Project Introduction

The Versatile Link is a joint ATLAS-CMS project that aims to deliver a radiation tolerant 4.8 Gb/s bi-directional optical link for the LHC upgrade program. The front-end interface module – VTRx – is a low power dissipation and low mass electro-optical transceiver that is protocol-agnostic. The link is also targeted to operate in tandem with the CERN GBT serializer-deserializer chip (https://espace.cern.ch/GBT-Project/default.aspx), as shown in this diagram.

Link versatility: two versions are being developed – single-mode and multi-mode operating at 850nm and 1310nm wavelength respectively.

<table>
<thead>
<tr>
<th>Front-end VTRx (CERN)</th>
<th>Fiber (Oxford UK)</th>
<th>Back-end Trx (fermilab)</th>
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<tbody>
<tr>
<td>EE laser, 1310 nm</td>
<td>Single-mode</td>
<td>LR-SFP+ TRX</td>
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<tr>
<td>VCSEL, 1310 nm</td>
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<tr>
<td>InGaAs PIN, 1310 nm</td>
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<tr>
<td>VCSEL, 850 nm</td>
<td>Multi-mode</td>
<td>SR-SFP+ TRX</td>
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<td>GaAs PIN, 850 nm</td>
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<td>InGaAs PIN 850 nm</td>
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Link Requirements and Specifications (optical power as an example)

The fundamental requirement for the Versatile Link is the reliable operation in radiation environments of particle physics detectors. Radiation induced degradation in circuits, optical modules and in fiber must be taken into account in the system level design. Parts must not only be resistant to ionizing, but also displacement damage while system level design to mitigate Single Event Effects (SEE) must in place. In the Versatile Link we design for two radiation tolerance grades: the calorimeter (10 kGy, 5×10^{14} neutron/cm^2) grade and the tracker (500 kGy, 2×10^{15} neutron/cm^2, 1×10^{15} hadron/cm^2) grade. Based on studies of optical components (lasers and PIN diodes) and fibers, we specify an optical power budget with margin for all link configurations. The timing jitter budget is adapted from FC 4G standards. A full set of system and components specifications can be found at https://edms.cern.ch/nav/P:CERN-0000076379-V0/P:CERN-0000090391-V0/TAB3

Front-end Prototype

The VTRx is the transceiver module that will be placed close to the upgraded SLHC detector elements at the front-end. It is a module that is based closely on a standard SFP+ transceiver in terms of electrical- and optical interfaces as well as overall dimensions.

The VTRx is customized for use in the HI-LHC detector environment: the laser driver and detector amplifier are custom-designed as part of the GBT project; the laser and photo-detector have been evaluated for their radiation tolerance; and the mechanical interface has been re-designed to reduce its mass and remove magnetic material.

A broad spectrum of optical devices and subassemblies have been tested using both neutron and pion beams to ensure that they will survive the HI-LHC lifetime fluence levels. System impact of radiation degradation is accounted for in the power budget. SEE testing has also been carried out on candidate photodiodes and ROSA assemblies. The Bit Error Rate induced by a particle beam requires the use of a forward error correction code. The one implemented in the GBT chipset has been shown to be effective.

Fiber and Back-end

Radiation Induced Absorption (RIA) of optical fiber is highly dependent on the dose rate and temperature of the environment. Given an equal integrated dose, fibers suffer greater RIA when that dose is delivered at a higher rate and at lower temperatures. Several single- and multi-mode fibers have been qualified with less than 1.0dB of overall RIA for link deployment.

Commercial single channel transceivers are qualified to comply with system specification for the detector back-end. Industry parallel transceiver development is emerging and the high density feature is desirable to the back-end. A number of 4- and 12- channel transceivers and receivers have been tested with promising performance.

Conclusion

The Versatile Link project is developing a 4.8 Gb/s optical link physical layer for use in upgraded LHC detectors. The approach chosen has been to qualify commercially available components for use in the HI-LHC environment and minimally customize them only where necessary. The project has now concluded its second phase with the successful demonstration of feasibility of the proposed optical link system. The full VTRx built from radiation-tolerant, low-mass components has been tested and shows good results. A full list of candidate optical link components has been established for all parts of the versatile link. These components have been validated according to the specifications established for functional performance and radiation tolerance. These specifications give us confidence that a large scale implementation of the Versatile Link will operate correctly. System demonstrators are in development and will soon be available to interested users for sampling.