PROCEEDINGS OF SCIENCE

Thermal Characterisation of the Versatile Link$^+$ Transceiver

Csaba Soós*, **Freya Lily Bottom, Stéphane Detraz, Andrea Kraxner, Lauri Olanterä, Carmelo Scarcella, Christophe Sigaud, Jan Troska and François Vasey**
CERN
Esplanade des Particules 1, CH-1211, Geneva 23
E-mail: csaba.soos@cern.ch

The miniaturised optical transceiver module, developed in the framework of the Versatile Link$^+$ project (VL$^+$) will be installed in the upgraded detector front-ends at the HL-LHC. The modules will have to operate over a wide temperature range (-35 °C to +60 °C). We describe the impact of the temperature on the performance of the transceiver and we present measurement results obtained during the thermal characterisation of the transceiver prototypes.

Topical Workshop on Electronics for Particle Physics (TWEPP2018)
17-21 September 2018
Antwerp, Belgium

*Speaker.

PoS(TWEPP2018)060

1. Introduction

During the phase II upgrades of the ATLAS and CMS experiments at the Large Hadron Collider (LHC) several detectors will be replaced to improve their physics performance. In particular, these upgrades aim to replace the innermost detectors that are exposed to the harshest radiation environments. To cope with the increasing data volume and the higher trigger rate, high-speed optical links will be deployed in large quantities as part of the upgrade programme. The Versatile Link$^+$ project proposes the link architecture shown in figure 1, based on custom electronics and commercial off-the-shelf components

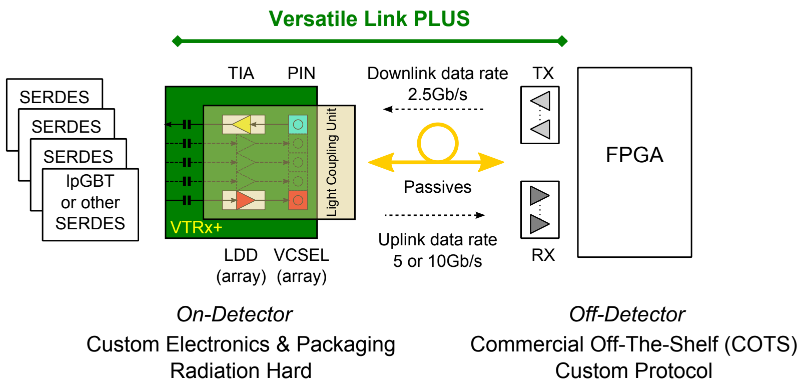

Figure 1: The Versatile Link$^+$ architecture.

2. Versatile Link$^+$ Transceiver

The tight space constraints and the high channel count of the on-detector electronics require to develop a low-profile (20 mm x 10 mm x 2.5 mm target), multi-channel front-end component the Versatile Link$^+$ Transceiver (VTRx$^+$) [1, 2]. During their expected lifetime these components will have to withstand the on-detector radiation levels (1 MGy total dose, 1×10^{15} n/cm^2 and 1×10^{15} hadrons/cm^2 total fluence) and will have to operate over a wide temperature range (-35 °C to $+60$ °C).

To fulfill these requirements the VTRx$^+$ is based on radiation-hard laser diode driver (LDD) [3] and transimpedance amplifier (TIA) [4] ASICs, and commercial Vertical Cavity Surface Emitting Laser (VCSEL) and PIN photodiode (PD) components. These components are assembled on a Printed Circuit Board (PCB) substrate using Chip-on-Board technology. The optical coupling between the optical dies and the multi-mode optical fibre is assured by the plastic moulded optical lens array. To achieve good optical performance, the assembly of the optical dies and the plastic moulded optical coupling block requires very high placement accuracy (few micrometer). Figure 2 shows a computer-generated image of a VTRx$^+$ prototype with its major components (left) and and the picture of an assembled prototype (right).

To minimise the risks the VL$^+$ project pursues two development paths. In the first case, CERN works with firms having the know-how and technology required to customize their existing optical multi-channel transmitter and receiver module to meet our specific requirements. As an alternative path to the commercial module customisation, CERN launched a full-custom module development.

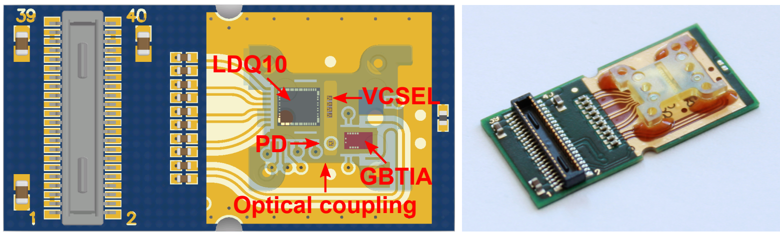

Figure 2: CAD view of the VTRx$^+$ showing its major components (left) and the picture of an assembled prototype (right).

Several transceiver prototypes have been designed by CERN, which have been assembled by an industrial partner. These prototypes allowed us to evaluate different optical coupling solutions and they also serve as test vehicles for radiation hard ASIC testing. The results shown below have been obtained by measuring version 5 prototypes (figure 2 right).

3. Temperature characterisation

Following the functional tests at room temperature, the transceiver prototypes were thoroughly tested in an environmental chamber in order to characterise their static and dynamic performance across the specified temperature range. The ambient temperature was controlled by the climate chamber. For more precise temperature control and to speed up the measurement, a Peltier element was attached to the bottom side of the transceiver. The on-board thermistor installed under the optical coupling near the VCSEL confirmed that the module temperature was approximately 8–10 °C higher than the temperature set by the Peltier element.

3.1 Static transmitter performance

The static characterisation of the modules consists of measuring the VCSEL's coupled light output power as a function of the VCSEL's bias current ranging from 0 mA to 20 mA. To calculate the real VCSEL current, the 2.5 V power consumption has been recorded during the measurement. The resulting L-I curve allows verifying the quality of the coupling between the VCSEL and fibre. For quantitative results, the VCSEL's threshold current and the slope efficiency is extracted from the L-I curve using linear fitting. The VCSEL threshold current and slope efficiency obtained by measuring 20 Tx channels are summarized on the plots in figure 3.

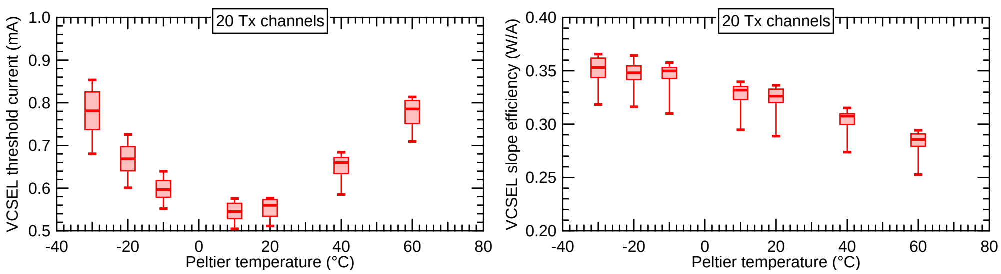

Figure 3: Summary plots showing VCSEL threshold current and slope efficiency as a function of module temperature. The results have been obtained by measuring 20 transmitter channels.

3.2 Dynamic transmitter performance

The dynamic characterization of the transmitter channels consists of measuring the optical eye diagrams at 10 Gb/s and extracting the salient amplitude and timing parameters. The results presented hereafter have been measured using the default bias and modulation settings of the laser diode driver (I_{bias} = 7.68 mA, I_{mod} = 5.12 mA). For a single transmitter channel the eye diagrams obtained using these settings are shown in figure 4. The statistical plots in figure 5 summarise the results of 20 Tx channels. These results prove that the prototypes can meet the VL$^+$ specifications across the specified temperature range.

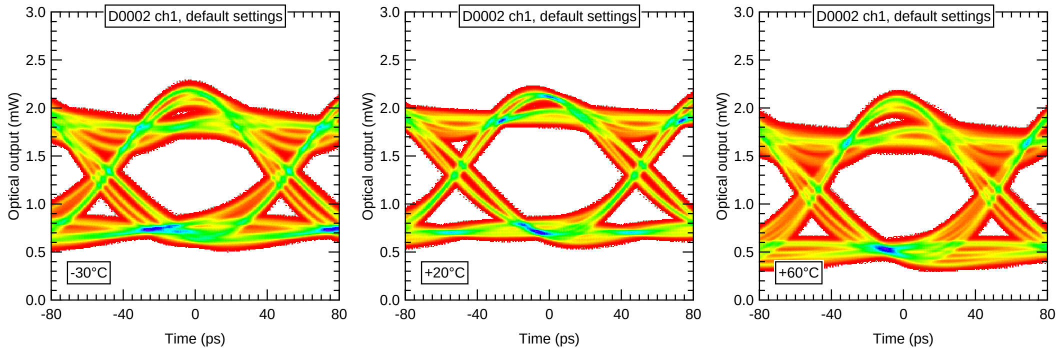

Figure 4: Eye diagrams measured on a VTRx$^+$ prototype using the default VCSEL driver settings at −30 °C, +20 °C and +60 °C.

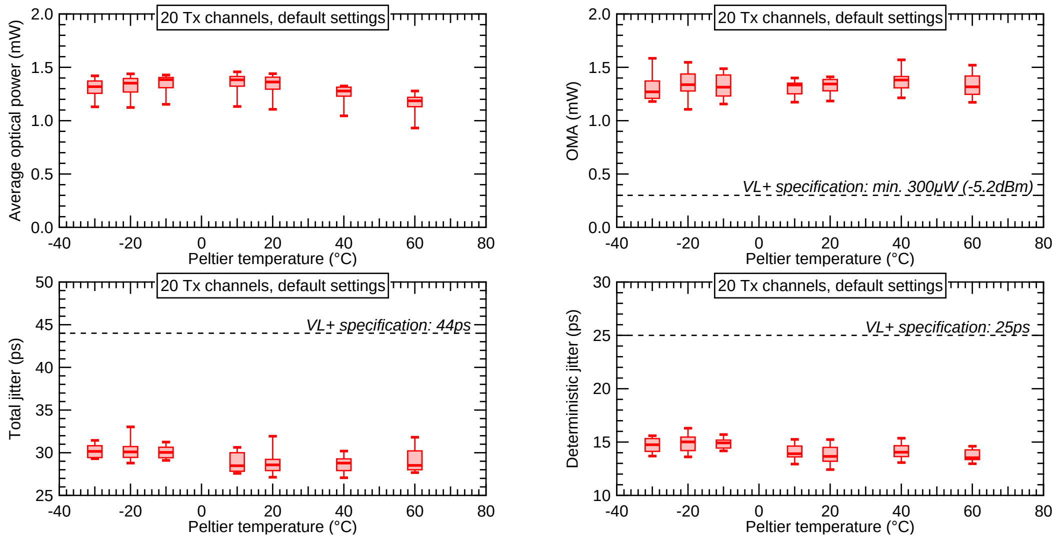

Figure 5: Summary plots showing average optical power, optical modulation amplitude, total and deterministic jitter as a function of module temperature. The results have been obtained by measuring 20 transmitter channels.

3.3 Dynamic receiver performance

To calculate the receiver sensitivity, the Bit Error Rate (BER) has been measured at 2.5 Gb/s and at 5 Gb/s using two different types of pseudo-random bit sequence (PRBS-7 and PRBS-23).

Using fitting and extrapolation the receiver sensitivity at 10^{-12} is calculated. The results are summarised in figure 6 for two devices. The calculated receiver sensitivity values are similar at both data rates with slightly better sensitivity at 2.5 Gb/s, which proves that the receiver performance does not depend much on the device temperature.

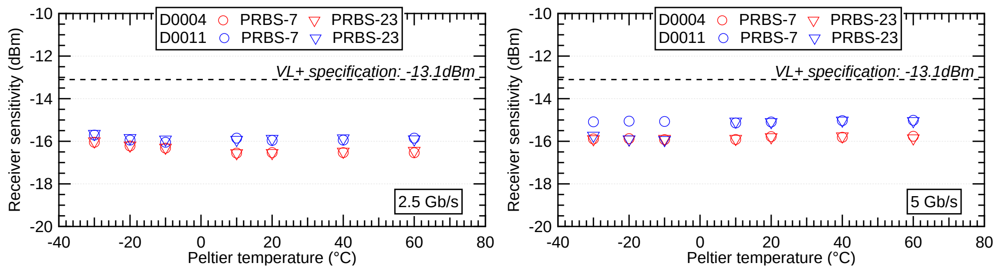

Figure 6: Summary plots showing receiver sensitivity at 2.5 Gb/s and at 5 Gb/s as a function of module temperature. The results have been obtained by measuring 2 receiver channels.

4. Summary

The Versatile Link$^+$ project is developing low-profile, multi-channel optical transceivers. To withstand high radiation levels during their lifetime, the transceivers are based on radiation hard ASICs and qualified optical components. Several prototype versions have been developed in the framework of the VL$^+$ project in order to test various optical components and to evaluate the performance of the different optical coupling solutions. The tests were carried out across the specified temperature range. The results presented here show that the transceiver can meet the VL$^+$ specifications using the default laser driver settings. Additional margin can be achieved by optimising the VCSEL bias and modulation currents according to the module temperature. The receiver performance is fairly independent of the device temperature and the receiver sensitivity specification can be met with ample margin.

References

[1] C. Soós et al., *Versatile Link PLUS transceiver development*, *Journal of Instrumentation*, Volume 12, March 2017 JINST 3 C03068

[2] J. Troska et al., *The VTRx$^+$, an optical link module for data transmission at HL-LHC*, *Topical Workshop on Electronics for Particle Physics*, 11–15 September, 2017, Santa Cruz, Ca, United States Of America, PoS(TWEPP-17)048.

[3] Z. Zeng et al., *LDQ10: a compact ultra low-power radiation-hard 4x10 Gb/s driver array*, *Journal of Instrumentation*, Volume 12, February 2017 JINST 12 P02020

[4] M. Menouni et al., *The GBTIA, a 5 Gbit/s radiation-hard optical receiver for the SLHC upgrades*, *TWEPP 2009 Topical Workshop on Electronics for Particle Physics*, 21–25 September, 2009 Paris, France, CERN-2009-006.