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CWDM-based radiation-tolerant high-speed optical links

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The consolidation of the Large Hadron Collider (LHC) Beam Instrumentation requires the digitisation of the analogue signals from the detectors within the radiation areas. Subsequently, the digital data are transmitted via the existing fibre plant to the back-end area for processing. In order to manage the increased volume of data with the existing infrastructure, the proposed Coarse Wavelength Division Multiplexing (CWDM) link project merges four optical carrier signals of different wavelengths into a single optical fibre through two high-speed radiation-tolerant optical twin transmitters. This paper outlines the project's current status and radiation tolerance of the constituent components.

Summary (500 words)

The upgrade of the LHC Beam Instrumentation aims to replace the current monitoring system, based on analogue circuits sensitive to ageing and close to the expected end-of-life, with a newly developed setup. The upgrade requires digitising directly the signals from the pick-ups and transmitting them to the back-end area as a serialised digital stream. To minimise the consolidation costs, the new system shall reuse the current infrastructure thus requiring an improvement of the throughput of the already installed 3 km optical fibres. The Coarse Wavelength Multiplexing Division (CWDM) technique allows to increase the bandwidth of the existing network merging independent optical carriers at different wavelengths, spaced according to the ITU standard G.694.2, in a single optical fibre. The throughput improvement factor is equal to the number of optical carriers multiplexed in the fibre.
In particular, the CERN CWDM Link project aims to provide a 40 Gbps uplink (i.e. from the front-end area towards the back-end area) multiplexing four optical carriers at the wavelengths λ= 1271,1291,1311, and 1331 nm. Each carrier is independently modulated through radiation-tolerant optical transmitter based on the existing design of the versatile transceiver (VTRx) developed at CERN. The datastreams are subsequently merged into a single optical fibre through a four-channels CWDM multiplexer and transmitted towards the back-end. While the back-end devices are installed in a free radiation area, the front-end devices (i.e. transmitters and multiplexers) are required to withstand the radiation levels expected during High-Luminosity LHC (HL-LHC) operations throughout their lifetime. Consequently, the constituent components must be qualified for a level of Total Ionising Dose (TID) of 10 kGy and a 20 MeV neutron equivalent fluence of 5·1014 neq/cm2.

The radiation-tolerant transmitter is primarily composed of a custom radiation-tolerant laser driver (i.e. GBLD) and a commercial transmitter optical sub-assembly (TOSA), which in turn is comprised of a distributed feedback edge-emitting laser diodes (LD) and a focusing lens.
In January 2024, following two distinct market surveys conducted in 2018 and 2021 to identify CWDM compatible single-mode TOSAs, the production series was approved, contingent upon successful radiation qualification testing of the production wafers. A neutron and a gamma irradiation test are scheduled for June 2024, with the results to be compared to those of the tests conducted following the aforementioned market surveys. Moreover, in order to guarantee the proper operation of the optical link until the expected end of life, the GBLDs must meet strict requirements regarding the bias current supplied, which is responsible for compensating the radiation induced degradation of the TOSAs and may differ from the nominal value due to fabrication process variations. In June 2024, we plan to conduct production tests on packaged GBLDs, grading them based on performance, with the top-performing ones designated for the transmitters. The CWDM

Muxes, realised through Thin-Film(TF) technology, have been characterised for TID In August 2023 and the results will be shown to meet the required specifications.

Finally, a proof of concept CWDM link is currently being developed utilising the recently procured components and its performance will be shown.

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