Proposed TDECQ Change in Clause 138.8.5*

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*Thanks to David Leyba, and Greg Lecheminant from Keysight for great support during the tests

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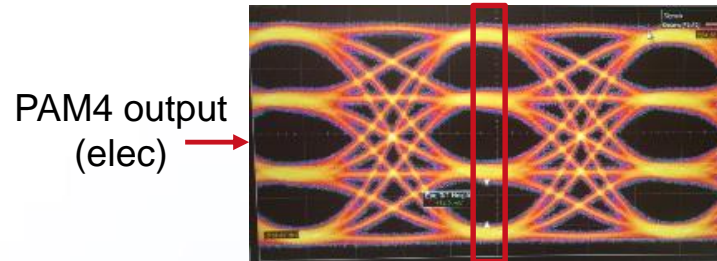
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Supporters

- Matt Traverso, Cisco

- Winston Way, NeoPhotonics

- Sudeep Bhoja, Inphi

- Ed Ulrichs, Source Photonics

- David Piehler, Dell EMC

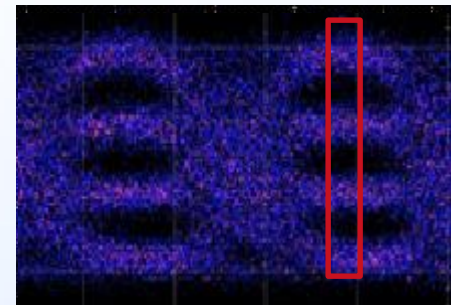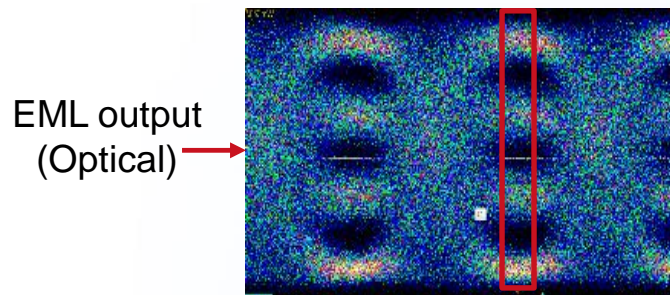- …… (TBD)

Problem statement (1)

- P802.3cd D2.1 Clause 138.8.5 and Table 138-8 define new TDECQ specs for SR1/2/4 but no actual tests under MMF reported so far.

  — All TDECQ tests posted are based on either LN MZM or EML for SMF.

- Currently defined 5 T-spaced equalizers are much simpler than actual chip implementations prevailing by industry, so making TDECQ specs still more stringent.

  — All 26.5GBd PAM4 DSP ASICs have implemented 9 or more T-spaced taps.

  — The situation with 53GBd PAM4 DSP ASICs could be only more complicated.

  — Unavoidably many "bad" TOSAs are still able to maintain the link closed.

- There are already efforts (e.g. way_3bs_01a_0517.pdf, way_3bs_01a_0717.pdf) to explore relaxing further TDECQ specs by:

  — Increase tap numbers, or,

  — Adjust filter BW, or,

  — Increase TDECQ value or,

  — Select different test pattern
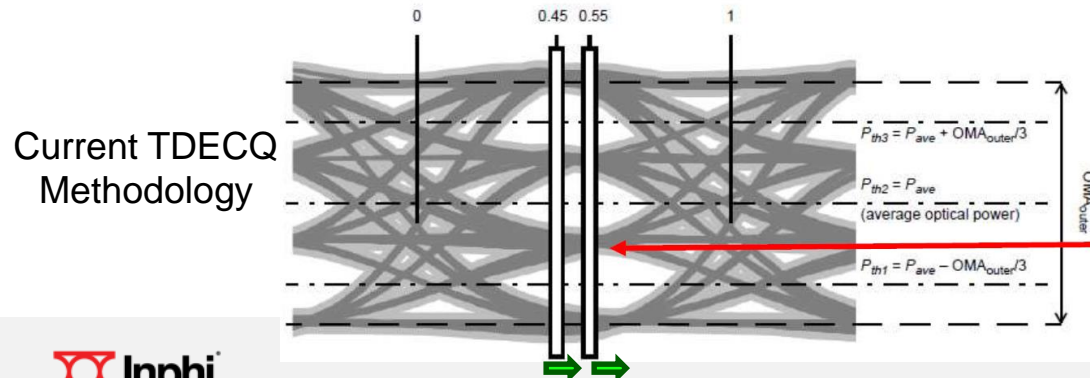
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Problem statement (2)

- **Laser characteristics with direct modulation cause seriously skewed waveform.**

  — Such non-linearity compensation can be readily implemented in PAM4 RX DSP and/or driver devices.

  — However, this is not defined in current TDECQ methodology possibly resulting in unrealistic & larger TDECQ values.

PAM4 output (elec)

One serious problem for directly modulated lasers: Amplitude-dependent skews with PAM4 eyes

EML output (Optical)

VCSEL output (Optical)

Current TDECQ Methodology

$$P_{th3} = P_{ave} + OMA_{outer}/3$$

$$P_{th2} = P_{ave}$$
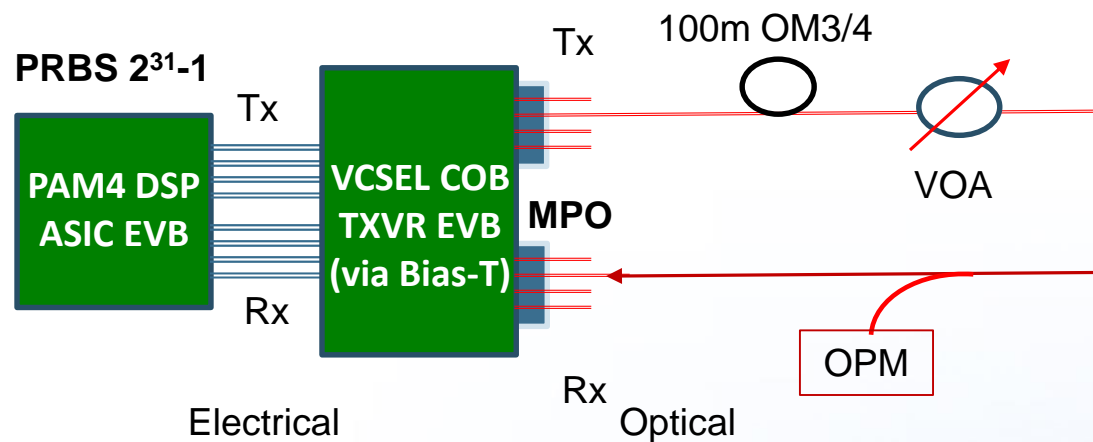(average optical power)

$$P_{th1} = P_{ave} - OMA_{outer}/3$$

$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$

Where:
Qt = 3.414 (target SER)
R = noise term

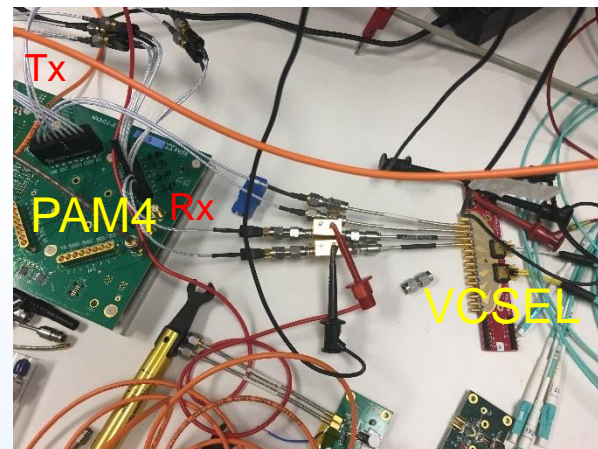Targeted samples on PAM-4 eye diagram.

Note:
The proposal to allow the overall sampling timing to move may not align skews independently between 3 PAM4 eyes

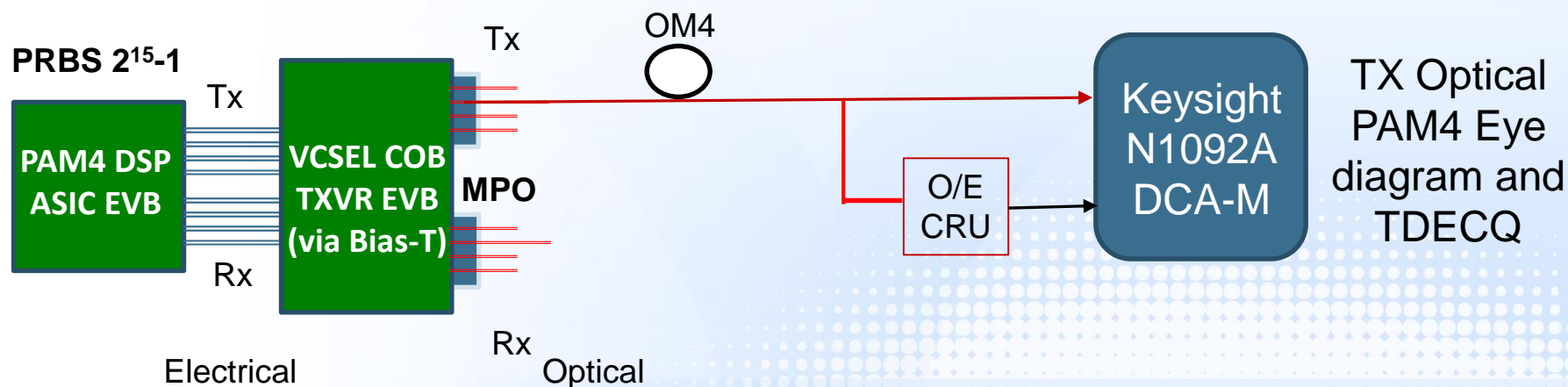# VCSEL/MMF Measurement Setup

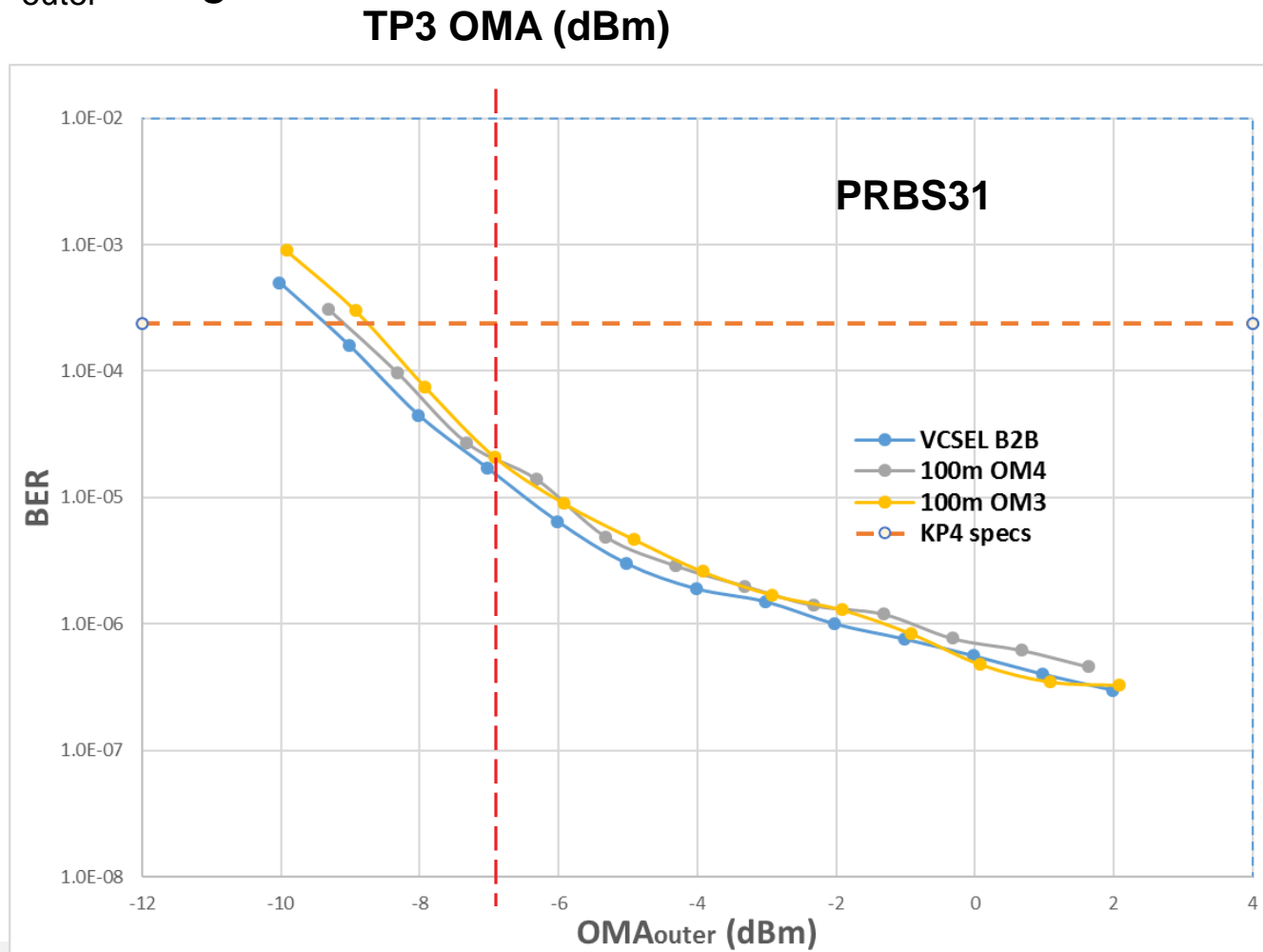## Setup for BER test after 100m OM3 and OM4

Setup photo

Setup for TDECQ (no test fiber needed)

BER versus OMA

- Test results of directly modulated VCSELs – pass with sufficient BER and OMA_{outer} margin.

TP3 OMA (dBm)

PRBS31

Legend:
- VCSEL B2B
- 100m OM4
- 100m OM3
- KP4 specs

Y-axis: BER
X-axis: OMA_{outer} (dBm)

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Example of VCSEL/OM4 TDECQ waveforms

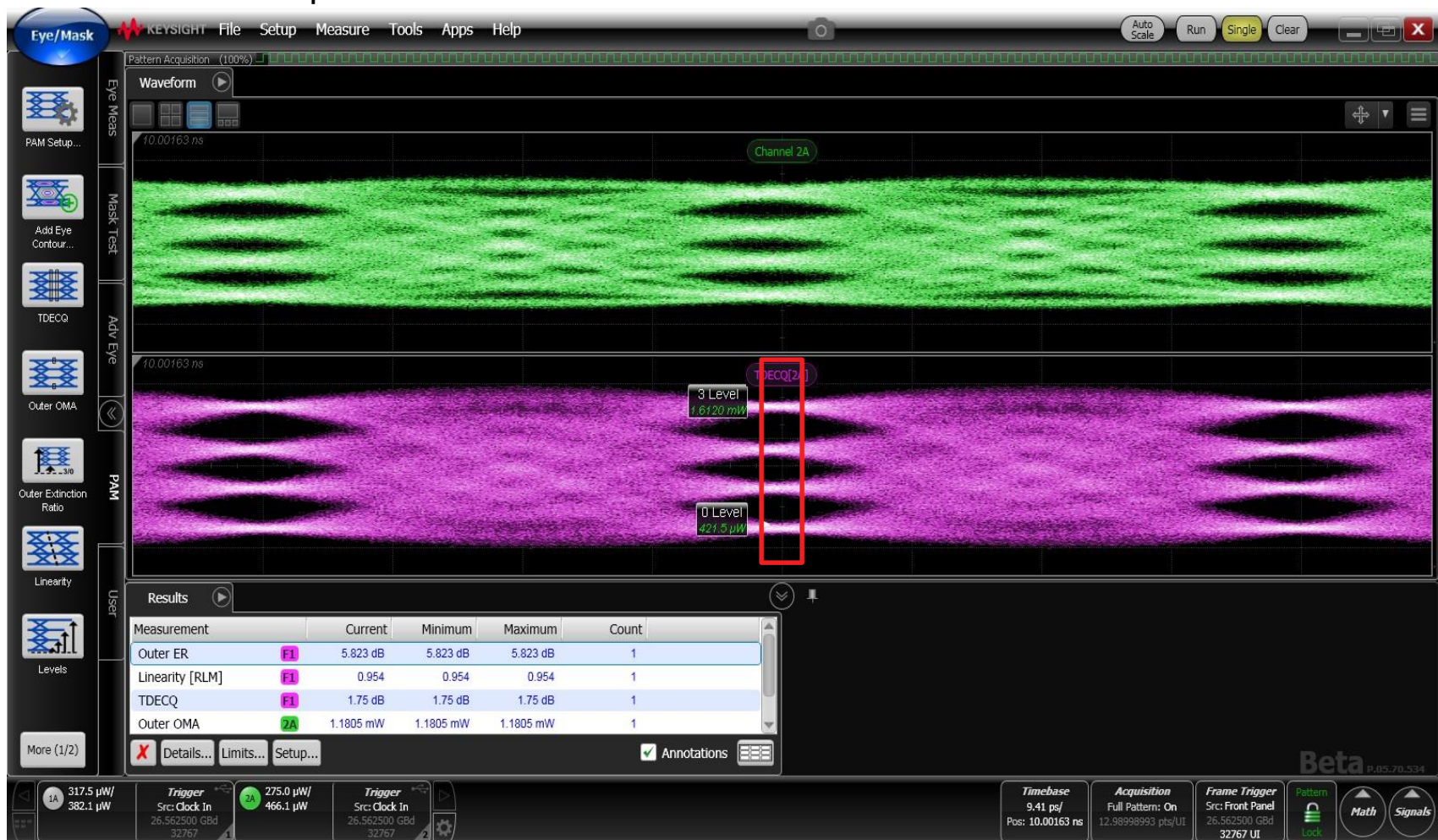## VCSEL Transmitter (P802.3cd D2.1 5 T-spaced at 11.2GHz)

— Use PRBS15 pattern as SSPRQ is not available

Comparing against EML TDECQ waveforms (example)

For reference to EML Transmitter (P802.3bs D3.3 5 T-spaced at 13.28GHz)

— Use PRBS15 pattern as SSPRQ is not available

Corresponding TDECQ using PRBS15

Directly modulated VCSEL Transmitter

— Use PRBS15 pattern as SSPRQ is not available for now

— Future PAM4 TX could implement more stressed SSPRQ as user define pattern

■ New 802.3cd D2.1 definitions (5 T-spaced at 11.2GHz)

TDECQ (dB)	Filter 11.2GHz	Filter 12.6GHz	Filter 13.28GHz (Nyquist)	Filter 15.5GHz	Filter 19.3GHz (75%)	802.3cd D2.1 specs
5 taps	5.60	5.29	4.92	4.44	5.12	<4.9dB (each lane)
7 taps	5.12	4.90	4.71	4.65	4.65	
9 taps	4.52	4.23	4.11	4.12	4.12	

Keysight Scope processing (beta version)

■ Comments:

— Much larger TDECQ variation (~1-1.5dB) for 5 taps, versus ≤ 0.5 dB for 7-9 taps.

— PAM4 DSP ASICs have implemented 9 or more T-spaced taps

— The modulation BW of directly modulated VCSELs normally limits to ~18GHz at optimum biasing current, and drops dramatically near threshold currents, resulting in seriously skewed PAM4 eyes (amplitude dependent).

— PAM4 chip implementation may readily incorporate non-linear compensation for vertical eye skews.

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Summary & recommendation

- Current TDECQ specs cause unnecessary yield loss of VCSEL-based transmitters, so is less practical.

- We propose to change Clause 138.8.5 for:
  — Reference equalizer from "5 tap, T spaced" to "7-9 tap, T-spaced"
    • Note tests with 7-9 tap also show much better TDECQ stability than 5 tap.
  — 4th-order Bessel-Thomson filter response from a bandwidth of "11.2GHz" to either "12.6GHz" or "13.28GHz".
    • 13.28GHz (Nyquist) is more consistent with the filter definition for all other SMF PMDs.

- Amplitude-dependent skews in PAM4 eye openings call for the need for non-linear compensation.
  — This could apply to directly modulated VCSELs and DFBs.
  — The proposal to allow overall sampling timing window to move (but not independently between the 3 eyes) may help, but whether it will fully resolve the issue or not remain to be seen.

XX Inphi