOH intended for Pixel detector system in CMS, a different version of the receiver RX40 may be used. In this case the pixel DOH may be grouped into one production lot.

Fig. 2.5: Electrical schematic of DOH

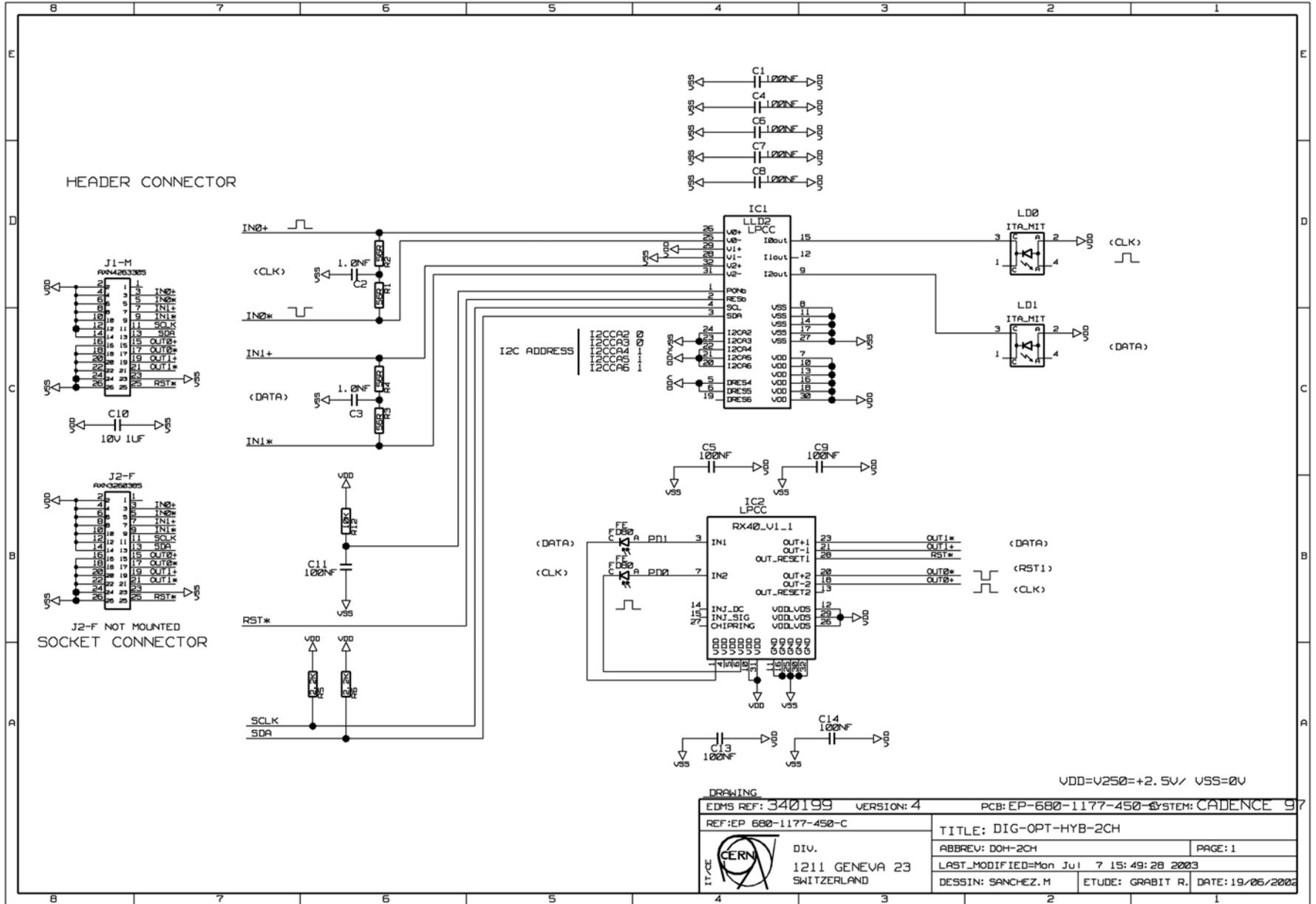


Figure 2.6: Laser assembly and MU-connector.

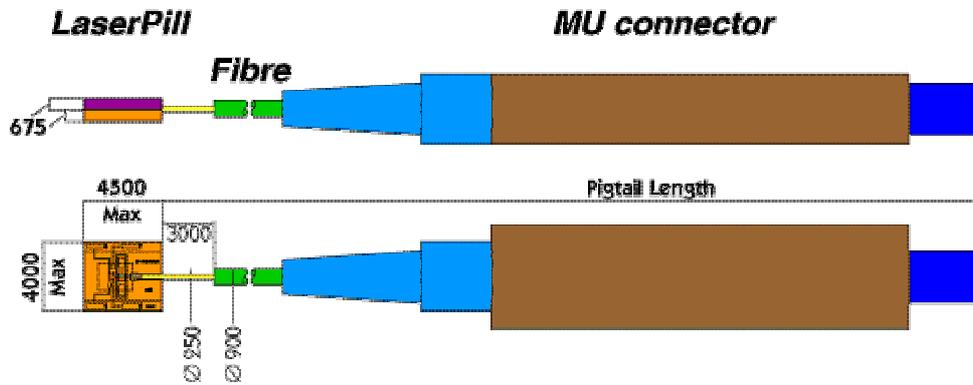
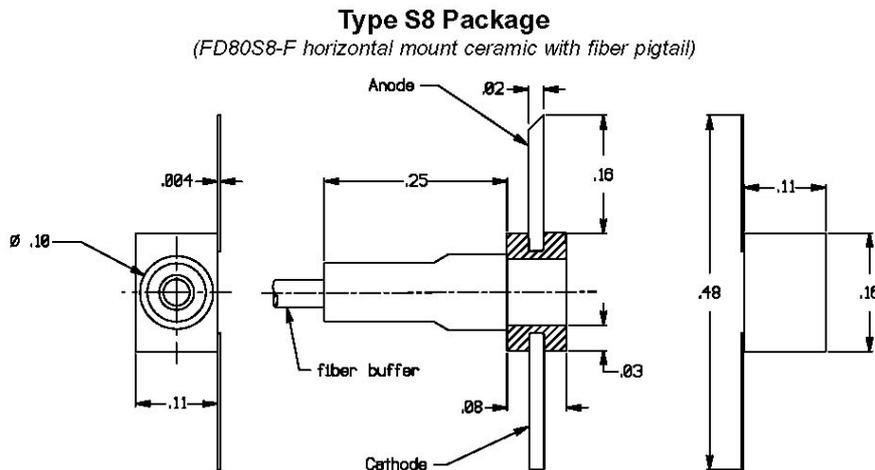


Figure 2.7: Photodiode assembly. Supplied with MU-connector identical to laser in Fig. 2.6.



(All dimensions in inches)

Figure 2.8: QR code label. Actual size 5x5x0.5 mm<sup>3</sup>. Fig. 2.2. shows where the label shall be attached.



## 2.5. Manufacturing Specifications

### 2.5.1. Substrate

| #     | Specification                           | min  | typ                   | max | unit | note  |
|-------|---|--|-----------------------|-----|------|---|
| 2.101 | Substrate Manufacture Quality Standard  | IPC A 600 Class 3<br>and<br>Norme Francaise<br>NF C 93-713 Classe 6 <sup>1</sup> |                       |     |      | Statement of compliance required from Manufacturer.                                     |
| 2.102 | Material                                | FR4  |                       |     |      |   |
| 2.103 | Number of layers                        | 4  |                       |     |      |   |
| 2.104 | Total final PCB thickness               |  | 500                   | 600 | μm   |   |
| 2.105 | Thickness of FR4                        | Top layer = 100  |                       |     | μm   | for impedance control<br>(see Fig. 2.4)   |
|       |   | Bottom = 100   |                       |     |      |   |
| 2.106 | Copper track thickness                  |  | 17<br>(+8<br>plating) |     | μm   | Top, bottom layers 17microns<br>copper plus 8 microns plating.<br>Impedance controlled. |
|       |   |  | 35                    |     | μm   | Inner layers  |
| 2.107 | Copper track width on signal lines      |  | 150                   |     | μm   | Impedance controlled.   |
| 2.108 | Copper track separation on signal lines |  | 180                   |     | μm   | Impedance controlled.   |
| 2.109 | Via diameter                            | 200  |                       |     | μm   | Plated area around via has<br>200μm larger diameter. <sup>2</sup><br>(NF Classe 6)      |
| 2.110 | Bond pad material                       | <i>Cu-Ni-Au</i>  |                       |     |      |   |
|       | Specs 2.111 to 2.130                    |  |                       |     |      | Reserved for future use   |

<sup>1</sup> Norme Francaise NF C 93-713 (1989) used by the CERN design office. See Ref [2.4].

<sup>2</sup> This feature of the DOH design is Class 6 in Norme Francaise NF C 93-713.

2.5.2. *Passive sub-components*

| #     | Specification                               | min   | typ | max | unit | note   |
|-------|---|---|-----|-----|------|--|
| 2.131 | Assembly Quality Standard                   | IPC A 610 Class 3                                 |     |     |      | Statement of compliance required from Manufacturer.  |
| 2.132 | Resistor type                               | R0402   |     |     |      | R1 to R6, and R12.   |
| 2.133 | Resistor values                             | See Section 2.4.1                                 |     |     |      |  |
| 2.134 | Resistor tolerances                         |   |     | 5   | %    |  |
| 2.135 | Capacitor types                             | C0402 X5R   |     |     |      | C1, C4 to C9, C11, C13 and C14.  |
|       |   | C0402 X7R   |     |     |      | C2, C3   |
|       |   | C0805 X7R   |     |     |      | C10  |
| 2.136 | Capacitor values                            | See Section 2.4.1                                 |     |     |      |  |
| 2.137 | Capacitor tolerances                        |   |     | 10  | %    |  |
| 2.138 | Connector type                              | NAiS Matsushita 26 pin Header                     |     |     |      | Part number: AXN426430S 26-pin male (0.8mm). Height = 4mm.   |
| 2.139 | Fibre clamp material                        | FR4 or Glue/ceramic <b>(TBD)</b>                  |     |     |      | FR4 piece-parts glued as for CERN prototypes.<br>Alternative solution similar to AOH.<br>Final solution <b>(TBD)</b>                   |
| 2.140 | Fibre clamp glue                            | Non-conducting epoxy                              |     |     |      | Maximum curing temperature 50°C.<br>No excess glue on lasers or naked fibre parts.   |
| 2.141 | Fibre clamp dimensions                      | Width <b>TBD</b><br>Length = 21.5<br>Height = 4.0 |     |     | mm   | Length matches DOH width.<br>Height matches mated NAiS connector.  |
| 2.142 | Fibre clamp positional tolerance            |   |     | 0.5 | mm   |  |
| 2.143 | Laser protection cover material             | FR4 or Ceramic <b>(TBD)</b>                       |     |     |      | Should be attached to the fibre clamp and LLD ASIC <b>(TBD)</b>  |
| 2.144 | Laser protection cover dimensions           |   |     | TBD | mm   | Check by visual inspection.<br>Total height of hybrid should be 4.5mm.   |
| 2.145 | Laser protection cover positional tolerance |   |     | 0.5 | mm   |  |
| 2.146 | Laser protection cover glue                 | Non-conducting epoxy                              |     |     |      | Maximum curing temperature 50°C.<br>No excess glue on lasers or naked fibre parts.   |
| 2.147 | Label                                       | QR code<br>5 x 5 x 0.5                            |     |     | mm   | See Fig. 2.8.<br>Positioning on bottom-side in same position as the connector.<br>There should be no other labels attached to the DOH. |
| 2.148 | Label glue type                             | <b>TBD</b>  |     |     |      | Maximum curing temperature 50°C.   |
|       |   |   |     |     |      |  |
|       | Specs 2.149 to 2.160                        |   |     |     |      | Reserved for future use  |

### 2.5.3. Active subcomponents

| #     | Specification                      | min | typ   | max | unit | note   |
|-------|------------------------------------|-----|---|-----|------|--|
| 2.161 | Assembly Quality Standard          |     | IPC A 610 C<br>Class 3  |     |      | Statement of compliance required.  |
| 2.162 | Laser driver ASIC package          |     | LPCC 32 pin   |     |      | Ref [1.7].<br>CERN supplied known good die.  |
| 2.163 | Receiver ASIC package              |     | LPCC 32 pin   |     |      | Ref [1.8].<br>CERN supplied known good die.  |
| 2.164 | Laser package                      |     | Custom  |     |      | See Fig. 2.6<br>CERN supplied known good die.<br>Same fibre length as for photodiode on same DOH.  |
| 2.165 | Laser package handling             |     | Very fragile  |     |      | Tensile force on fibre <3N.<br>No torsion to be applied to fibre.<br>Not pick-and-place compatible.<br>All fibres to be unwound and relaxed during assembly. |
| 2.166 | Laser package glue                 |     | Thermally conductive,<br>electrically insulating<br>epoxy.<br>Type <b>TBD</b> . |     |      | No excess glue on or around laser.<br>Maximum curing temperature 50°C.   |
| 2.167 | Laser package bonding              |     | Double bond<br>25um Al Si 1%<br>Or Au 25-31um<br>MIL-STD-883E                   |     |      | For redundant reliability.<br>Minimize height of bond.<br>Bond-strength specification must satisfy MIL-STD-883E, Method 2011.7 Wire-pull, Condition D.       |
| 2.168 | Photodiode package                 |     | Custom  |     |      | See Fig. 2.7<br>CERN supplied known good die.<br>Same fibre length as for laser on same DOH.   |
| 2.169 | Photodiode package handling        |     | Fragile   |     |      | Tensile force on fibre <3N.<br>No torsion to be applied to fibre.<br>Not pick-and-place compatible.<br>All fibres to be unwound and relaxed during assembly  |
| 2.170 | Photodiode package glue            |     | Non-conductive<br>epoxy   |     |      | Maximum curing temperature 50°C.   |
| 2.171 | Photodiode package soldering       |     | <b>TBD</b>  |     |      | e.g. Sn60Pb40, Type 5 core ERSIN 362, diameter 0.46mm.<br>Lead-frame to be cut to correct size.<br>Rework limits <b>TBD</b> .                                |
| 2.172 | Hybrid mechanical shock resistance |     | MIL-STD-883E  |     |      | Must satisfy Method 2002.3 Condition B.  |
|       |                                    |     |   |     |      |  |
|       | Specs 2.173 to 2.199               |     |   |     |      | Reserved for future use  |

## 2.6. Quality Assurance

### 2.6.1. Standards

Manufacturer to provide details of compliance with relevant standards:

- Substrate manufacture: IPC A 600F Class 3.
- SMD mounting: IPC A 610C Class 3
- Solder mounting (Photodiode): IPC A 610C Class 3
- Bonding. (Laser): MIL STD 883

### 2.6.2. Documentation

Manufacturer to provide process flow details to CERN.

Test data to be provided by manufacturer for every delivered DOH. All test data will be exchanged in electronic form.

### 2.6.3. CERN supplied components

Minimum 100% free-issued supply of lasers, photodiodes, RX40 ASICs, LLD ASICs, QR codes.  
Up to 10% additional quantities of each part will be free-issued to cover <100% yield.

### 2.6.4. Testing

The testing is summarized in Section 2.7 and the procedures are detailed in a separate QA document, Ref. [2.5].

Visual inspections to be performed according to IPC standards.

Electrical tests to be performed during DOH assembly using CERN-supplied test equipment.

Electro-optical tests to be performed after DOH assembly (100%) using CERN-supplied test equipment as in Section 2.7.2.

All DOH to be burned in 72hrs at 50°C.

Reliability, Qualification and Acceptance testing to be performed on pre-production and production lots as in Sections 2.7.2 and 2.7.3 following procedures in Ref. [2.5].

### 2.6.5. Component Traceability

QR codes (for lasers and photodiodes supplied by CERN already attached) near MU connectors.

QR code (supplied by CERN) to be attached on DOH at location shown in Fig. 2.2.

Manufacturer will be required to use QR codes for associating test data with components.

### 2.6.6. Shipping, storage and handling requirements

Packaging: Delivery package from ST (containing 2 lasers) to be re-used as the DOH package.

ESD: Protection measures to be applied at all times, according to IPC A 610C.

Fibre handling: No excessive strain to be put on fibres, neither pull nor twist.

Always ensure that the fibres are relaxed during mounting and testing of the components.

The fibres should always be handled carefully to avoid scratches and cuts to the acryllate buffer material.

## 2.7. Specification Test Table

### 2.7.1. Manufacturing Tests

| #     | Specifications to be tested                 | <i>Kapsch</i>         |                                      |                   |                     |
|-------|---|-----------------------|--------------------------------------|-------------------|---------------------|
|       |   | Pre-production series |                                      | Production series |                     |
|       |   | Intention to Test     | Sample quantity (%)                  | Intention to Test | Sample quantity (%) |
| 2.102 | Material                                    | x                     | 1                                    |                   | 1                   |
| 2.103 | Number of layers                            | x                     | 1                                    |                   | 1                   |
| 2.104 | Total final PCB thickness                   | x                     | 1                                    |                   | 1                   |
| 2.105 | Thickness of FR4                            | x                     | 1                                    |                   | 1                   |
| 2.106 | Copper track thickness                      | x                     | 1                                    |                   | 1                   |
| 2.107 | Copper track width on signal lines          | x                     | 1                                    |                   | 1                   |
| 2.108 | Copper track separation on signal lines     | x                     | 1                                    |                   | 1                   |
| 2.132 | Resistor type                               | x                     | 0.1                                  |                   | 0.1                 |
| 2.133 | Resistor values                             |                       |                                      |                   |                     |
| 2.134 | Resistor tolerances                         |                       |                                      |                   |                     |
| 2.135 | Capacitor types                             | x                     | 0.1                                  |                   | 0.1                 |
| 2.136 | Capacitor values                            |                       |                                      |                   |                     |
| 2.137 | Capacitor tolerances                        | x                     | 0.1                                  |                   | 0.1                 |
| 2.138 | Connector type                              |                       |                                      |                   |                     |
| 2.139 | Fibre clamp material                        |                       |                                      |                   |                     |
| 2.140 | Fibre clamp glue                            | x                     | 1                                    |                   | 1                   |
| 2.141 | Fibre clamp dimensions                      | x                     | 1                                    |                   | 1                   |
| 2.142 | Fibre clamp positional tolerance            | x                     | 100                                  |                   | 100                 |
| 2.143 | Laser protection cover material             |                       |                                      |                   |                     |
| 2.144 | Laser protection cover dimensions           | x                     | 1                                    |                   | 1                   |
| 2.145 | Laser protection cover positional tolerance | x                     | 100                                  |                   | 100                 |
| 2.146 | Laser protection cover glue                 | x                     | 1                                    |                   | 1                   |
| 2.147 | Label                                       |                       |                                      |                   |                     |
| 2.148 | Label glue type                             |                       |                                      |                   |                     |
| 2.164 | Laser package                               | x                     | 1                                    |                   | 1                   |
| 2.165 | Laser package handling                      | x                     | 100                                  |                   | 100                 |
| 2.166 | Laser package glue                          |                       |                                      |                   |                     |
| 2.167 | Laser package bonding                       | x                     | 100<br>(10% bond pull strength test) |                   | 100                 |
| 2.168 | Photodiode package                          |                       |                                      |                   |                     |
| 2.169 | Photodiode package handling                 |                       |                                      |                   |                     |
| 2.170 | Photodiode package glue                     |                       |                                      |                   |                     |
| 2.171 | Photodiode package soldering                | x                     | 100                                  |                   | 100                 |
|       |   |                       |                                      |                   |                     |

### **2.7.2. *Assembly tests, pre-production qualification and lot acceptance tests***

CERN will provide a test-system to the manufacturer which will allow the key functional parameters (marked 'C' in the following Table) to be tested rapidly on 100% of assembled DOH boards.

100% of DOHs shall be burned-in at 50°C for 72 hours. This may take place in parallel with the final epoxy curing step.

The manufacturer is expected to supply CERN only DOH that pass the assembly test and meet all other criteria detailed in the IPC standards.

Reworking or repair of DOHs by the manufacturer is acceptable only as long as the delivered DOH meets the required standards and specifications and passes the assembly test.

A complete set of tests to characterise the full functionality of the hybrid will be made on DOH boards at CERN at 100% level during pre-production and at least 5% level during lot acceptance. All of these tests are detailed in Ref [2.5]. No failures are allowed in a given pre-production test step, or during acceptance of a delivered lot.

In the case of failure of a DOH during pre-production qualification or during lot acceptance the cause of failure will be determined by CERN and/or the manufacturer. If required, a larger quantity of devices could be subjected to tests, or more detailed testing carried out, in order to diagnose the cause of failure.

If a device failure is related to a manufacturing process, the manufacturer is expected to resolve the problem and then supply a new delivery of devices for qualification or lot acceptance. In the case of failure during burn-in that is related to a manufacturing process, the manufacturer is expected to repair or replace the failed device.

If device failure occurs due to reasons not associated to the manufacturing process, then CERN reserves the right to modify the DOH design, the component parts, the specifications, or the test-procedures as necessary.

| #    | Specifications to be tested            | At Manufacturer   | At CERN                                   |                         |
|------|--|---|---|-------------------------|
|      |  | Assembly test<br>(100%)<br><br>'C' denotes measurement using<br>CERN-supplied test-system | Pre-production<br>qualification<br>(100%) | Lot acceptance<br>(>5%) |
| 2.1  | Bit-rate                               | C   | ◆   | ◆                       |
| 2.2  | Bit-error-rate                         |   | ◆   | TBD                     |
| 2.3  | Skew                                   |   | ◆   |                         |
| 2.4  | Jitter                                 |   | ◆   |                         |
| 2.11 | Number of Tx channels                  | C   | ◆   | ◆                       |
| 2.12 | Number of Rx channels                  | C   | ◆   | ◆                       |
| 2.13 | Size                                   | ◆   | ◆   | ◆                       |
| 2.21 | Differential input voltage             | C   | ◆   | ◆                       |
| 2.22 | Input impedance                        |   | ◆   | ◆                       |
| 2.23 | Differential output voltage            | C   | ◆   | ◆                       |
| 2.24 | Reset output                           | C   | ◆   | ◆                       |
| 2.25 | Power supply                           |   | ◆   |                         |
| 2.26 | Power dissipation                      |   | ◆   | ◆                       |
| 2.27 | I2C address                            | C   | ◆   | ◆                       |
| 2.28 | Default LLD laser I2C bias<br>setting  | C   | ◆   | ◆                       |
| 2.29 | Default LLD gain setting               | C   | ◆   | ◆                       |
| 2.30 | Electrical connector                   | C   | ◆   | ◆                       |
| 2.42 | Tx average output power at<br>power-up | C   | ◆   | ◆                       |
| 2.43 | Tx optical modulation<br>amplitude     | C   | ◆   | ◆                       |
| 2.44 | Rx sensitivity                         | C   | ◆   | ◆                       |
| 2.45 | Rx saturation (d.c.)                   | C   | ◆   | ◆                       |
| 2.47 | Fibre type                             | ◆   | ◆   | ◆                       |
| 2.48 | Pigtail length                         | ◆   | ◆   | ◆                       |
| 2.49 | Optical connector                      | ◆   | ◆   | ◆                       |

### 2.7.3. Reliability tests on pre-production devices

All of the following tests are detailed in Ref [2.5].

All of the tests will be performed by CERN with the exception of the mechanical shock and bond-pull tests, which the manufacturer will perform on pre-production DOH samples. The manufacturer will report the test results to CERN within one month of the test.

All of the tests have to be passed for successful qualification of the pre-production batch.

For the magnetic field and radiation damage tests, the responsibility for the tests and the consequences of the results is taken by CERN.

If there are found to be problems in these tests, CERN reserves the right to modify the DOH design, change the specifications, change component parts, or modify the test-procedures as necessary.

| #     | Specifications to be tested                         | Reliability Tests by Manufacturer | Reliability Tests by CERN |
|-------|---|-----------------------------------|---------------------------|
|       |   |                                   |                           |
| 2.50  | Tensile strength                                    |                                   | ◆ <sup>1</sup>            |
| 2.61  | Magnetic field resistance                           |                                   | ◆                         |
| 2.62  | Hadronic fluence                                    |                                   | ◆                         |
| 2.63  | Gamma dose  |                                   | ◆                         |
| 2.64  | Temperature   |                                   | ◆                         |
| 2.167 | Laser package bonding                               | ◆                                 |                           |
| 2.172 | Hybrid resistance to mechanical shock and vibration | ◆                                 |                           |
|       |   |                                   |                           |

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<sup>1</sup> Non-destructive tensile tests will also be part of lot acceptance.

### 3. Glossary

#### 3.1. Skew

The skew is determined by measuring, for two channels, the average time  $\overline{t_{50}}$  required for a step response signal to reach 50% of its end value. The skew between channels i and j is defined as:

$$t_{\text{skew}} = \overline{t_{50,j}} - \overline{t_{50,i}}$$

#### 3.2. Jitter

The rms jitter is defined as the rms deviation of the time  $t_{50}$  required for a step response signal to reach 50% of its end value:

$$t_{\text{jitter}} = \sqrt{\overline{(t_{50} - \overline{t_{50}})^2}}$$

## 4. References

- [1.1] <http://cmsinfo.cern.ch/cmsinfo/Welcome.html>
- [1.2] <http://www.cern.ch/>
- [1.3] A. Marchioro, " Specifications for the Control Electronics of the CMS Inner Tracker", Draft V2, CERN
- [1.4] The tracker project, technical design report, CERN/LHCC 98-6, CMS TDR 5
- [1.5] A. Marchioro, "FEC specification", Draft, CERN
- [1.6] A. Marchioro, "CCU specification", Draft, CERN
- [1.7] G. Cervelli et al., "A radiation tolerant laser driver array for optical transmission in the LHC experiments", Proceedings of LEB Workshop, 2001.  
<http://proj-lld.web.cern.ch/proj-lld/>
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- [2.1] M. Huhtinen, "Studies of neutron moderator configurations around the CMS inner tracker and Ecal", CERN CMS TN/96-057, 1996.
- [2.2] K. Gill, "Laser safety in the CMS Tracker optical links", <http://edms.cern.ch/document/338505/1>.
- [2.3] [http://www.cern.ch/CERN/Divisions/TIS/safdoc/instr\\_en.html](http://www.cern.ch/CERN/Divisions/TIS/safdoc/instr_en.html)
- [2.4] CERN Design Office DOH spec file: 680 1177-450 C
- [2.5] Front-end Digital Optohybrid (DOH) Test Procedures. CMS-TK-QP-0009