Evaluation of 400m, 5 Gbit Versatile Link lengths over OM3 and OM4 fibres for the LHCb upgrade

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Summary

The LHCb experiment will upgrade its DAQ system to a trigger less, 40MHz read-out during the upcoming, second long shutdown of the LHC. To be able to process the approximately 40 Tbit/s of data we will require a large computing farm. This computing farm can not be installed underground, in the vicinity of the detector anymore due to the increased power and cooling requirements.

An affordable data transport solution has to be found to carry the data from the detector to the new data center on the surface. The distance to cover has been measured to be 310 m. The only off-the-shelf technology capable of such distances, at affordable prices, is 10 Gbit Ethernet over OM3 or OM4 multimode fibres with 10GBASE-SR transceivers.

The Versatile Link, developed by ATLAS and CMS, is a radiation tolerant 5 Gbit/s optical link which is based on and compatible with the optical components used for 10GBASE-SR equipment. Since LHCb is planning to use this link for the front-end readout, we are evaluating the possibility of using the front-end optical transmitters to directly transmit to the remote data center. This would eliminate the need for an additional 10 Gbit/s transmit to the remote data center. This would cut down costs for the DAQ system.

The proposed fibre system layout foresees a direct connection of approximately 300m length between the detector and the new LHCb data center at the surface of Point 8 of the LHC. The system contains a minimum of 3 break points. Data is transferred via a 5 Gbit/s signal produced on the detector by Versatile Link transmitters (VTx). Control signals are sent from the data center to the detector by the same carrier system and received on the detector with Versatile Link receivers (VRx). The complete system will contain approximately 17,000 individual fibres.

Test Setup

To evaluate various optical fibres and to test the proposed read-out scheme on a system level, we used a standard setup for measuring Bit Error Rates (BER) of optical systems. A pattern generator produces a PBERT signal, which drives the optical transmitter (VTx). The signal goes through the fibre under test and a variable optical attenuator (VOA). The signal is split into an optical power meter (OPM) and into the receiving circuit (MiniPOD RX).

This test setup actually contains 5 instead of the foreseen 3 break points of the final system. It also contains two additional breakpoints on the VOA.

A similar setup is used for testing 10 Gbit/s signals. In this case the VTTx is replace by a commercial SFP+ transceiver like they are found in commercial networking equipment.

Results

- Multimode distortion and Receiver sensitivity measurement. We tested several 400m fibre strands vs. a short 0.5m fibre. The plotted values are BER vs. received Optical Modulation Amplitude (OMA). Signal degradation caused by the fibre is less than 0.5 dB.

- Receiver sensitivity at 10\textsuperscript{-13} is approximately -16 dBm. The squelch limit of the receiver is at -14 dBm. It was measured at -11 dBm for a 10 GHz signal, which conforms to the specs of the receiver.

- Optical Link Budget calculated from the measured values for various optical fibres of 400m length and specifications for transmitters and receivers. The value with the biggest uncertainty was the mode dispersion at 5 Gbit/s since all fibres are specified for 10 Gbit/s operation. We found almost no degradation in OM3 and OM4 in contrast to a 10 Gbit/s signal. Since there is still enough margin, we have used the more pessimistic receiver sensitivity of -11 dBm instead of the measured -14 dBm.

Conclusion

We have shown that a long distance read-out based on a 5 Gbit/s Versatile Link is feasible over a distance of at least 400m. Especially the following points have been settled:

- There is no significant difference between OM3 and OM4 for 5 Gbit/s. Degradation of a 5 Gbit/s signal seems mostly dominated by attenuation and not by optical dispersion. As expected there where significant differences for 10 Gbit/s.

- There is no significant difference between different fibre manufacturers. Cheap fibres performed as well as expensive ones.

- The commercial, active optical components are behaving much better than at their spec. for 10 Gbit/s.

In the future we will test more fibres and transmitter - receiver pairings. This is especially important since the receivers are multi lane receivers and only very few lanes have been tested so far. The current study draws a very promising picture, but needs more statistics.