Versatile Transceiver and Transmitter Production for Phase I Upgrades of LHC Experiments

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Outline

● Optical Link Common Project
● Versatile Link front-end module (VTXx) design status
● VTXx procurement status
● VTXx radiation validation
● VTXx quality assurance plan
Optical Link Project

- CERN common project
- Bidirectional, ~5Gbps
- Versatile
  - Multimode (850nm) and Singlemode (1310nm) versions
  - Point to Point and Point to Multipoint architectures
- Front-end pluggable module

- CERN Common Project endorsed by LHC experiments
- Collaboration between CERN and partner institutes
- Kick-off mtg in April 2008
- Production planned for 2014/5
- Target LS2 upgrades

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**On-Detector**
Custom Electronics & Packaging
Radiation Hard

**Off-Detector**
Commercial Off-The-Shelf (COTS)
Custom Protocol
Versatile Link Overview

1 Introduction

The purpose of this document is to define the purchasing strategy for optical link components for users identified to date: LHCb, CMS HCAL, and CMS Pixel phase 1 upgrade. An overview of a typical optical link is given in Figure 1. This document gives an overview of the items to be procured and how these will be matched to the CERN purchasing procedures. Three types of CERN purchasing procedure are available:

• Market Survey, Call for Tender, and contract placement
• Price Enquiry and contract placement
• Generic purchase order

Use of the different procedures is dictated by the total value of CERN funds used to pay for the supply. It is therefore instructive to review the total quantities and costs as estimated at present, which are given in Table 1.

We note that the majority of the funding for the purchase of these items is likely to come from the experiments' common funds.

2 Purchasing Strategy

The supply of all items will be broken down as indicated in Table 1. The details of each of the procedures in approximate time order (see Section 3) are given below:

Gr`e`a-gr`e 1
Supply of Single-mode (SM) TOSAs, manufacturer to supply objects meeting our technical specification. Justification:

• Excellent candidate already identified - significantly more rad-hard than others.
• Previous good experience with supplier in context of CMS Tracker optical links.

Figure 1: Overview of the two optical link variants showing the various components and sub-components: (top) bidirectional link with a VTRx and TRx (SFP+) module; and (bottom) uni-directional link with VTTx and DRx12.
Front-end pluggable module
## Design Status

<table>
<thead>
<tr>
<th>Variant</th>
<th>Laser Driver</th>
<th>TOSA</th>
<th>ROSA</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-mode VTRx</td>
<td>GBLD v4.1</td>
<td>Edge Emitter Laser</td>
<td>InGaAs GBTIA v2</td>
<td></td>
</tr>
<tr>
<td>Multi-mode VTRx</td>
<td>GBLD v4.1</td>
<td>850 nm VCSEL</td>
<td>GaAs GBTIA v2</td>
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<tr>
<td>Multi-mode VTTx</td>
<td>GBLD v4.1</td>
<td>850 nm VCSEL</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Rad-soft VTTx</td>
<td>ONET8501V</td>
<td>850 nm VCSEL</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

- Performance demonstrated at TWEPP 2012
- Final circuit board layout complete
- Prototypes available
# Procurement quantities

<table>
<thead>
<tr>
<th>Experiment &amp; User</th>
<th>VTRx SM</th>
<th>VTRx MM</th>
<th>VTTx MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHCb</td>
<td>2750</td>
<td>6830</td>
<td></td>
</tr>
<tr>
<td>CMS HCAL</td>
<td>200</td>
<td>270</td>
<td>2710</td>
</tr>
<tr>
<td>ATLAS</td>
<td>650</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>SmallWh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATLAS LArg</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALICE</td>
<td>3550</td>
<td>3200</td>
<td></td>
</tr>
<tr>
<td>BE-BI-BL</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE-BI-QP</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBM@FAIR</td>
<td>1000</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1200</td>
<td>8370</td>
<td>15340</td>
</tr>
</tbody>
</table>

- CERN organises procurement on behalf of users
- Overall budget for all items is around 2.8 MCHF
Procurement plan

- Procurement process defined and started
  - CERN will provide outlay
  - Tendering needs to be completed to know final cost
- Volume production starting early 2015
Radiation tolerance levels

- VL specifications define two tolerance levels depending on application

<table>
<thead>
<tr>
<th>Tolerance level</th>
<th>Dose and fluence(^1) (1MeV neutron equivalent)</th>
</tr>
</thead>
</table>
| 4.1.1.1 Calorimeter | 10 kGy  
5 x 10\(^{14}\) n/cm\(^2\) |
| 4.1.1.2 Tracker | 500 kGy  
2 x 10\(^{15}\) n/cm\(^2\)  
1 x 10\(^{15}\) h/cm\(^2\) |

- All of the upcoming production will be qualified for the Calorimeter tolerance level
- Nevertheless, up until now component qualification for selection purposes has been carried out up to HL-LHC Tracker levels
Component Radiation Testing

● Radiation tolerance assessment mandatory for COTS parts
  ● Laser diodes
  ● Photodiodes
  ● Fibre, Connectors

● Extensive online testing carried out over last years
  ● Neutron total fluence irradiation at UCL, Belgium
  ● Pion total fluence irradiation at PSI, Switzerland
  ● Gamma total dose (passive) at Ionisos, France
  ● Proton SEU at PSI, Switzerland

● No unexpected results obtained, devices will withstand Calorimeter grade production
  ● For Post-LS3 Trackers this remains to be validated
SEU mitigation with GBT protocol

- SEUs in the photodiode are unavoidable
- GBT implements an interleaved Reed-Solomon Forward Error Correction (FEC) scheme to mitigate the induced errors
Final validation: VTRx in n-beam

- Final prototype VTRx (SM & MM) exposed to neutron beam at UC Louvain cyclotron facility in Nov. 2013
  - Complex test
  - VTRx in addition to lasers/pins

- Direct comparison between devices irradiated with DC measurements and AC measurements on VTRx
  - Large dataset still being evaluated

- Devices on VTRx behave as expected from static testing
Final validation: VTRx in n-beam (2)

- Comparable results for intrinsic laser behaviour in standard irrad test setup and on VTRx
- Also true for responsivity drop and leakage current increase in photodiodes
Final validation: VTRx in n-beam (3)

- Dynamic performance of lasers unchanged at 4.8 Gb/s
Quality Assurance

● **Pre-series**
  ● Qualification through verification of all specifications
    ● including environmental testing (temperature, radiation)
  ● Long-term aging tests

● **Production batches**
  ● 100% testing of reduced specification set
    ● Power consumption
    ● RX Sensitivity
    ● Tx Eye diagram
  ● Lot validation through sample testing of fuller set of specifications
    ● Not including environmental testing
Testing & traceability

- Test stand for Qualification & Lot acceptance
  - Based on lab instruments (scope & BERT)
- Test stand to be located in Assembly House for 100% testing of modules
  - Based on FPGA evaluation platform
- All modules to be labelled with 2D barcodes
- Test stands communicate with a database
  - History of actions
  - Record of test results
    - Process tracking & statistics
  - Location
Conclusions

- Candidate components for Versatile Link front-end modules qualified
  - Will also verify wafer-wafer variations on production quantity

- VTXx procurement process proceeding
  - Volume production will begin in 2015

- Measured the performance/degradation of full VTRx module during neutron irradiation
  - O-E components behaved as expected, high-speed operation verified in-beam for the first time
  - SEU issue found with GBLD, to be fixed
Further Reading

- **GBT**
  - Presentation by Paulo Moreira at ACES 2014
    - http://indico.cern.ch/event/287628/session/1/contribution/12/material/slides/

- **Versatile Link**
  - Presentation by Francois Vasey at ACES 2014
    - http://indico.cern.ch/event/287628/session/1/contribution/13/material/slides/
  - Electronics Seminar 2014
    - http://indico.cern.ch/event/267423/
GBT Radiation Qualification

- **GBTIA**
  - X-ray Total Dose validated to 1 MGy
  - Proton SEU tolerance at PSI, Switzerland

- **GBLD**
  - X-ray Total Dose validated to 1 MGy
  - Proton SEU at PSI, Switzerland
  - Neutron SEU at UCL, Belgium (see later)
  - Ion SEU at Legnaro, Italy identified some issues, being fixed