50 Gb/s demonstration in extreme temperatures using 850nm VCSELs

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Introduction and objectives

• A new 850nm VCSEL designed by TRUMPF for 25 Gb/s NRZ transmission was characterized according to the methodology reported in [1] and used for 50 Gb/s PAM4 real-time transmissions

• In order to build a technical feasibility assessment with margin, operation with low current densities of less than 13 kA/cm$^2$ in high temperature experiments has been demonstrated, with margin with respect to the maximum 15 kA/cm$^2$ considered in [2]

• It is demonstrated that 50 Gb/s is feasible in extreme temperatures using PAM4 modulation scheme, even using a VCSEL not designed for that aim, when the proper transmitter and receiver are used (i.e. TX FFE, RX timing-recovery & equalization, etc)

• These experiments will be the base for a 50 Gb/s PCS/PMA baseline proposal as well as for a first 50 Gb/s link budget assessment that demonstrate that a PMD based on VCSEL + OM3 is able to fulfill 100% of the project’s objectives

• Nevertheless, in the short term, characterization, reliability data, real-time transmission experiments, as well as link budget assessments will be provided for longer wavelength VCSEL devices able to operate even faster and with better reliability in high temperatures, therefore allowing lower power consumption and lower complexity transceiver implementations (i.e. reduced DSP requirements like lower TX FFE gain and smaller RX equalizer computational complexity)
Characterization of
ULM850-25-TT-W0101U 25 Gbps NRZ VCSEL
L-I characteristic

AOP characteristic per temperature

-40 °C
0 °C
25 °C
85 °C
105 °C
125 °C

Ibias (mA)

AOP (mW)
Threshold current characteristic
Small signal frequency response

Considered source impedance 100 Ω
Relative intensity noise (RIN<sub>OMA</sub>)

In red is the considered limit for 50 Gb/s operation
Real-time transmission setup
Equipment & Software

1. Amphenol SVmicrowave SF1521-60115, 2.92mm female solderless LiteTouch PCB Connector, 2 Hole (CPW / Microstrip)
   - Coaxial to CPWG transition used to connect the coax cable to the PCB where the VCSEL is assembled
2. Marki Microwave BTN-0040 bias tee (40 kHz to 40 GHz)
   - Used to combine bias current with RF signal from VNA or AWG
3. Minicircuits TMP40-1M-KMKM+, temperature stable 2.92mm cable, 40.0 GHz
   - Used to connect bias tee output to the DUT
   - Used to provide trigger clock from AWG to DCA
4. Keysight B2901A Precision Source/Measure Unit
   - Bias current to VCSEL
   - Voltage drop measurement (V-I curve)
5. SEIKOH GIKEN 7100142-211-1002 APC to PC, MM, SX, OM3, 3mm, 2 meters
   - Used to connect the DUT to the measurement equipments: O/E converters and DCA
   - APC is used in the DUT side to reduce back reflection effect
6. Keysight M8195A 65 GSa/s, 25 GHz, Arbitrary Waveform Generator
   - Used to generate time-domain RF signal that drives the VCSEL
   - Capability of real-time digital signal processing with 8 bits DAC
   - One port used to provide symbol clock to DCA
7. Keysight N1092C DCA-M Sampling Oscilloscope (one optical and two electrical channels)
   - Used to make the time-domain characterization with periodic arbitrary signal generated by VCSEL
   - Background noise calibrated for RIN measurement
8. Keysight N1010A FlexDCA Sampling Oscilloscope Software R&D software package
9. Matlab 2019b:
   - Test automation
   - Signal processing
   - Model extraction
Test setup

AWG M8195A → Bias tee BTN-0040 → VCSEL

Bias current

SMU B2901A → TMP40-1M-KMKM+

Temperature chamber

Optics

DCA-M N1092C

TMP40-1M-KMKM+
Trigger clock

SEIKOH GIKEN
7100142-211-1002
2 meters
Tests setup

Temperature forcing system

Temperature chamber

SMU

DCA

AWG
Real-time performance at 25°C
25°C, 53.76 Gb/s PAM4, Ibias 7mA, ER 4 dB
25°C, 53.76 Gb/s PAM4, Ibias 6mA, ER 4 dB
25°C, 53.76 Gb/s PAM4, Ibias 5mA, ER 4 dB

< 13 kA/cm²
25°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 4mA, ER 4 dB

< 13 kA/cm²
25°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 4mA, ER 4 dB

< 13 kA/cm²
Real-time performance at 125°C
125°C, 53.76 Gb/s PAM4, Ibias 6mA, ER 3 dB
125°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 6mA, ER 4 dB
125°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 6mA, ER 4 dB
125°C, 53.76 Gb/s PAM4, Ibias 5mA, ER 3 dB

< 13 kA/cm²
125°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 5mA, ER 4 dB

< 13 kA/cm²
125°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 5mA, ER 4 dB

< 13 kA/cm²
125°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 4mA, ER 4 dB

< 13 kA/cm²
Real-time performance at -40°C
-40°C, 53.76 Gb/s PAM4, Ibias 7mA, ER 3 dB
-40°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 7mA, ER 3 dB
-40°C, 53.76 Gb/s PAM4, 3-tap TX FFE, Ibias 7mA, ER 2 dB

Operation with ER is possible due to the excess optical power
Conclusions

• A new 850nm VCSEL designed by TRUMPF for 25 Gb/s NRZ transmission was characterized according to the methodology reported in [1] and used for 50 Gb/s PAM4 real-time transmissions

• It was demonstrated that 50 Gb/s is feasible in extreme temperatures using PAM4 modulation scheme, even using a VCSEL not designed for that aim, when the proper transmitter and receiver are used (i.e. TX FFE, RX timing-recovery & equalization, etc)

• Nevertheless, in the short term, characterization, reliability data, real-time transmission experiments, as well as link budget assessments will be provided for longer wavelength VCSEL devices able to operate even faster and with better reliability in high temperatures, therefore allowing lower power consumption and lower complexity transceiver implementations (i.e. reduced DSP requirements like lower TX FFE gain and smaller RX equalizer computational complexity)
References


Thank you!