Thermal Characterisation of the VL+ Transceiver

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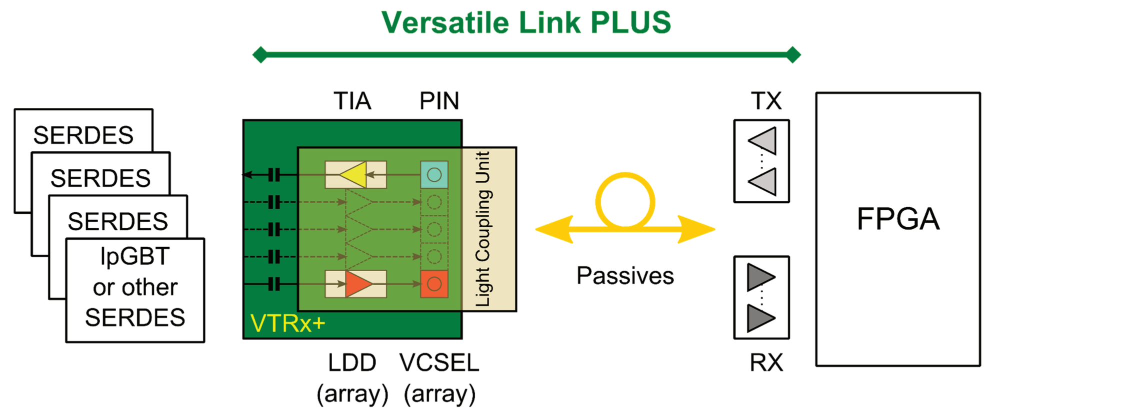
Versatile Link+

Introduction

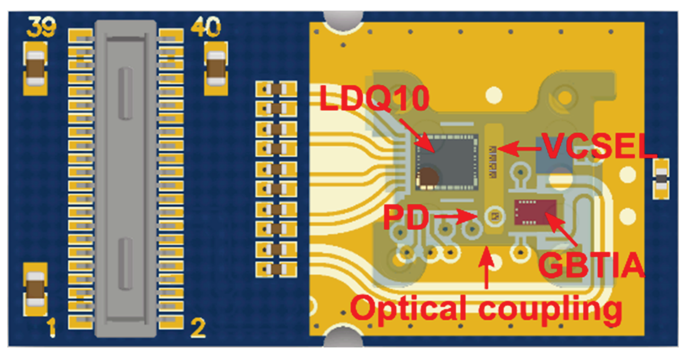
During the phase II upgrades of the ATLAS and CMS experiments at the Large Hadron Collider (LHC) several detectors will be replaced to improve their physics performance. In particular, these upgrades aim to replace the innermost detectors that are exposed to the harshest radiation environments. To cope 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 tight space constraints and the high channel count of the on-detector electronics will require to develop a low-profile (20mm x 10mm x 2.5mm target), multi-channel front-end component the Versatile Link PLUS Transceiver (VTRx+). During their expected lifetime these components will have to withstand the on-detector radiation levels (1MGy total dose, 1x10^15 n/cm2 and 1x10^15 hadrons/cm2 total fluence) and will have to operate over a wide temperature range (-35 °C to +60 °C).

Versatile Link+ Transceiver

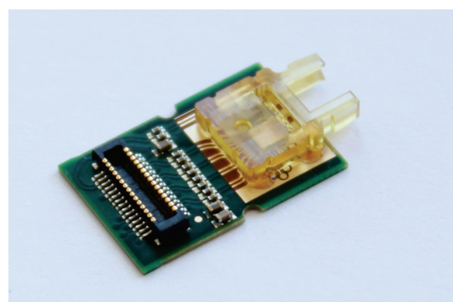
The Versatile Link PLUS (VL+) project is developing custom front-end modules that fulfil these requirements. The VTRx+ is based on radiation-hard laser diode driver (LDD) and transimpedance amplifier (TIA) ASICs, and commercial Vertical Cavity Surface Emitting Laser (VCSEL) and PIN photodiode (PD) components. These components are assembled on a Printed Circuit Board (PCB) substrate using Chip-on-Board (CoB) 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).



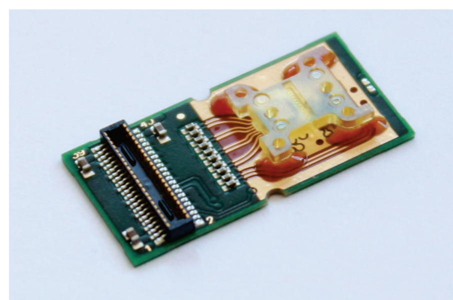
Version 5 CAD view

VL+ Transceiver Development

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. 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.



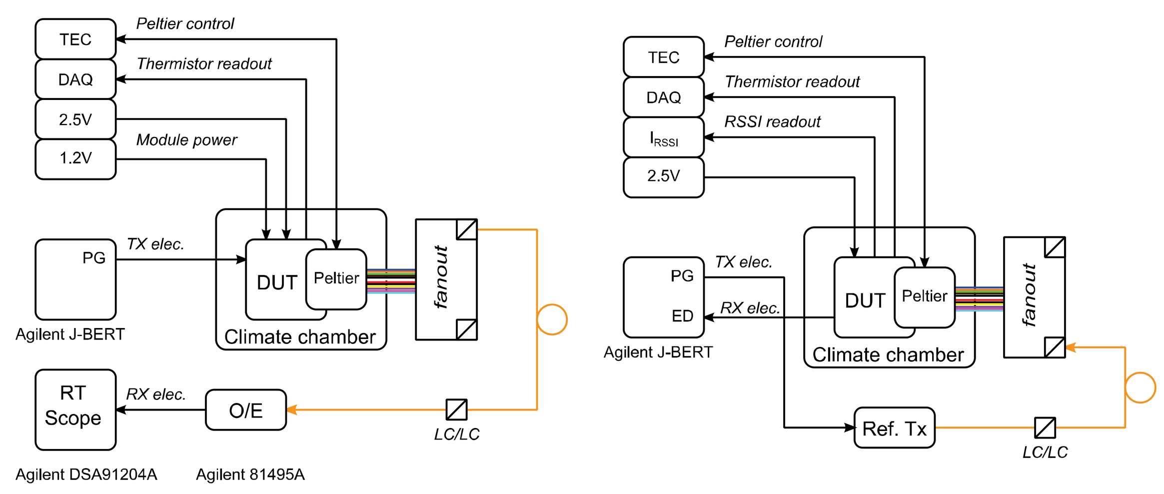
Version 4
2 Tx + 1 Rx



Version 5
4 Tx + 1 Rx

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 module temperature was measured using the on-board thermistor, which is installed under the optical coupling close to the VCSEL. The block diagrams below show the test setup used for transmitter (left) and receiver (right) characterisation.



Measurement results

Static Transmitter tests

- **Measure VCSEL LI curve**
- **Extract threshold current and slope efficiency**

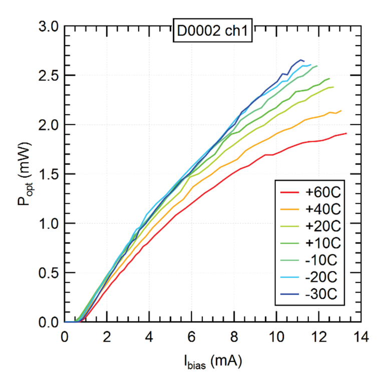
Dynamic Transmitter tests

- **Measure eye diagram**
- **Extract amplitude and timing characteristics**

Dynamic Receiver tests

- **Measure bit error ratio**
- **Extract receiver sensitivity**

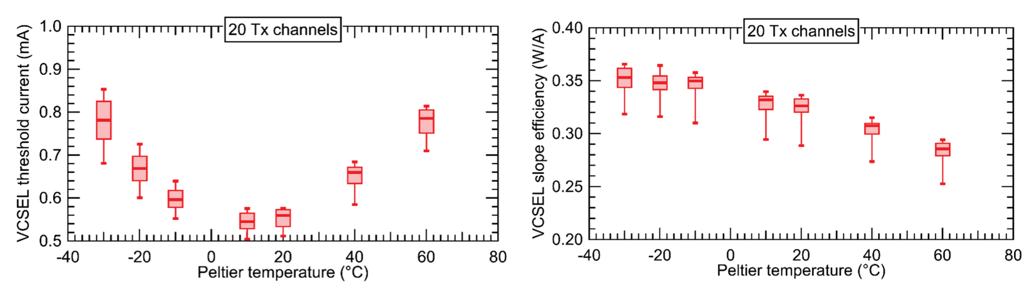
The static characterisation of the modules consists of measuring the VCSEL's coupled light output power as a function of the VCSEL's bias current. The bias current is swept from 0mA up to the maximum allowed by the laser driver. To calculate the real VCSEL current, the 2.5V power consumption has been recorded during the measurement. The resulting L-I curve allows to verify 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.



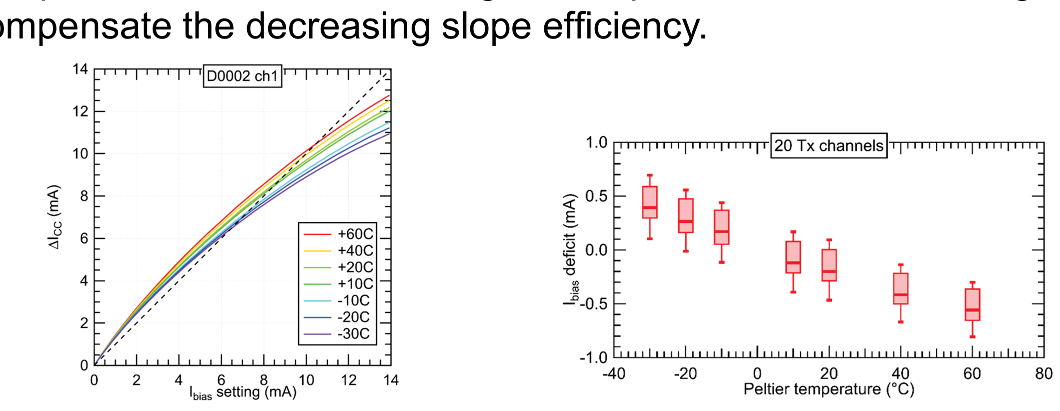
Extraction

T [C]	I_{th} [mA]	Slope [W/A]
60	0.84	0.28
40	0.69	0.30
20	0.60	0.32
10	0.57	0.34
-10	0.62	0.35
-20	0.68	0.36
-30	0.80	0.35

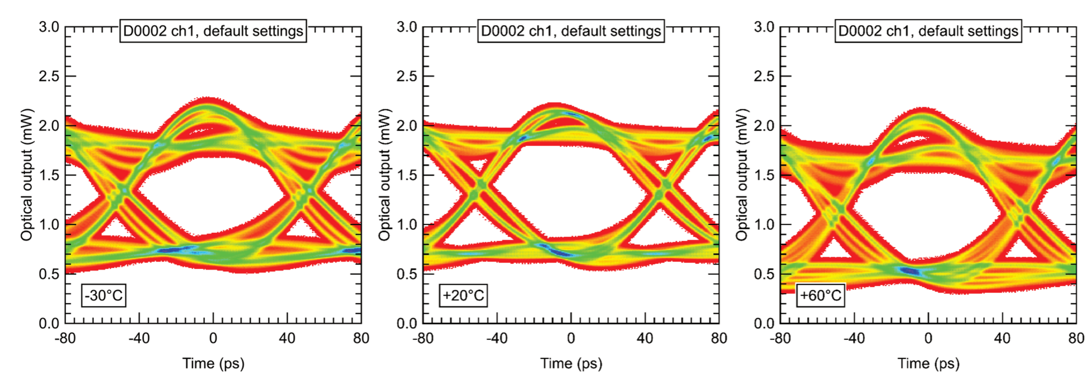
The VCSEL threshold current and slope efficiency obtained by measuring 20 Tx channels are summarized on the following plots.



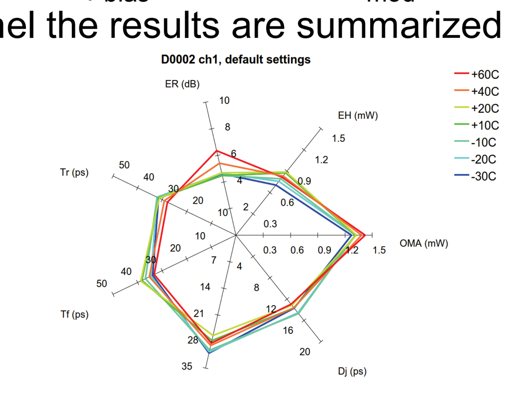
To see the impact of the temperature dependent VCSEL series resistance on the laser driver output the I_{bias} deficit – difference between the bias current setting and the real VCSEL bias current – has been calculated. It is interesting to note that the laser driver can provide more current at higher temperature, which can slightly compensate the decreasing slope efficiency.



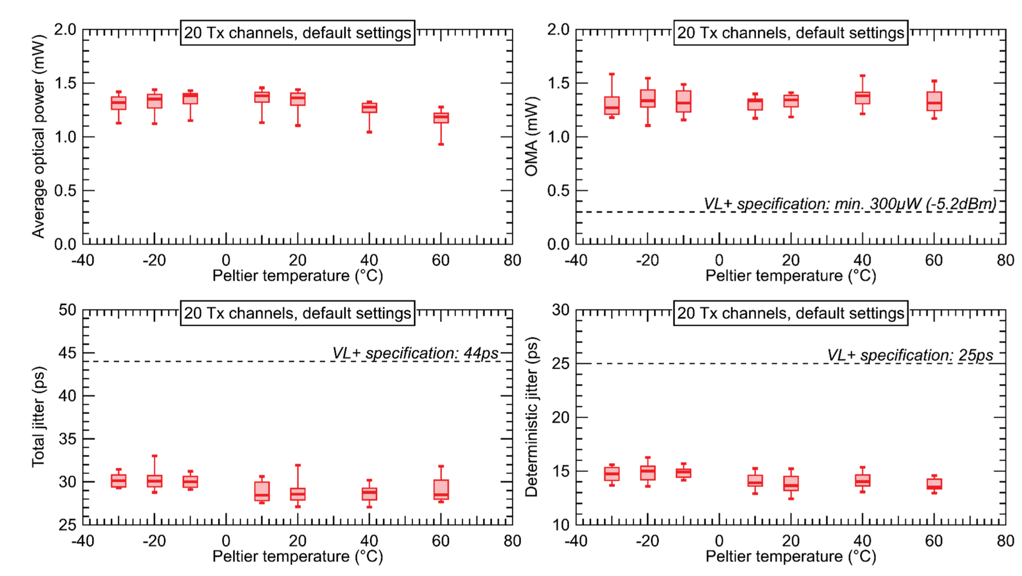
The dynamic characterization of the transmitter channels consists of measuring the optical eye diagrams using different VCSEL bias and modulation current settings.



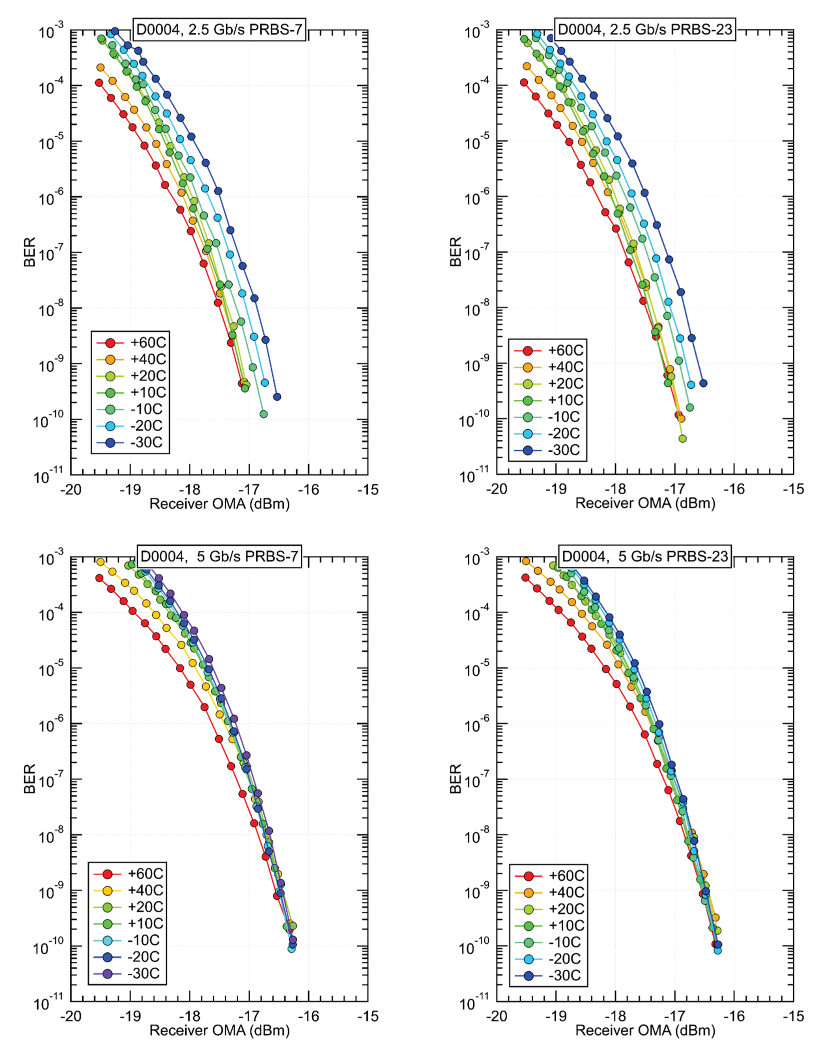
The eye diagrams have been captured and salient amplitude and timing parameters have been extracted by the analysis software running on the real-time oscilloscope. The results presented here have been measured using the default bias and modulation settings of the driver (I_{bias} = 7.68mA, I_{mod} = 5.12mA). For a single transmitter channel the results are summarized on a radar plot.



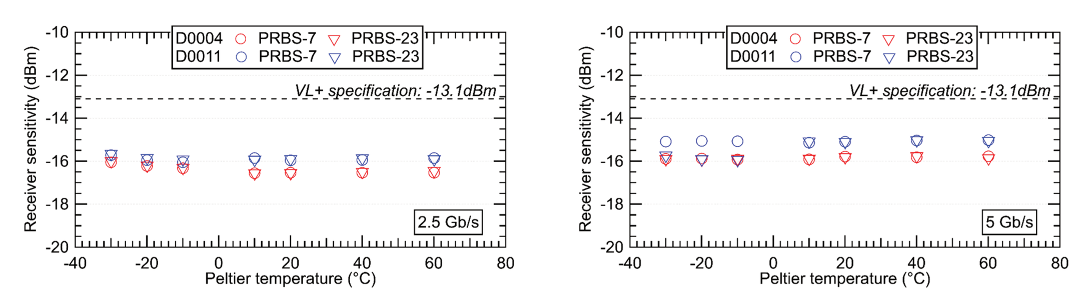
The statistical plots summarising the results of 20 Tx channels prove that the prototypes meet the VL+ specifications.



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



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



Summary

The Versatile Link+ project is developing low-profile, multi-channel optical transceivers. To withstand high radiation levels during their lifetime inside the upgraded LHC detectors, 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.