

## Upgrade of the L2 electronics in the CMS Muon Drift Tubes system

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**Summary.** — The excellent performance of the DT system during the past years is expected to be pursued at the increased luminosity, so the main motivation driving the DT upgrade is focused on improving the electronic system to maintain its reliability. The fulfillment of this project envisages to turn electrical signals into optical signals for a total number of 3500 optical channels that run at up to 480 Mb/s data rate. A Bit Error Rate (BER) of the order of  $10^{-12}$  with a confidence level (CL) of 95% has been measured which ensures that an appropriate components choice has been made in view of the full boards production.

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### 1. – Introduction

The muons, generated by the collisions inside the Compact Muon Solenoid (CMS) experiment, are detected in the barrel region by the Drift Tube (DT) chambers. The present DT system has shown an excellent performance during the two years data taking period of CMS. In order to maintain the expectations of an adequate operation of the detector at higher luminosity, an upgrade plan is focused on improving the reliability of the system and in particular of a few electronics parts [1].

The second level of the DT electronics is the Sector Collector (SC) system which is placed in the racks on the one side of the CMS wheels. It consists of Readout Server (ROS) boards which are in charge of data merging and quality monitoring, and Trigger Sector Collector (TSC) boards which synchronise the trigger information coming from the DT chamber of one sector of CMS and provide the information about position, transverse momentum and data quality of the muon tracks [2].

The whole system is accessible only during shutdown periods of the LHC and the limited access together with the electronic ageing issue represent a risk factor that may jeopardise detector operation. In order to minimise the downtime in case of failure a

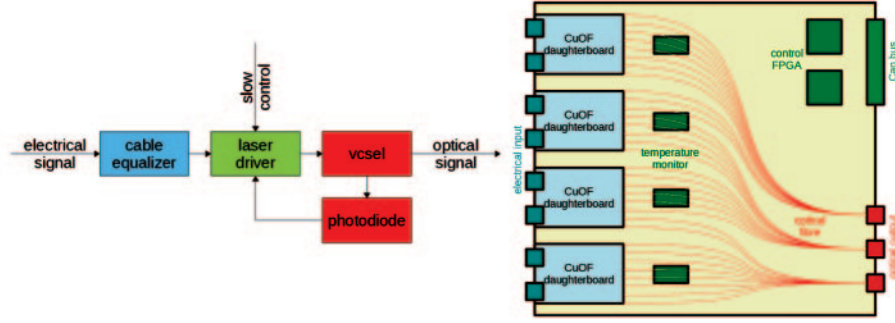


Fig. 1. – Block diagram of the CuOF mezzanine (on the left) and motherboard (on the right).

relocation of the Sector Collector readout and trigger electronics from the CMS cavern to the CMS counting room is planned for the next long LHC shutdown and it will be described in the present report.

In the cavern, inside the current SC electronic crates, new electronic modules will be developed which have the aim to translate each copper link coming from the DT chambers into an optical link that will be routed to the counting room.

A total of 3500 electrical to optical converters has to assure the robustness of the link and translate the electrical signal coming from 40 m copper cables at 240 Mb/s and 480 Mb/s for readout and trigger signals, respectively.

In the following chapters the layout and the tests on the first prototype of the copper to optical converter boards (CuOF system) are described.

In the counting room the optical links will be translated back to electrical links and they will be input again to the present sector collector electronics.

## 2. – CuOF system

The CuOF modules are designed as a set of daughterboards, carrying the high-speed electronics, hosted on a motherboard that provides the slow control services to manage the optical link quality.

The CuOF mezzanine accommodates 8 high speed conversion channels that are fed with serial streams coming from the Minicrates, and carried by Shielded Twisted Pair (STP) copper cables with the Low Voltage Differential Signaling (LVDS) standard (fig. 1, left).

The block diagram of the mezzanine has at input stage an equalizer with the goal to recover the signal quality after a cable about 50 m long, and to restore the DC level reduced on the way.

The next stage is a laser driver that fixes the bias current, to keep the diode near its working threshold, and the modulation current, to determine the dynamic signal applied differentially to the AC coupled laser. The output stage of the conversion channel is the Vertical Cavity Surface Emitting Laser (VCSEL) that was preferred, with respect to the Edge Emitting Laser (EEL), due to the low power consumption and the good radiation tolerance.

The CuOF motherboard (fig. 1, right) is designed in a 9 U VME standard format and it holds 4 mezzanines, where the optical conversion is performed, that can be easily plugged in their respective slots.

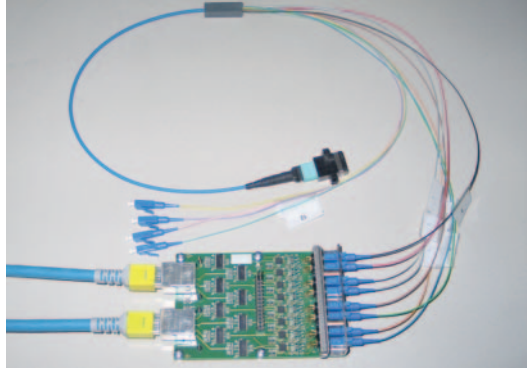


Fig. 2. – The CuOF mezzanine prototype connected to the cables and to the optical fanout.

To avoid a single point of failure the slow control is performed by two Actel FPGA (field programmable gate arrays) that manage two independent Controller Area Network (CAN) buses so, in case of problem on one FPGA, the other bus may be used to take charge of the system. Environmental parameters, as the laser driver temperatures or the power supply voltages, are monitored for each mezzanine in several points by some ADC that transfer the acquired information to the control FPGA. The optical links are terminated on the daughterboard side with single LC connectors while on the motherboard side multiple MTP connectors are planned, therefore optical fanouts are required to get together 12 independent fibres.

### 3. – CuOF prototype

A CuOF test board was designed and assembled to check the performance of the parts under irradiation test, aimed at reproducing the Total Ionizing Dose (TID) and neutron fluence corresponding to more than 10 years run of LHC. The selection of the most suitable parts was accomplished and a choice was made for: the lmh0024 equalizer from Texas Instruments, operating up to 540 Mb/s; the onet1101 laser driver from Texas Instruments, running well above 10 Gb/s; the tp85lcp1f VCSEL and integrated photodiode from Optowell.

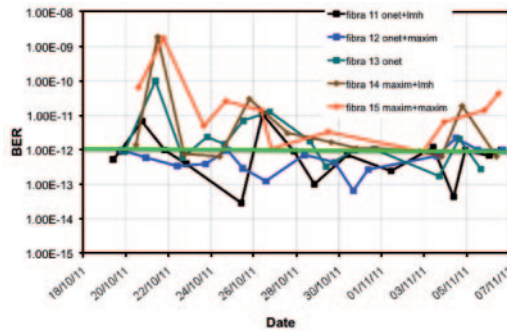


Fig. 3. – The Ber for 5 channels of the CuOF test board during the irradiation test.

With the chosen components the first CuOF prototype (fig. 2) has been assembled and a first irradiation test has been performed at the H4IRRAD CERN facility [3] in October 2011. In about 20 days of run the CuOF prototype has been exposed to  $4 \cdot 10^{10}$  n<sub>eq</sub>/cm<sup>2</sup> neutron fluence and a 1.7 Gy TID that corresponds roughly to what is expected in more than 10 years LHC lifetime [4].

During the irradiation test values of about 2 mA and 3 mA were used for the bias and modulation currents respectively and a Pseudo Random Bit Sequence (PRBS) pattern was sent to the channels at a rate of 622 Mb/s through a 50 m copper cable. No variation of the optical power was detected in any of the channels through all the irradiation period. The measured averaged value was of the order of 300  $\mu$ W. No Single Event Upset (SEU) have been observed and the BER was measured during all the irradiation period. The BER results are shown in fig. 3 for all the channels of the CuOF prototype. No particular relation with the integrated dose is evident and the best channel measures a BER less than  $10^{-12}$  at 95% confidence level.

#### 4. – Summary and outlook

The first CuOF mezzanine prototype has been designed and assembled after a careful selection on the market of Commercial components Off The Shelf (COTS). An irradiation test has been performed at the H4IRRAD CERN irradiation facility and a BER of  $10^{-12}$  at 95% CL has been measured for the best conversion channel using a PRBS input pattern at 622 Mb/s. This irradiation test is validating the COTS for a radiation exposure that corresponds to more than 10 years of LHC lifetime.

A new test at H4IRRAD facility is in progress where two CuOF mezzanines are mounted onto an evaluation board which contains the full set up of components of the CuOF motherboard. The irradiation conditions will be higher with respect to the 2011 test, allowing to validate the CuOF system for the radiation conditions expected at the High Luminosity Large Hadron Collider (HL-LHC).

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