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A Network Architecture for Bidirectional Data Transfer in High-Energy Physics Experiments Using Electroabsorption Modulators

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The forthcoming increase of rate of data production and radiation levels, associated with the transition to HL-LHC, necessitates a readout link upgrade. This upgrade is also an opportunity to move to a more efficient network infrastructure and to introduce new technologies and it is in light of this that we explore the possibility of using a unified architecture based on Reflective Electroabsorption Modulators. We evaluate the performance of this new architecture and investigate the way performance degradation factors, including the imperfect extinction ratio and reflection feedback, affect it. We also report on the optimization of operating parameters, such as the modulation voltage and operating wavelength.

Summary 500 words

The HL-LHC upgrade will be accompanied by an increase at which particle detectors produce data. This in turn motivates research and development into data transmission links that are able to cope with data-rates as high as 10Gb/s as new detector systems are designed to be able to exploit the physics potential associated with the increased rate of particle production. In addition to raw data-rate increases, the upgrade gives an opportunity for investigating more efficient network architectures than those currently used. One such example is the use of a bidirectional, consolidated network infrastructure that can carry all of the types of information (data, clock, trigger and control information) that are currently transferred over different physical links. Furthermore, there is the opportunity to explore the utilization of different link technologies than those currently in use. We investigate how such a different technology, the Electroabsorption Modulator (EAM), can be used in a unified infrastructure to meet the demand for higher data rates.
EAMs modulate light according to the voltage applied across them. Research suggests that EAMs are potentially radiation-hard, low mass, low power consumption components that can be modulated up to very high data rates. Their properties attracted the interest of the particle physics community in the past but they were not employed at the LHC due to a lack of maturity of the technology. We revisit the concept of using EAMs at the front-end as the technology is now more mature. In particular, we investigate the use of Reflective Electroabsorption Modulators (REAMs) that allow the use of a single optical fiber, reducing number of fibers as well as the component size.
We have designed and investigated the performance of a network architecture that matches the highly asymmetric, upstream-intensive - from the detector to the counting room - nature of traffic generated by particle detectors well. The architecture uses a combination of REAMs and optical receivers at the detector side for the upstream and downstream transmission, respectively. The downstream transmitter and the CW light source that provides the light to be modulated by the REAM for upstream transmission are both located in the counting room and are shared between multiple front-end destinations. The architecture thus combines the benefits of a point-to-multipoint configuration in the downstream direction and a point-to-point configuration in the upstream direction. Single-fiber bidirectional transmission is achieved using different wavelengths.
The performance limitations of this architecture are investigated. We focus on upstream performance, as it dictates the system efficiency in terms of resource sharing. We report on our measurements of the quality of the received modulated signal as a function of its power and quantify the impact of factors that can lead to its deterioration, primarily the extinction ratio and reflection feedback.
As parameters that have an impact on system performance are strongly influenced by the characteristics of the REAM, we investigate how these characteristics vary with external parameters, with a focus on the effects of temperature variation. These are typically compensated using a thermo-electric cooler (TEC) which is not acceptable in an on-detector application since it would increase the mass and the power consumption of the front-end component. Finally, we report on our study of the optimization of operating parameters, namely the modulation voltage levels and input wavelength. Finally, we discuss a possible implementation with descriptions of the front- and back-end components necessary to operate a full system based on the use of REAMs that we believe can achieve 10 Gb/s bi-directional transmission in a particle physics application.

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