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Low-cost, high-precision propagation delay measurement of 12-fibre MPO cables for the CMS DT Electronics Upgrade

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CMS DT electronics upgrade involves laying down 3500 optical links from the CMS cavern to the counting room, whose lengths must be matched to minimize skew, so that the present upstream electronics can be reused at an initial stage. In order to assess the cables'compliance, a high resolution and cost-effective system has been developed to measure the length uniformity of these fibres. Transit-time oscillation method has been implemented with matched MPO 12-channel fibre optic transmitter and receiver and a Spartan-6 FPGA. After proper corrections and averaging, millimetre-range accuracy has been achieved.

Summary

HL-LHC is foreseen to raise the luminosity up to a factor ten with respect to nominal LHC. Consequently, some of the electronics in different sub-systems will be upgraded in order to adapt to the increased data rate. For the CMS DT subdetector, an upgrade to the second level of the trigger and readout electronics, currently placed in the CMS cavern, is in progress. This upgrade will be carried out in two stages: relocation of the current second-level electronics to an accessible area, the CMS counting room, free of radiation and strong magnetic field, and a further upgrade of the electronics to increase performance. The twisted-copper pair differential data links currently arriving to these crates from the detector wheels are being converted to optical fibre to cover the distance between their current location and the counting room. For the case of the trigger links, there are strict requirements on channel-to-channel skew, and thus the fibres'lengths have to be characterized. The number of fibres to assess is 3500, arranged in 60 trunk cables, for a total of 480 MPO fibre cords. In view of this high number of cables, a simple and fast system is needed. Common systems available in the market based in reflectrometry are expensive and/or low resolution (˜20 cm), and usually oriented to single fibre measurement and not 12-channels MPO cord, increasing significantly the required time of the operation. A compact system that can achieve high resolution in differential length measurements has been developed and is reported in this work.

Since fibre validation is to be done before the installation, both ends of the cable are available for the test, and transmission methods can be used instead of the more demanding reflectometry ones. The transit-time oscillation method has been implemented for this purpose. It consists in driving the optical fibre with a short-duration pulse and feeding the receiver signal back to the transmitter, thus creating a self-sustained oscillation. The fibre propagation delay is one of the terms contributing to the period of this oscillation, and can be calculated from its frequency once the other terms are characterized. The transmitter and receiver are 12-channels MPO modules from Avago Technologies. The oscillation-starting pulse generation, system control, and frequency counting was implemented in a Xilinx SP605 Spartan-6 evaluation board, which communicates with a computer through a serial link. The computer runs a LabVIEW program that allows semi-automatic cable testing.

Slight differences were observed in the measured oscillation frequency of different channels, which can be attributed to the intrinsic skew of the transmitter and receiver modules. Following the connection of a new fibre cable, a transient can be observed before the oscillation frequency stabilizes, possibly due to the effect of the operating temperature on the transmitter and receiver rise and fall times. After proper offset corrections and averaging, length differences were measured with accuracy in the millimetre range, allowing to obtain a detailed characterization of these fibres.

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