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An Optical Link for ATLAS Liquid Argon Calorimeter Front-end Electronics Readout

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This paper presents the design, production quality assurance, integration, installation and commissioning of the optical link system for the ATLAS Liquid Argon Calorimeter front-end electronics readout. Operation experience and the recent problems with the optical transmitters are discussed. Also presented are the up-to-date results in searching for failure modes, experiences gained in that process, and a possible drop-in backup solution with redundancy for the optical transmitter.

Summary

The optical link system to read out the front-end board (FEB) for the ATLAS Liquid Argon Calorimeter (LAr) is based on a commercial 1.6 Gbps (de-)serializer chipset with a custom assembly of optical interface modules based on VCSEL and p-i-n diode. The assemblies are called OTx and ORx. The system uses a graded-index multi-mode fiber. The interface to upstream electronics is realized with an ASIC based on the DMILL technology. The interface to downstream electronics is implemented in FPGA. All components in the front-end together with the fiber are evaluated for operations in the radiation environment where the LAr front-end crates are situated inside the ATLAS detector.

With Level-1 trigger returning back to the FEB, the data bandwidth is modest which eases the requirements on the optical link in both speed and power dissipation. The optical power budget is chosen to be 10 dB, with OTx satisfying laser eye-safe (-3 to -7 dBm) requirement. To reach a sensitivity of -17 dBm in ORx, especially with 8 ORx in one PCB of the read-out-driver (ROD), special care has to be taken in the ORx design, and the corresponding PCB layout on ROD, to reach this sensitivity in the system. In an effort to avoid single-point-failure mode and to improve the system reliability, a dual channel redundancy scheme called the dual G-link design was developed. This design was not adopted in the final implementation. Most important lessons learned in the integration: interface and modulation are important in a complex system in which the developments of subsystems are not synchronized.

In production quality assurance (QA) of OTx and ORx, a special set of specification is generated based on GbE standards. Reliability tests and results interpretation are based on conventional thermo-stress tests. This has later proven to be insufficient. In the early operation periods, we experience OTx failures: the VCSEL stops lasing. Great efforts have been spent to understand the cause(s) and postmortem symptoms are consistent with those caused by electro-static-discharge (ESD), electro-over-stress (EOS) and material defects in laser fabrication. So far there is no complete understanding of the failure mechanism. Based on the optical spectrum of the lasers, a semi-empirical, non-invasive measure has been developed to assess future failures. Studies have been carried out to understand the relationship of the optical spectrum and the ESD levels damage a VCSEL experiences. This method may also be used in QA for future systems. Two drop-in backup designs for the current OTx will be discussed. A lesson learned for future designs: channel redundancy is mandatory given the demanding level of reliability.

Other than the VCSEL failure at a few percent level, the 1524 channel optical link system for ATLAS LAr front-end electronics readout is functioning as designed and transmitting physics data. This system provides valuable experience for developments of future generation optical links. Lessons learned are helping in the ATLAS-CMS common project, the Versatile Link, which develops the radiation tolerant optical interface module for optical links working at 5 Gbps.

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