Feasibility of Unretime 100Gbase-SR4

IEEE 802.3bm Task Force

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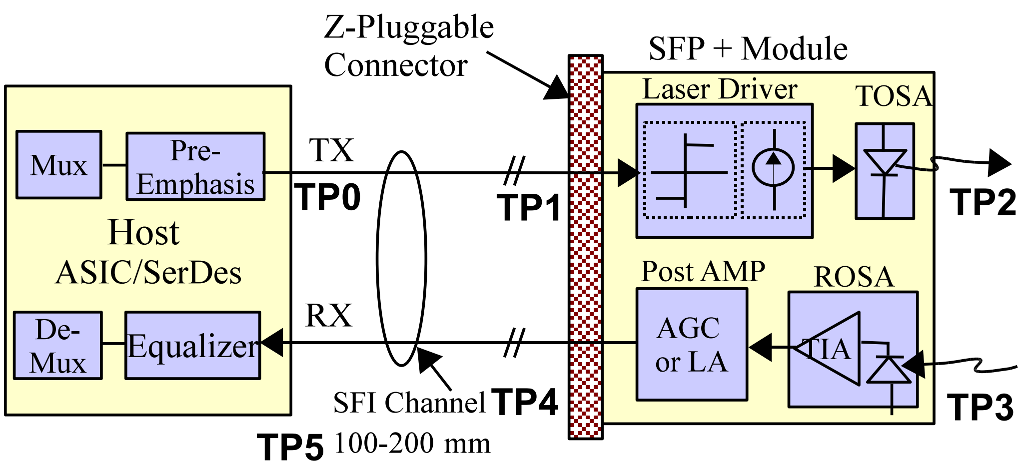
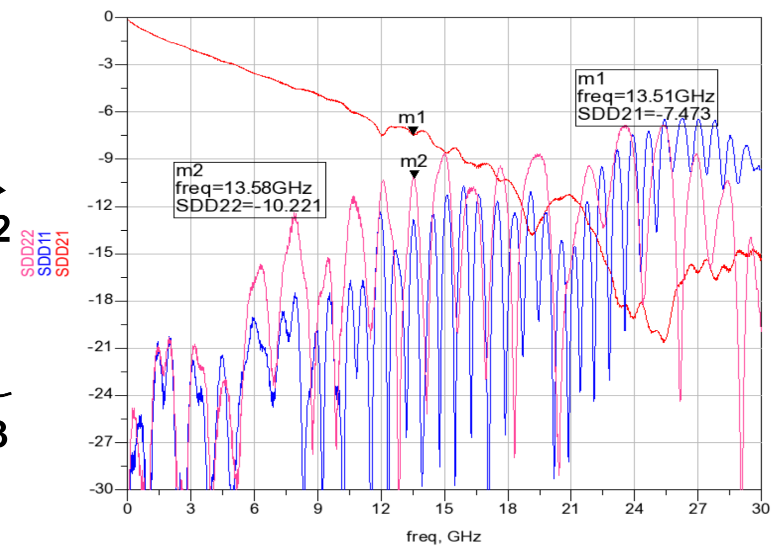
Overview

- Material presented here previously have been presented at one or more of the following venue
  - 100GNGOPTX study group http://www.ieee802.org/3/100GNGOPTX/public/index.html
  - ‘Feasibility of Unretimed 100 GbE Based on 4x25. 78 GBd’,OWJ1.2, OFC 2012
  - IEEE Photonic Interconnect, ‘Enabling 850 nm VCSEL for 100 GbE Applications, Santa Fe, 2012
- There has been renewed interest in the low cost, low power, unretime cPPI-4 interface for 20-30 m SR4 application and this presentation explores
  - Meeting transmitter TP1a jitter requirement
  - Example channels meeting cPPI-4
  - How to make limiting interface
  - How to make linear RX interface work
- The key questions is does it have to be compatible with retime version of SR4 at reduce reach?

cPPI-4 Channel Based on TE Quattro II

- Channel has 7.4 dB loss at Nyquist





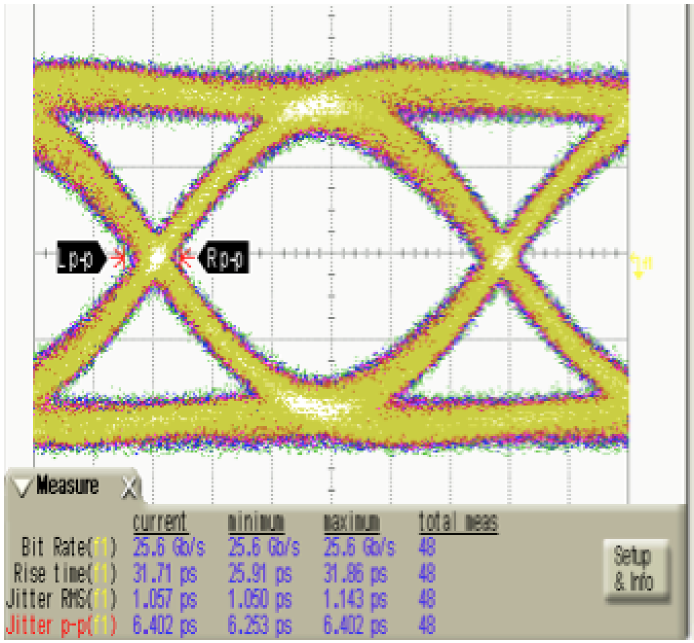
Connector Quattro II

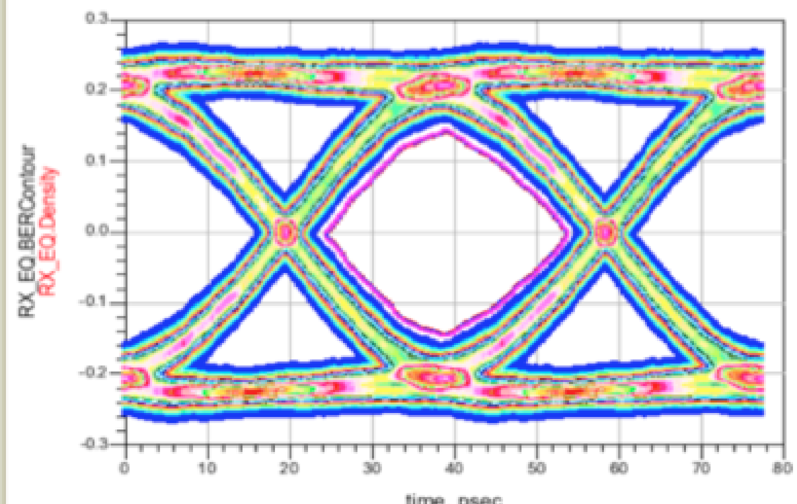
Host PCB
Material =N4000-13SI
Trace Length =4”
Traces = 5 mils stripline

Plug PCB
Material =N4000-13SI
Trace Length =1.5”
Traces = 5 mils Microstrip

cPPI-4 Far end Eye Diagram

- Measured and simulated eye → could drive optics unretimed





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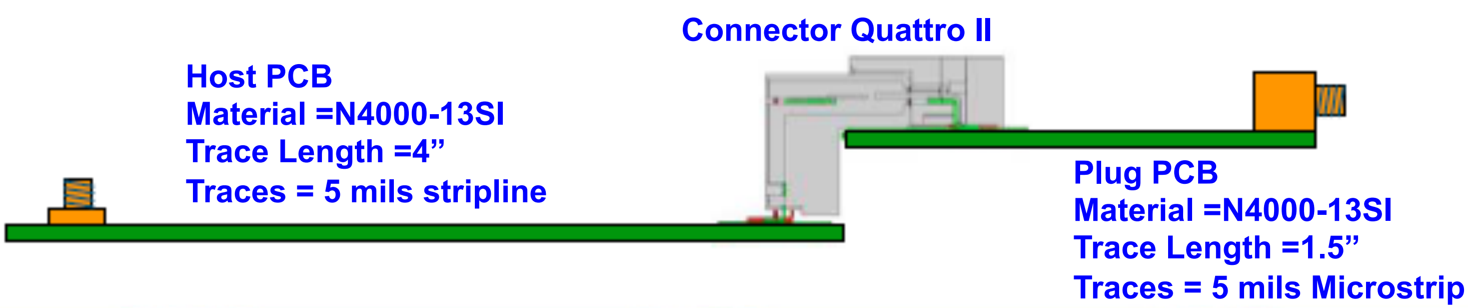
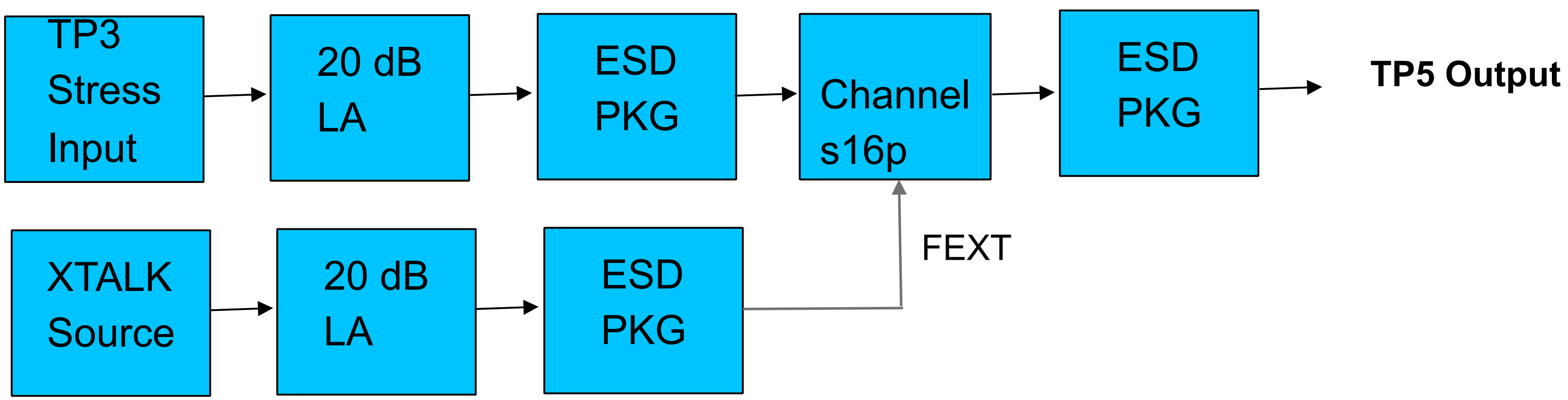


TP5 Simulation Block Diagram with TP3 Stress Input

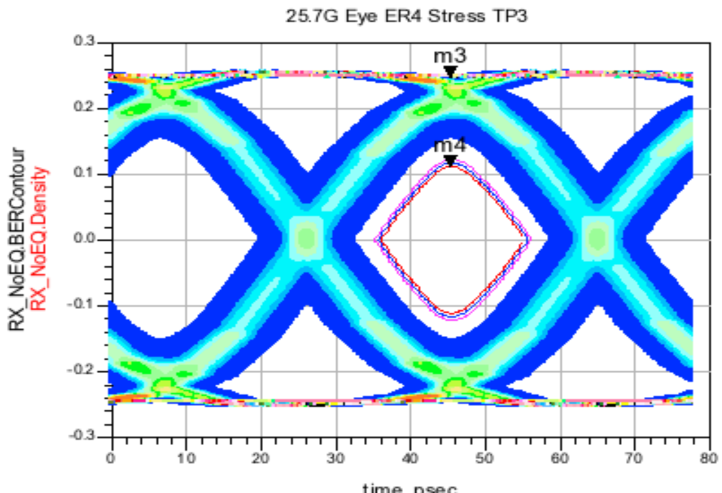
- Channel based on s16p and includes worst case FEXT in the simulation
- 100Gbase-ER4 TP3 stress input with 3.5 dB VECP
  - VECP for 1310 nm FR4 PMD expected to be 1.5-2.5 dB
  - VECP for 850 nm SR4 PMD could be 3.5 dB
- TP5 sensitivity with minimum optical receiver sensitivity 0.7 UI TJ at slicer and one with 0.65 UI at slicer
  - A linear interface will relax the requirement of 0.7/0.65 UI jitter at 25G



TP3 Stress Input

- Based on 100Gbase-ER4 definition which has higher

3.5 dB VECP, J2=0.3 UI, J9=0.47 UI



index	....WidthAtBER)	...HeightAtBER)	VECP
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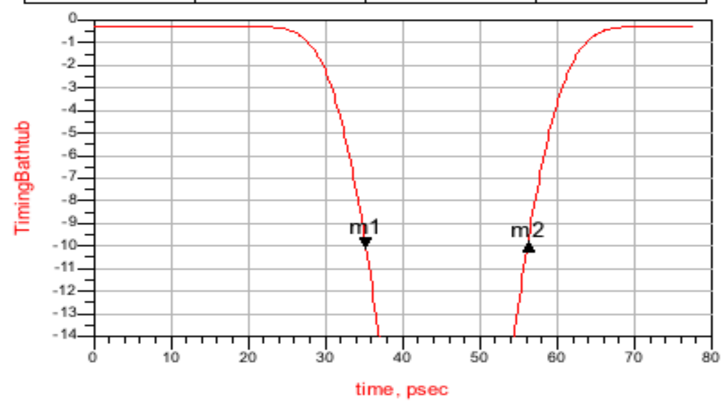
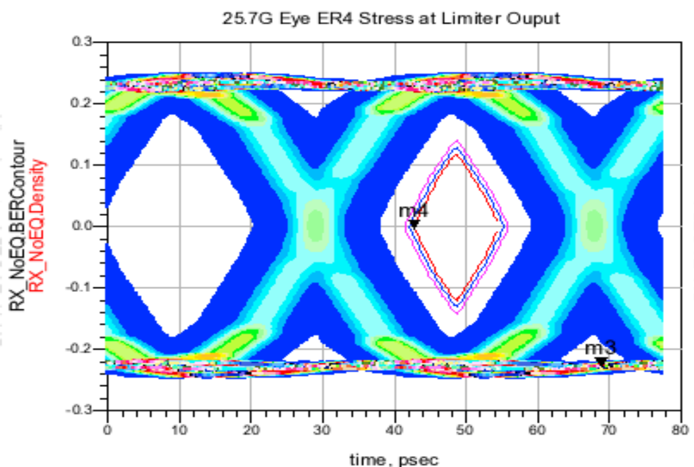


Limiter Output

- For minimum required sensitivity and slightly better receiver with 0.4 UI opening at sampling point instead of 0.3 UI



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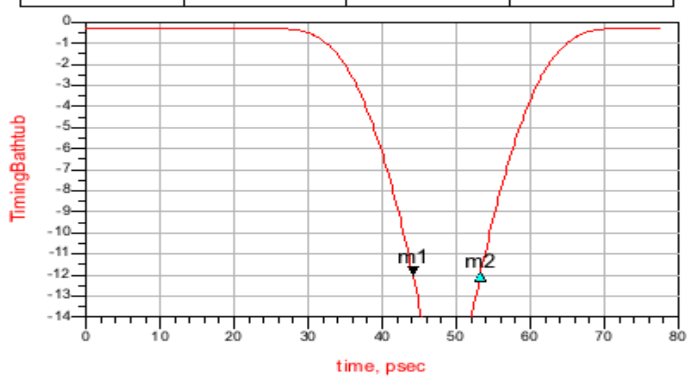

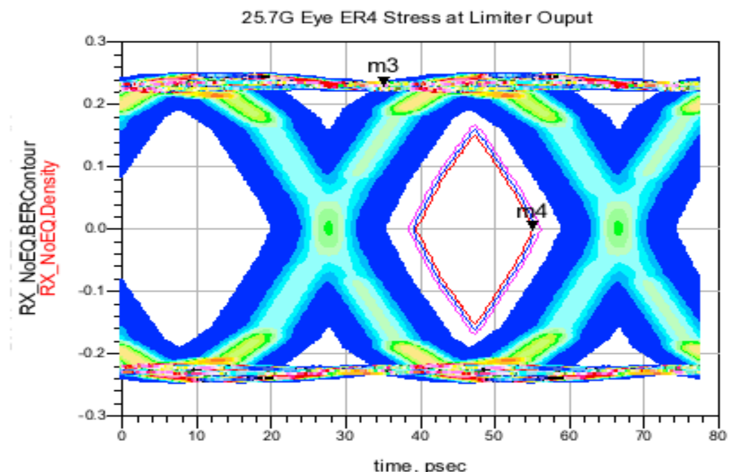

index	....WidthAtBER)	...HeightAtBER)	VECP
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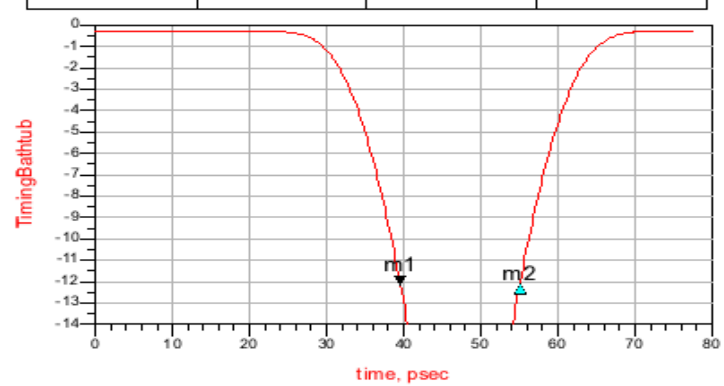
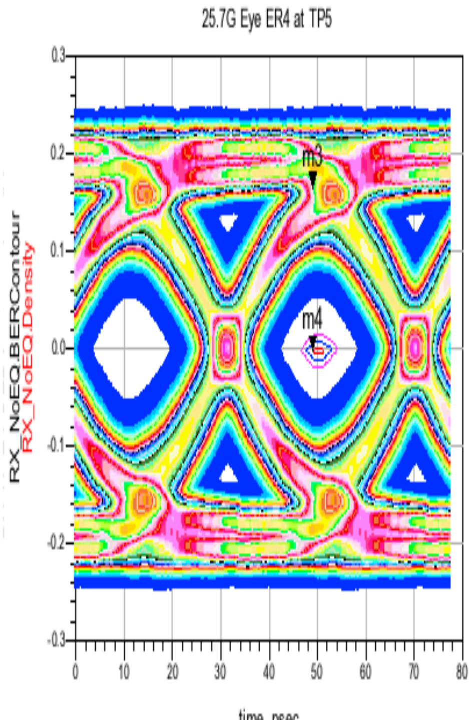


100 mm cPPI Like Channel

- Results at TP5 with 0.3 and 0.4 UI at sampling point
  - Increasing sampling point by 0.1 dB equates to ~2 dB sensitivity increase



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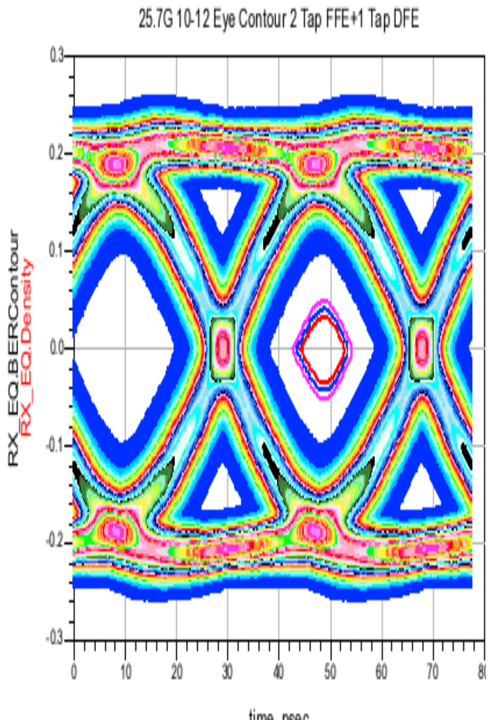

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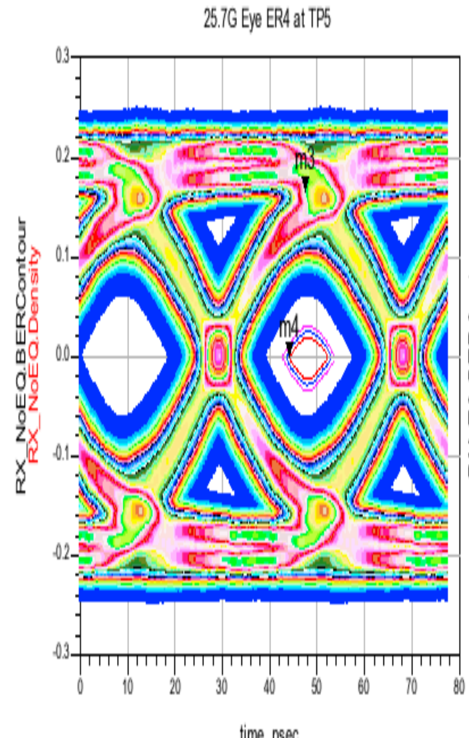

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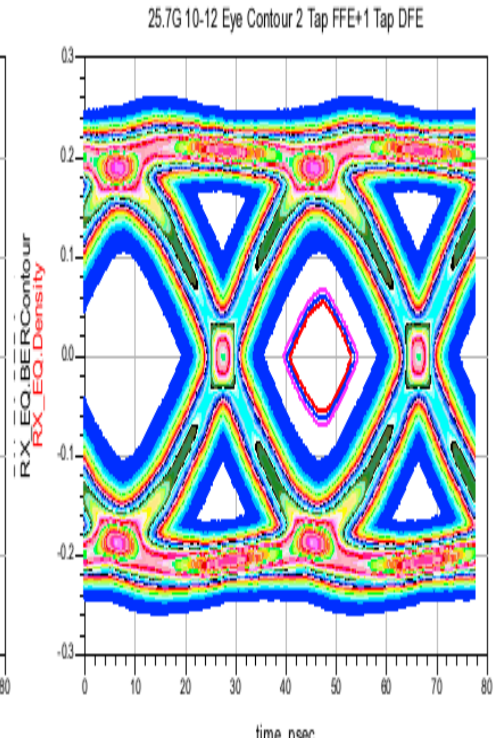

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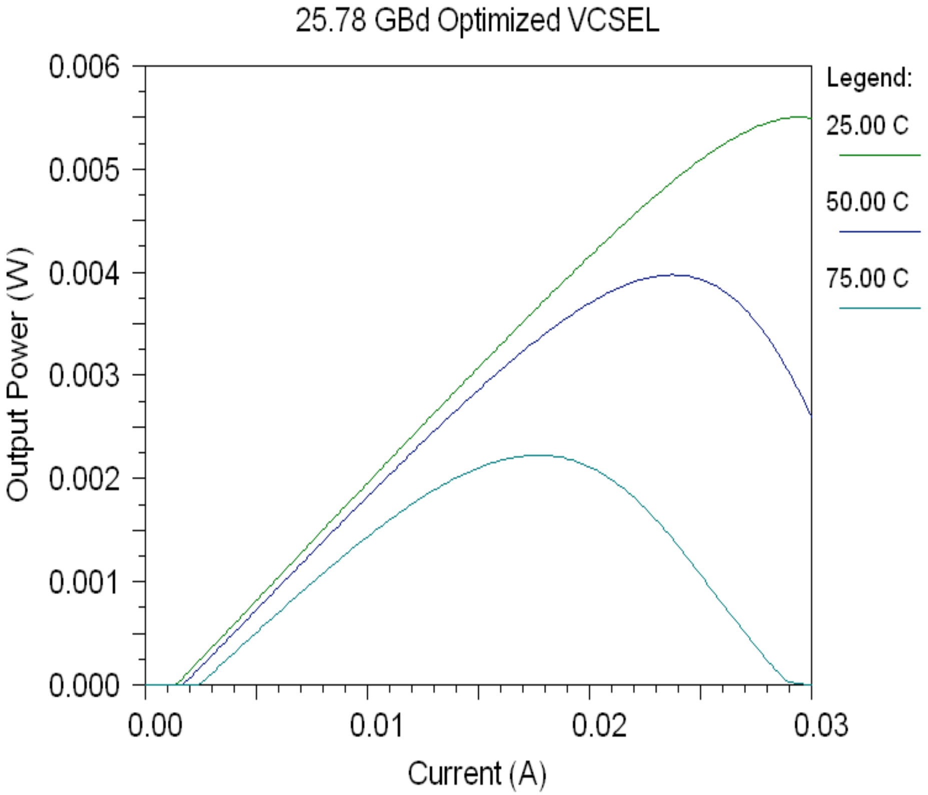
0.000	1.265E-11	0.109

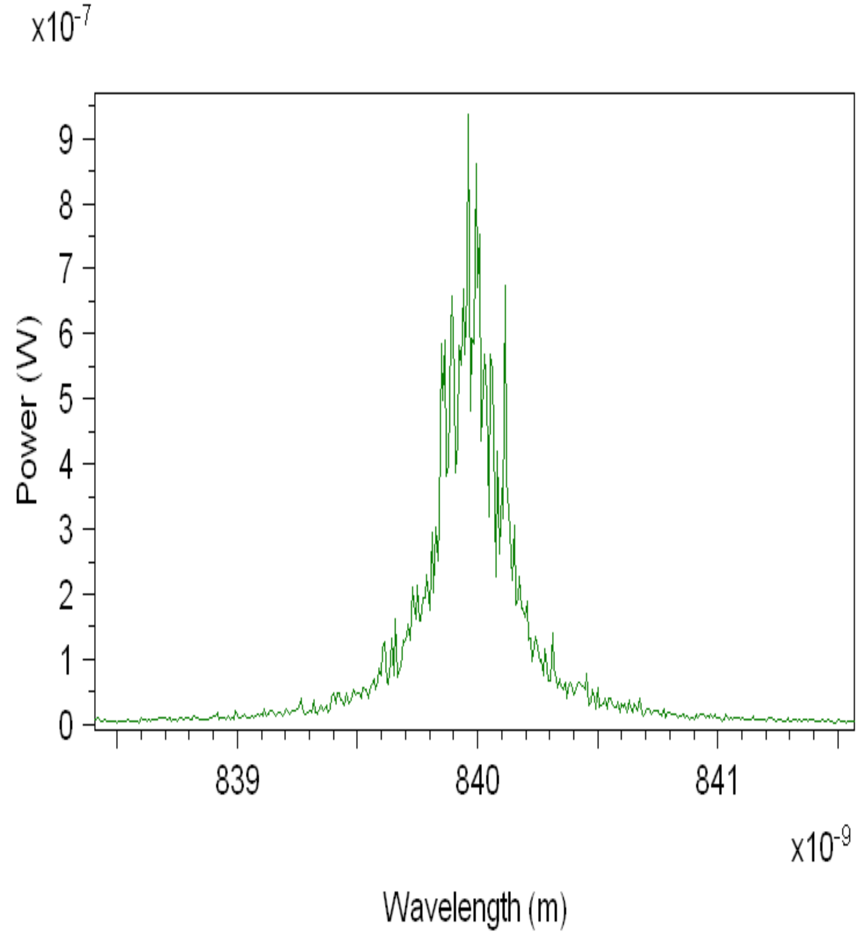
VCSEL Rate Equation Model and Link Model

- RSOFT simulation
- Transmitter parameters
  - VCSEL model based on spatial rate equation optimized for 25.78 GBd, 840nm center wavelength
  - Spectral width = 0.6 nm
  - VCSEL RIN = -129 dB/Hz
  - Mode size 7.5 um with 7.5um offset launch
  - 4 ps p-p PJ was added to the electrical driver
  - ER ~ 6 dB
  - Operating Temp = 25 C
  - Direct measurement of pulse $Tr_{10\text{-}90\%}$ = 20 ps, $Tf_{10\text{-}90\%}$ = 44 ps, $Tr_{20\text{-}80\%}$ = 14 ps, $Tf_{20\text{-}80\%}$ = 22 ps
- Receiver parameters
  - Receiver BW = 0.6*25.78 GBd
  - Receiver Sensitivity with ideal optical signal = -7 dBm AOP
  - PD responsivity 0.45 A/W
  - TIA gain 1 kΩ
- Fiber/link parameters
  - S0 = 0.10275 ps/nm^2.km, $\lambda 0$ = 1316 nm
  - Linear fiber model assumes fiber BW = 2000 MHz.Km, fiber loss = 3.5 dB/Km
  - Spatial fiber model assumes peak index = 1.46, Delta = 1%, alpha = 2.09
    - 20 primary modes where propagated in the case of spatial fiber
  - Connector loss = 1 dB

Rate Equation VCSEL LI and Spectrum

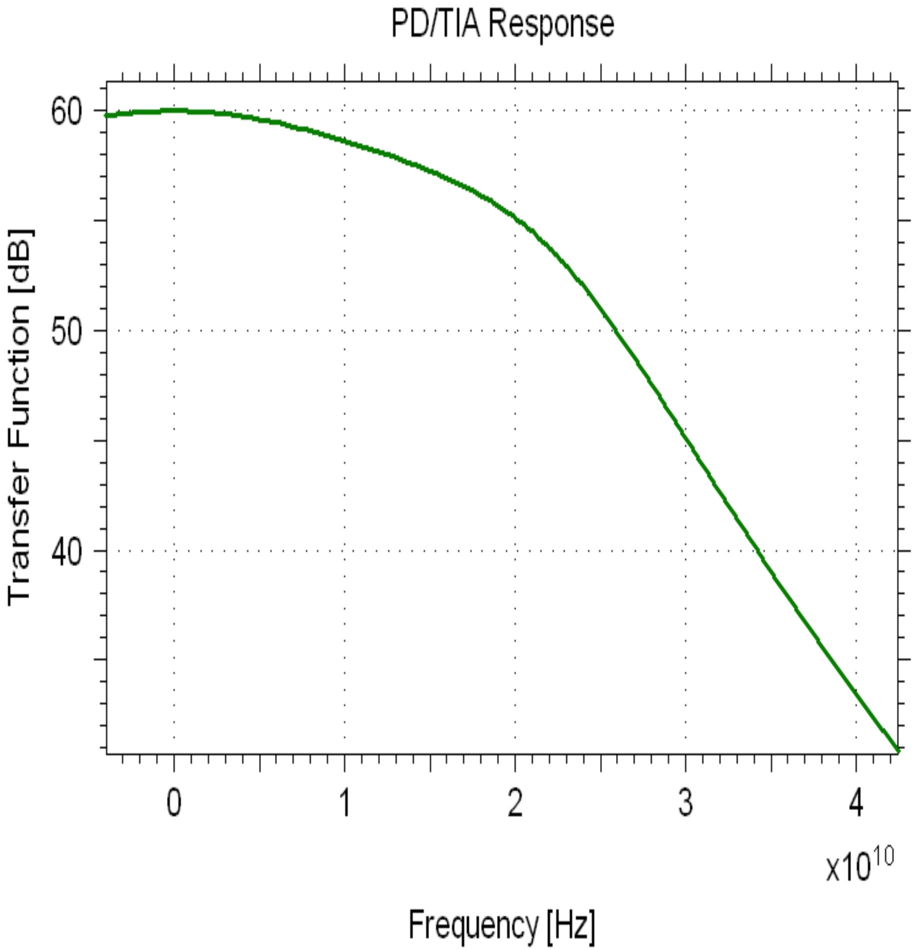
- Model includes thermal effects
  - Spectral width was further expanded by optical phase noise to get 0.6nm FWHM (matching typical VCSEL)

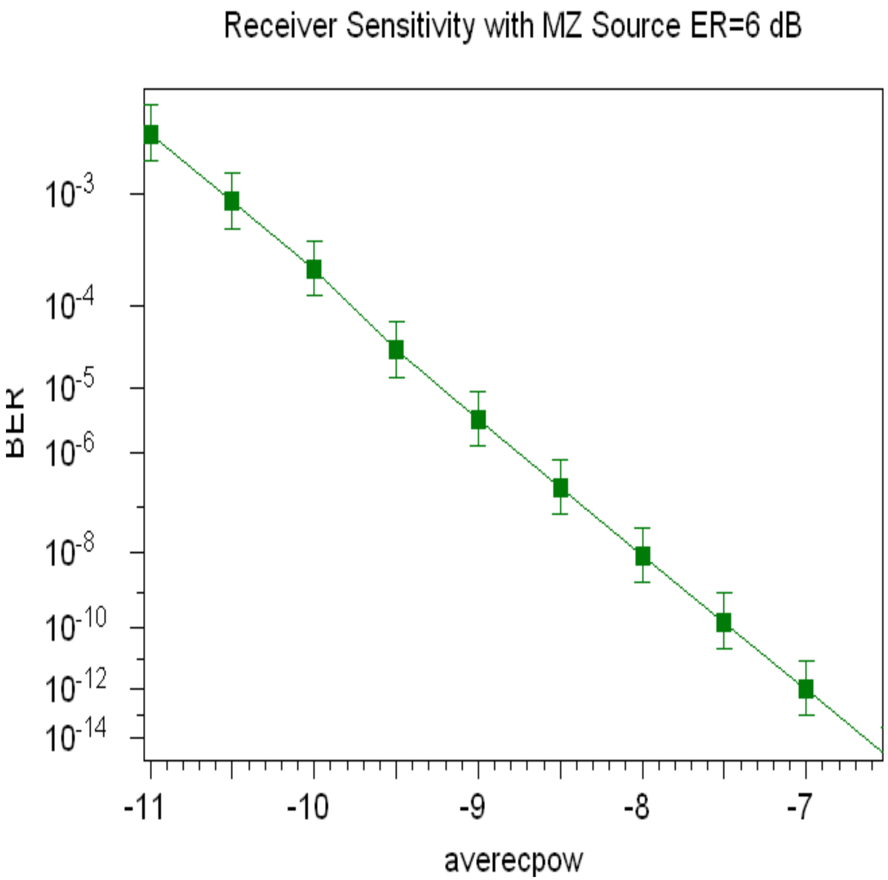




PIN/TIA

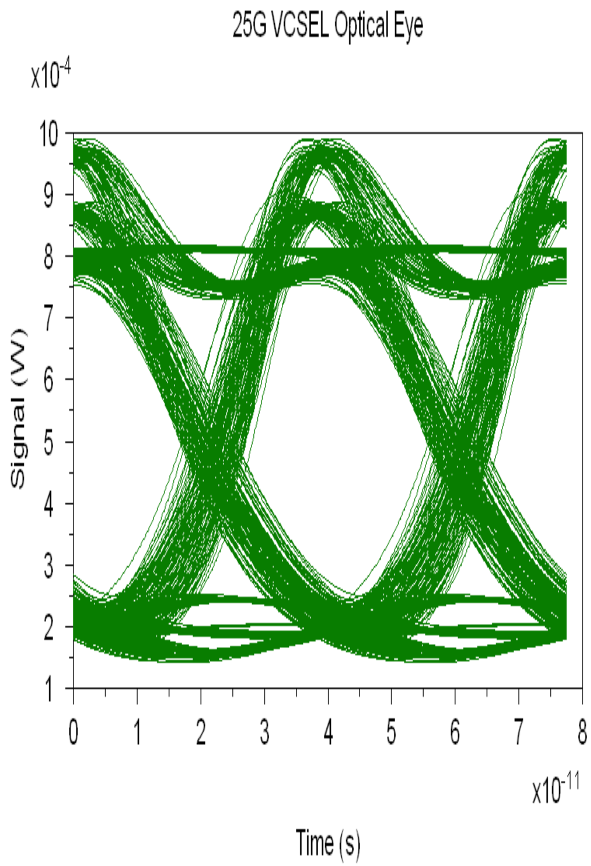
- TIA has TZ = 1 kΩ, with 15.75 GHz BW and -7 dBm sensitivity (Source is MZ with 6dB ER)

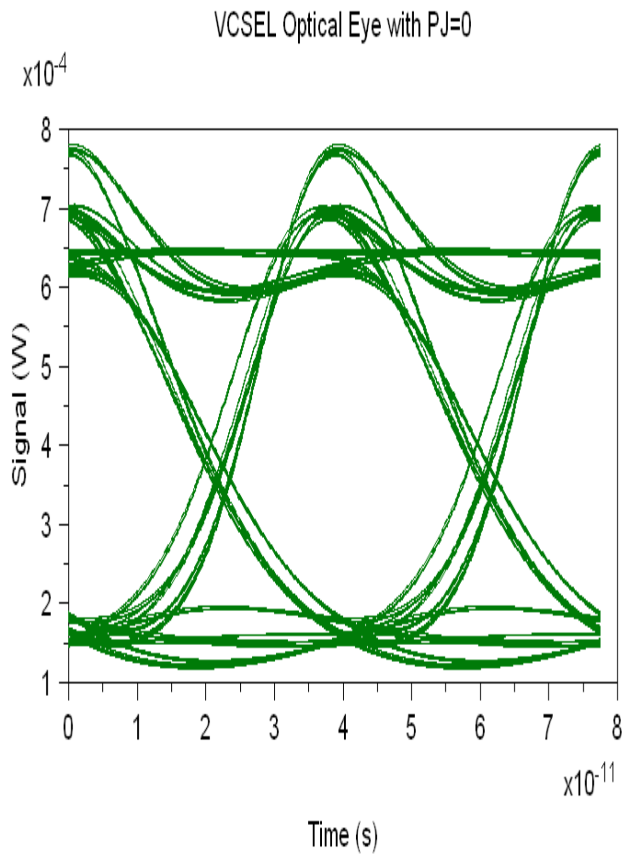


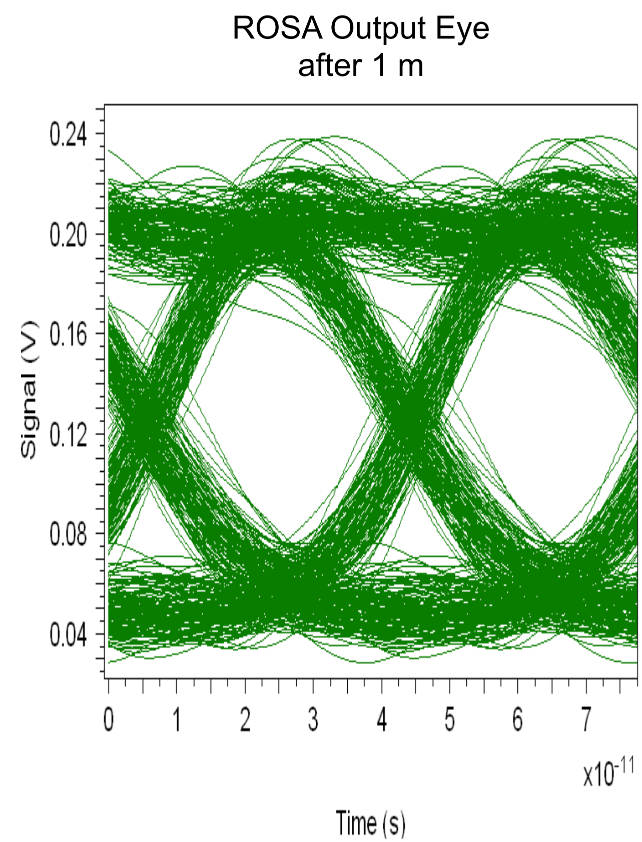


Rate Equation VCSEL Optical Eye and Back to Back Eye at 25.78 GBd

- Model based on RSOFT VCSEL spatial rate equation optimized for this application
  - Left optical eye PJ = 4 ps, middle optical eye PJ = 0, right electrical B2B eye PJ = 4 ps

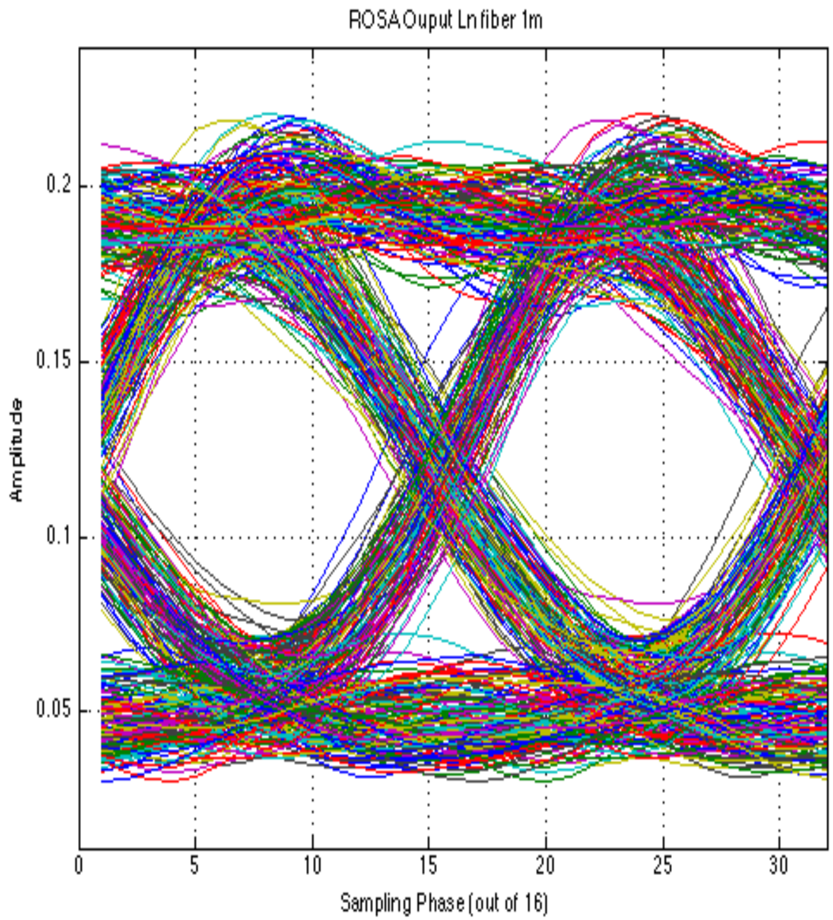


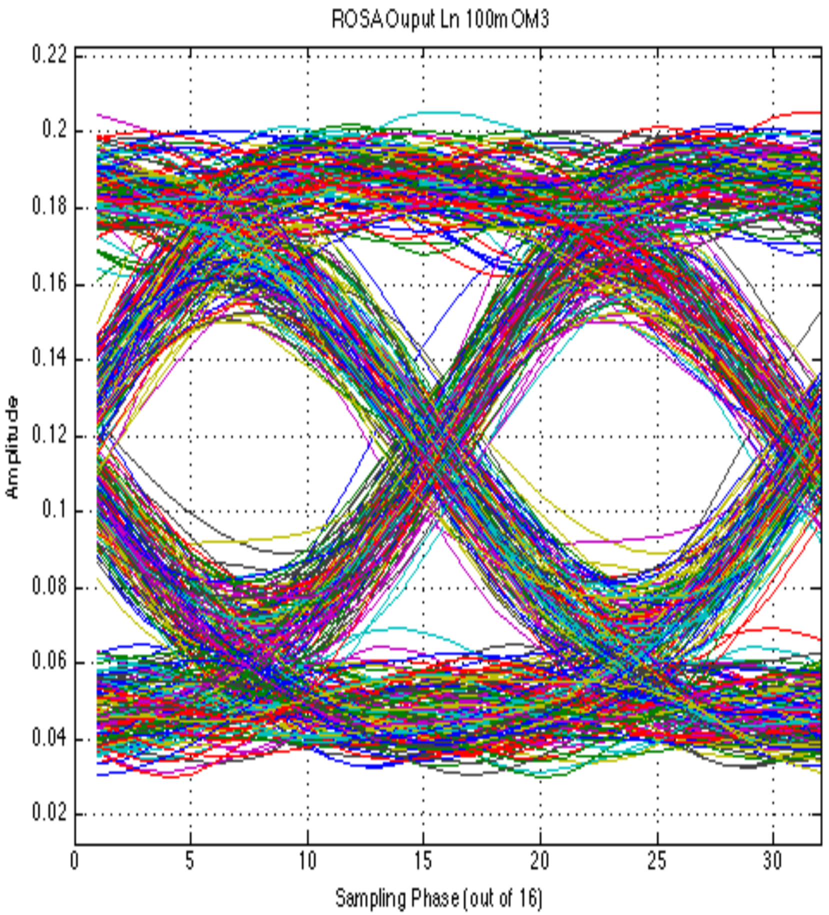




Simulated ROSA Output

- After 1 m and 100 m of OM3 fiber

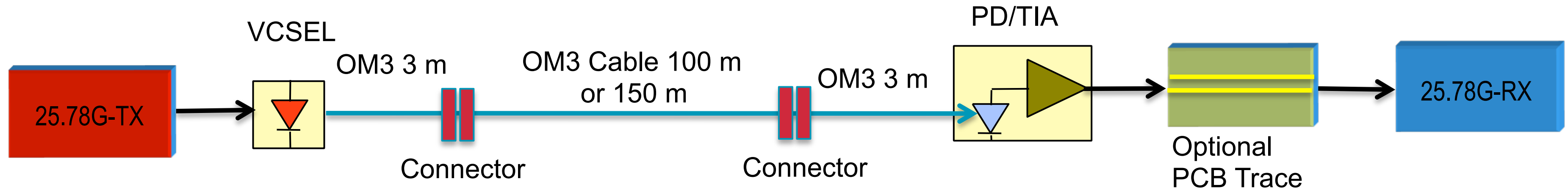




Basic Test Setup

- VCSEL was driven directly from a 25.78 GBd SerDes test chip
  - Laser was biased through bias-T and driven single-ended with 250 mVpp amplitude
  - No benefit seen by increasing de-emphasis beyond compensating for the test board
  - Laser test and reliability results were presented at Photonics West by Finisar
- The VCSEL die output was collimated with NA=0.47 lens then focused with NA=0.23 lens into an 50/120 um OM3 fiber patch cord
- VCSEL was biased at 5 mA with ~ 5dB extinction ratio
- Optical receiver had 15.5GHz BW, ~ 150V/W differential conversion gain, and -5.5dBm sensitivity

Authors are thankful to Jim Tatum and Jonathan King of Finisar for their contributions and for providing VCSELs samples for this work.
Authors are thankful to Robert Lingle and Xinli Jiang of OFS for fiber measurements and for their contributions.



Simulated TP3 Eye Without EQ and With 6 T/2 FFE after 1 m, 75 m, and 100 m of OM3

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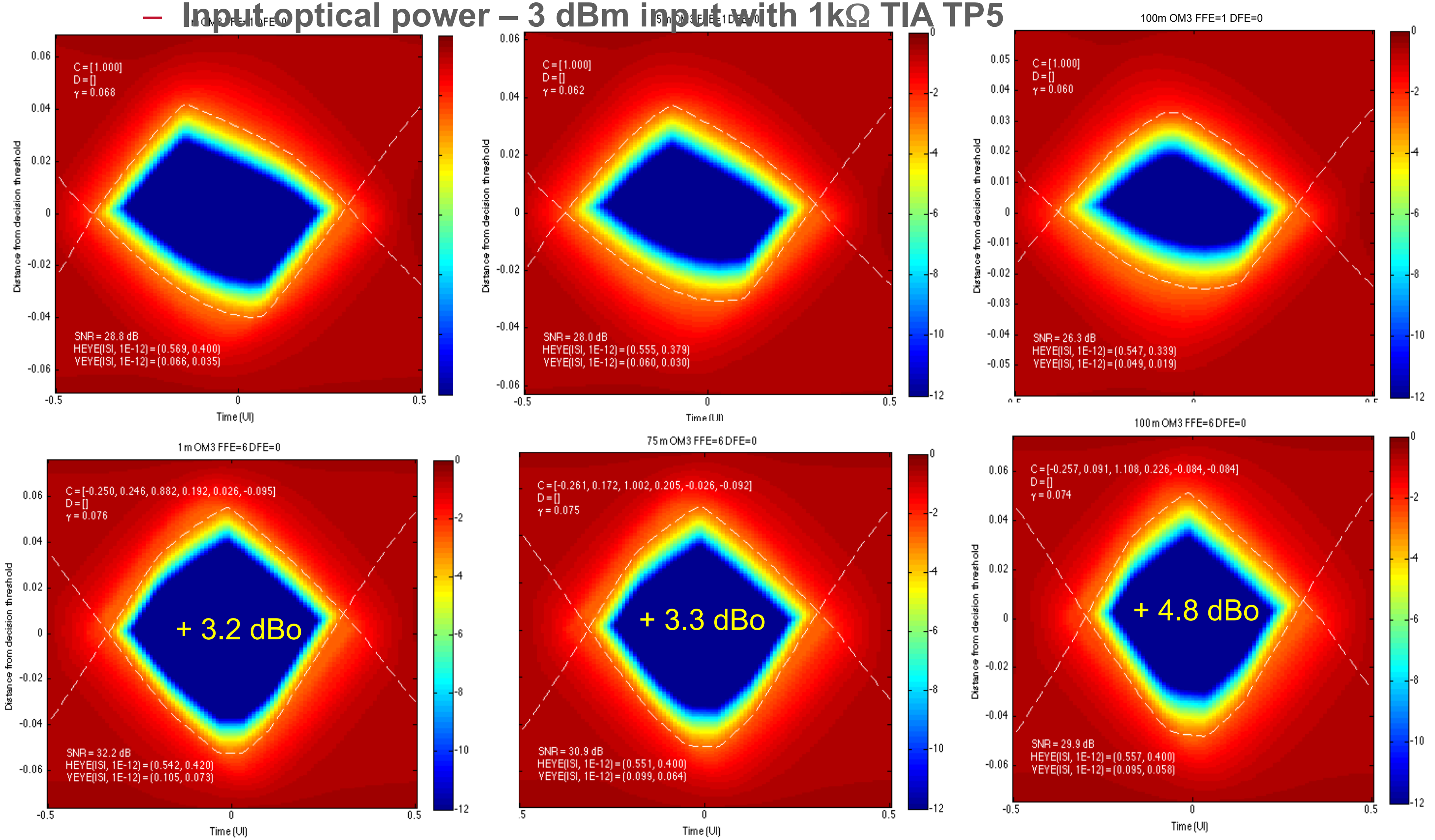
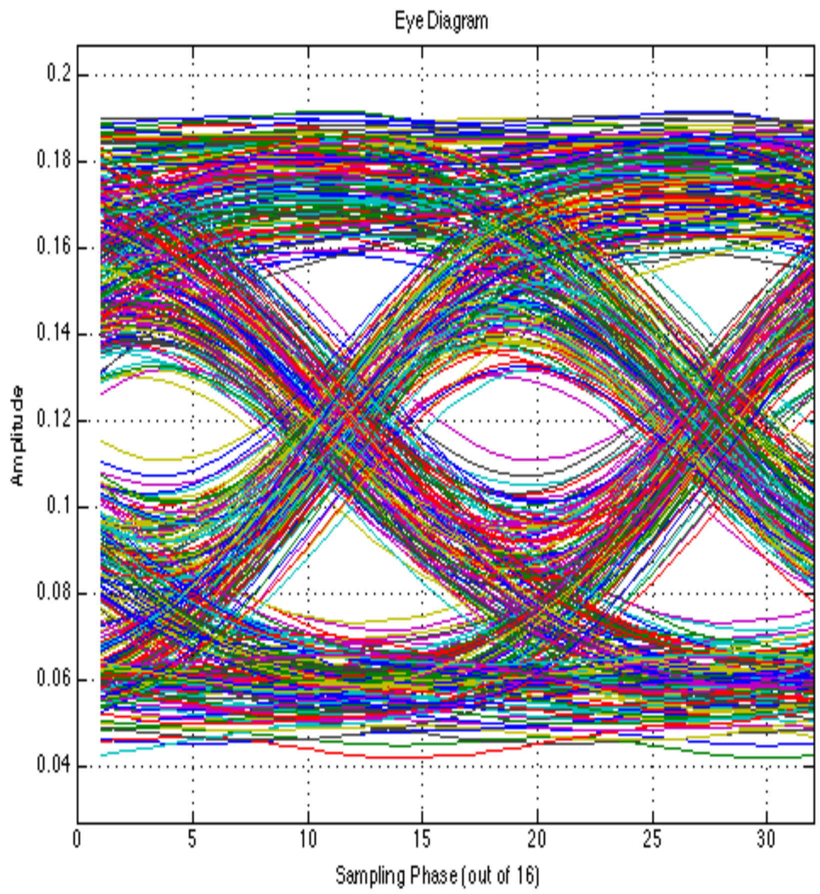
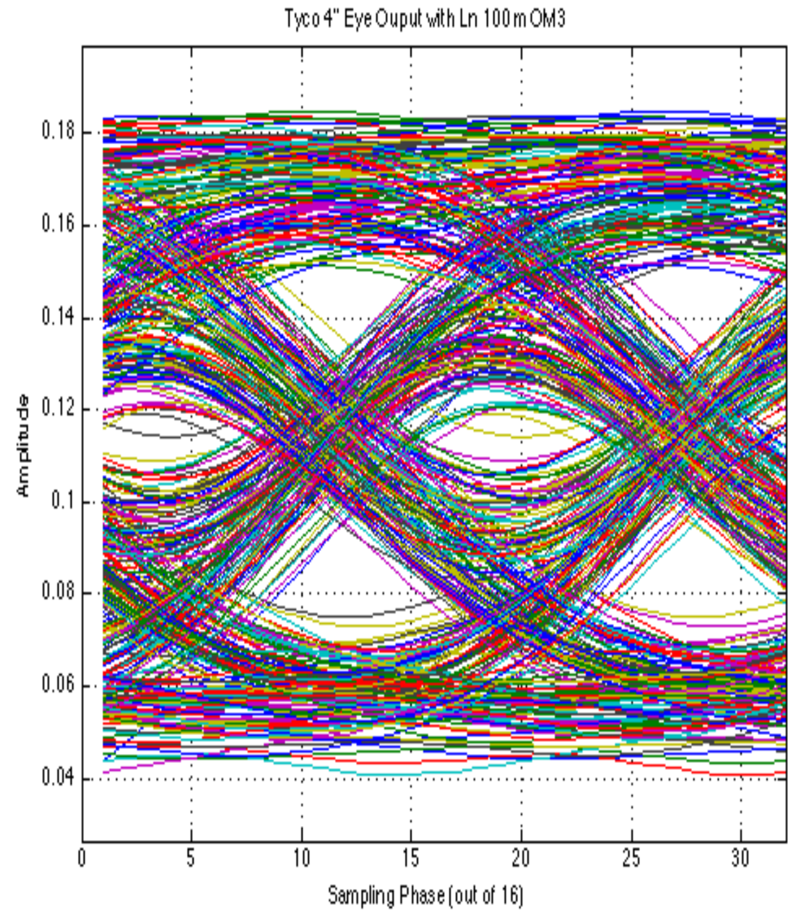
- At 100 m EQ increases the eye opening increases by +4.8 dBo @1E-12
  - Input optical power – 3 dBm input with 1kΩ TIA TP5



Simulated TP5 Eye for OM3 Fiber Model

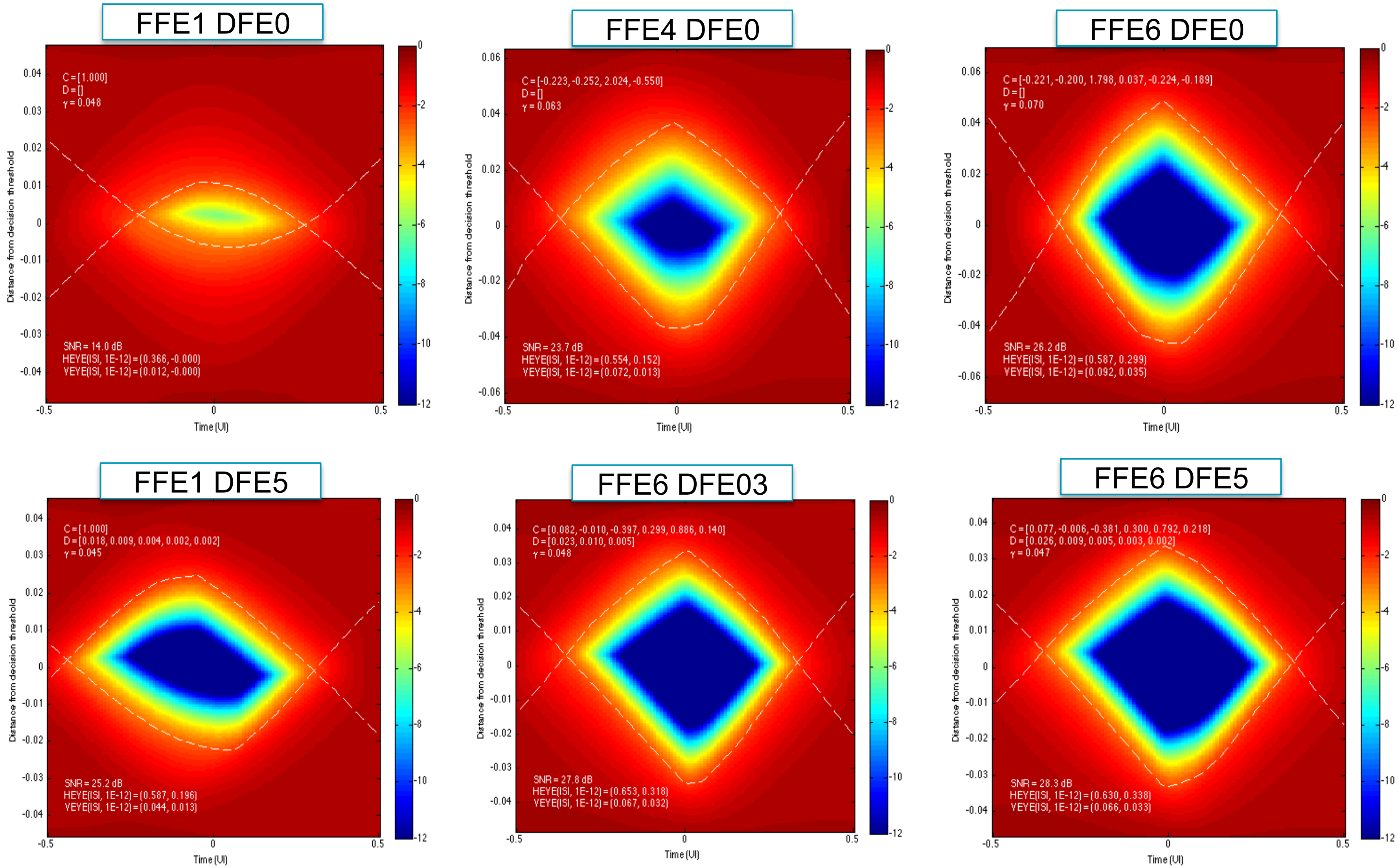
- After Tyco 4” channel with 1m and 100 m of OM3 fiber





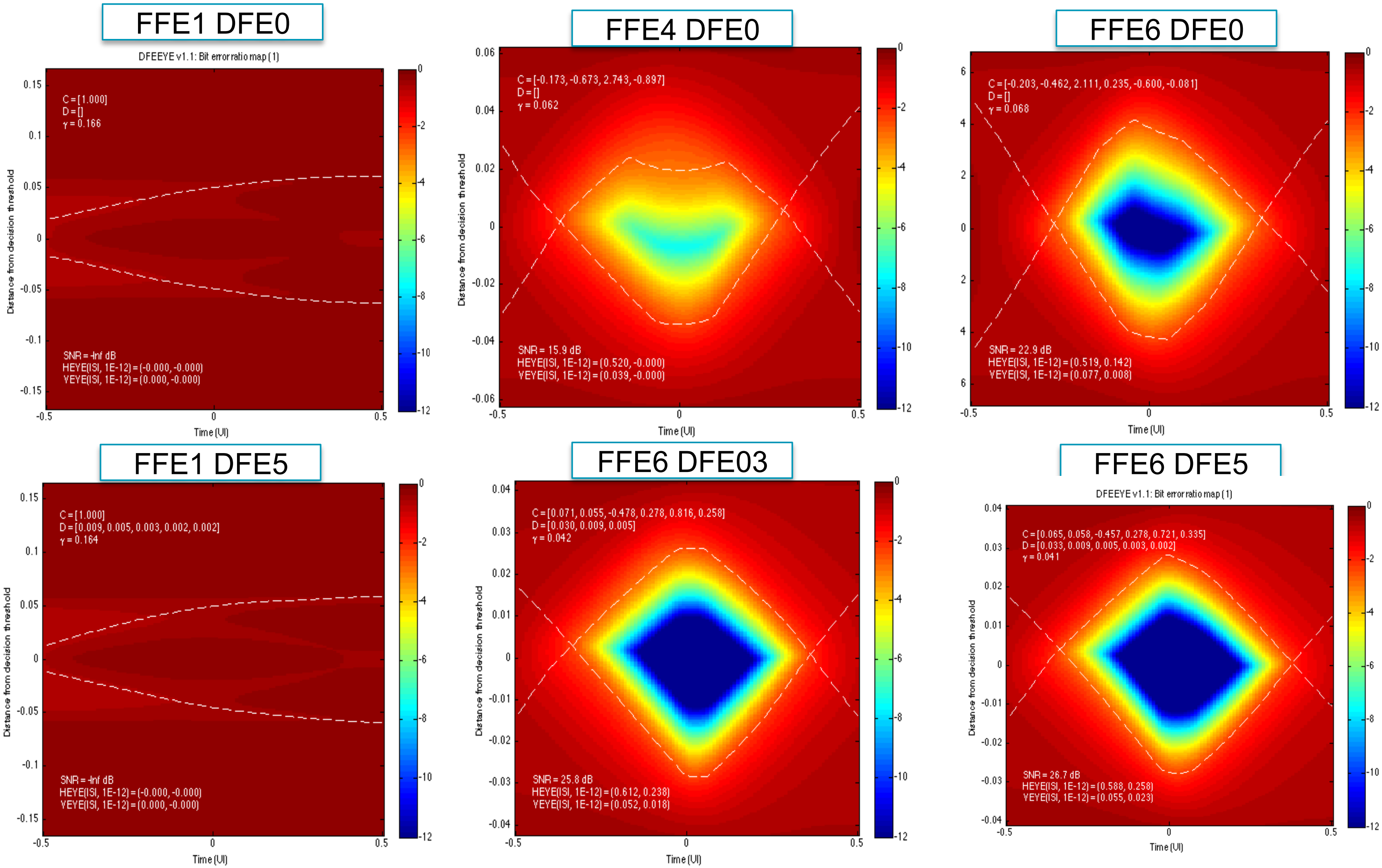
Simulated TP5 Eye with 4” host PCB and 1 m OM3

- **At –3 dBm input with 1kΩ TIA ,TP5 eye opening at 1E-12 is 32 mV with 6 T/2 FFE + 3 DFE**



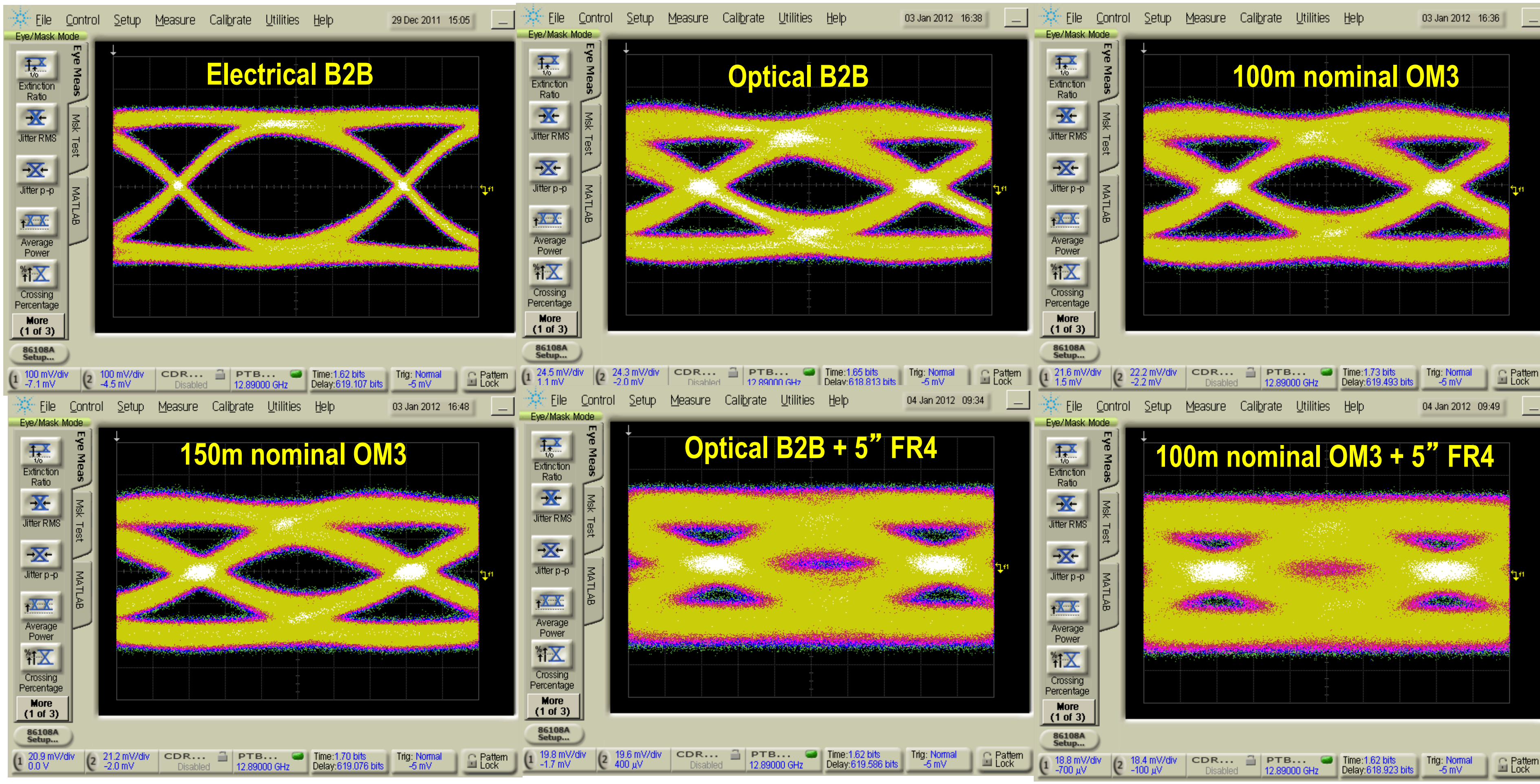
Simulated TP5 Eye with 4" host PCB and 100 m OM3

- At –3 dBm input with 1kΩ TIA, TP5 eye opening at 1E-12 is 18 mV with 6 T/2 FFE + 3 DFE



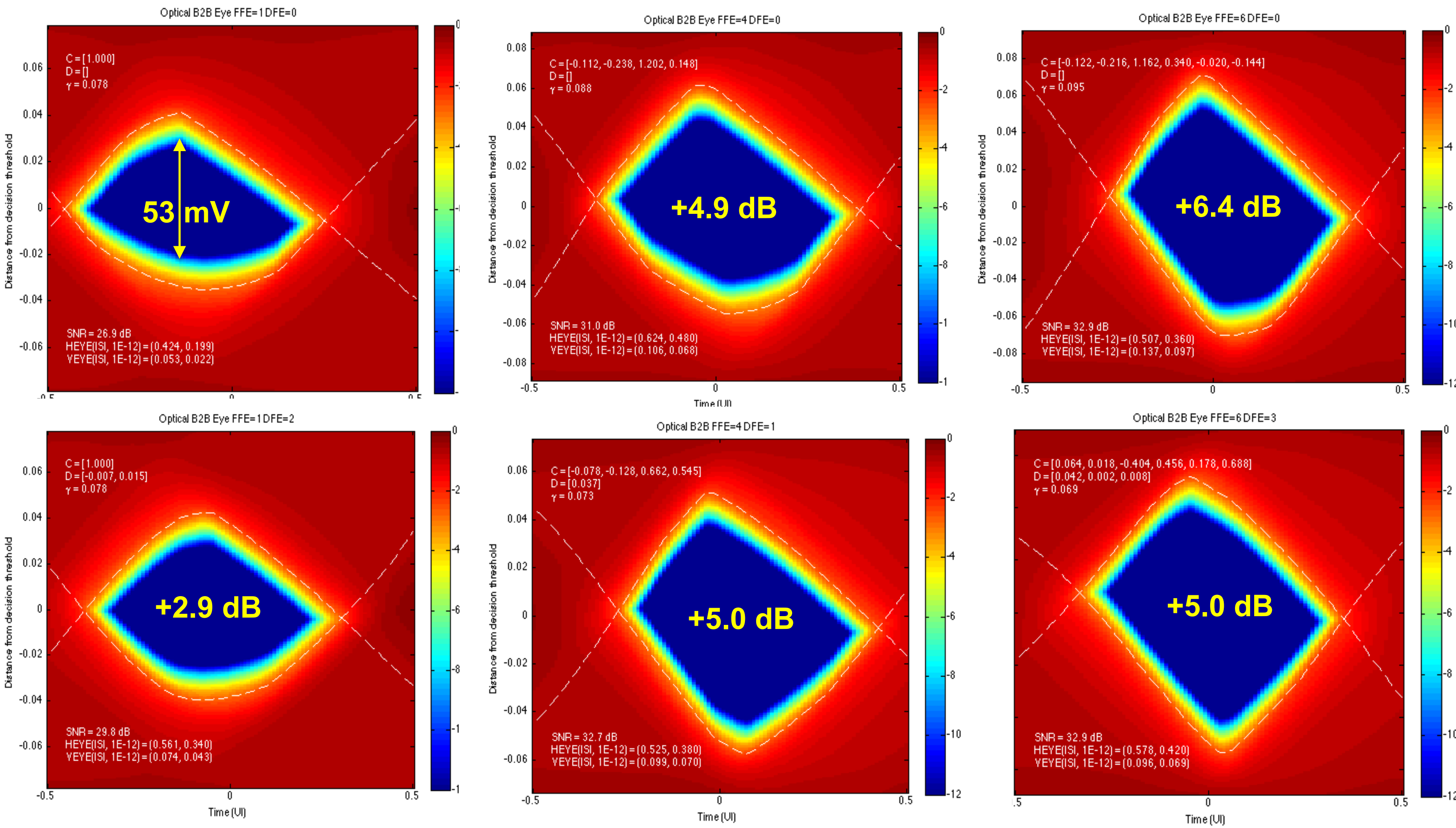
Measured 25.78 GBd Eyes with PN31

- 5mA VCSEL bias current, ~ 5dB ER



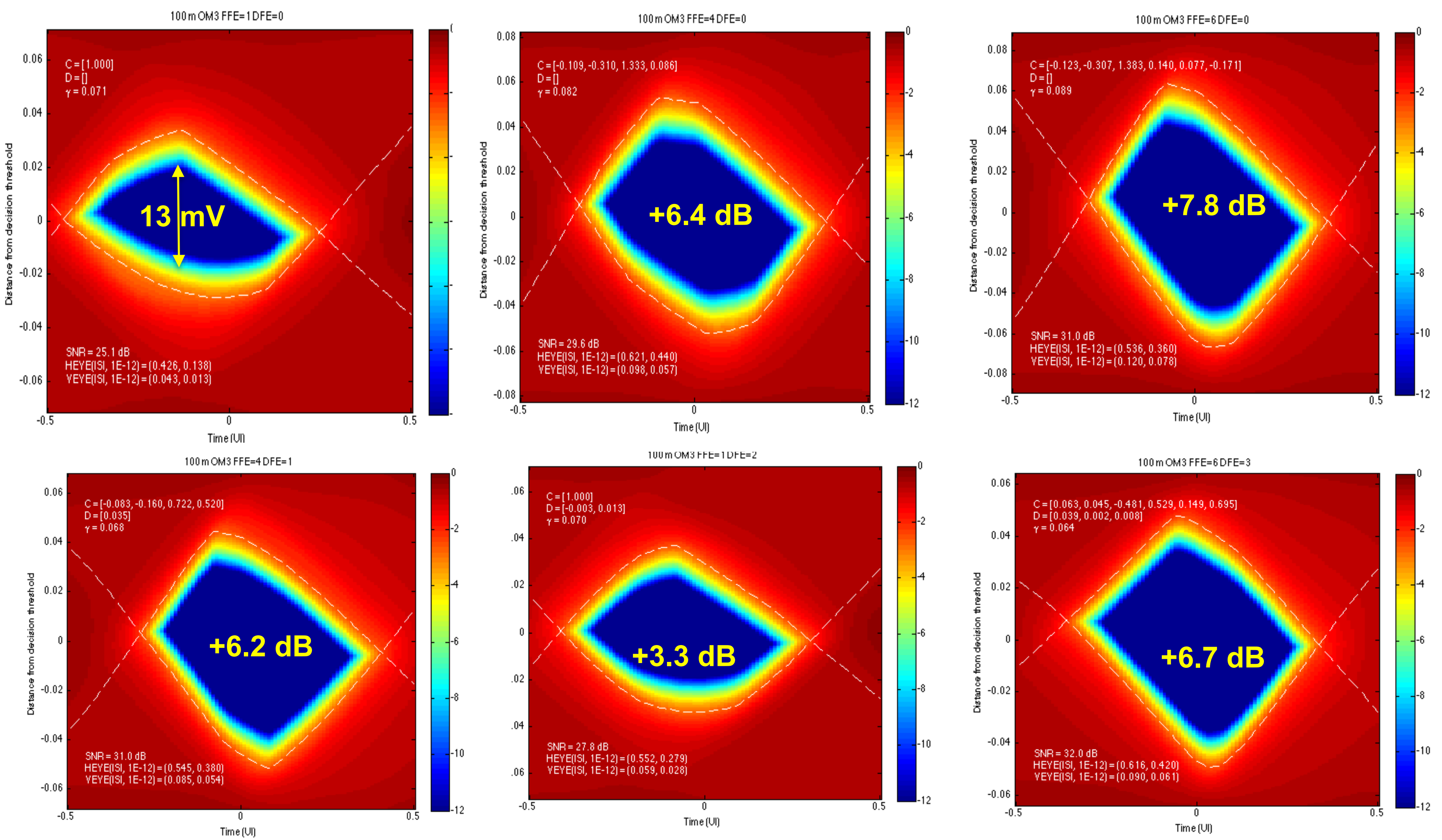
Eye Diagram at 25.78 GBd with 6 m of OM3 Fiber

- Even in case of B2B, the equalizer can provide 5+ dBo of gain caused by VCSEL and PD/TIA impairments



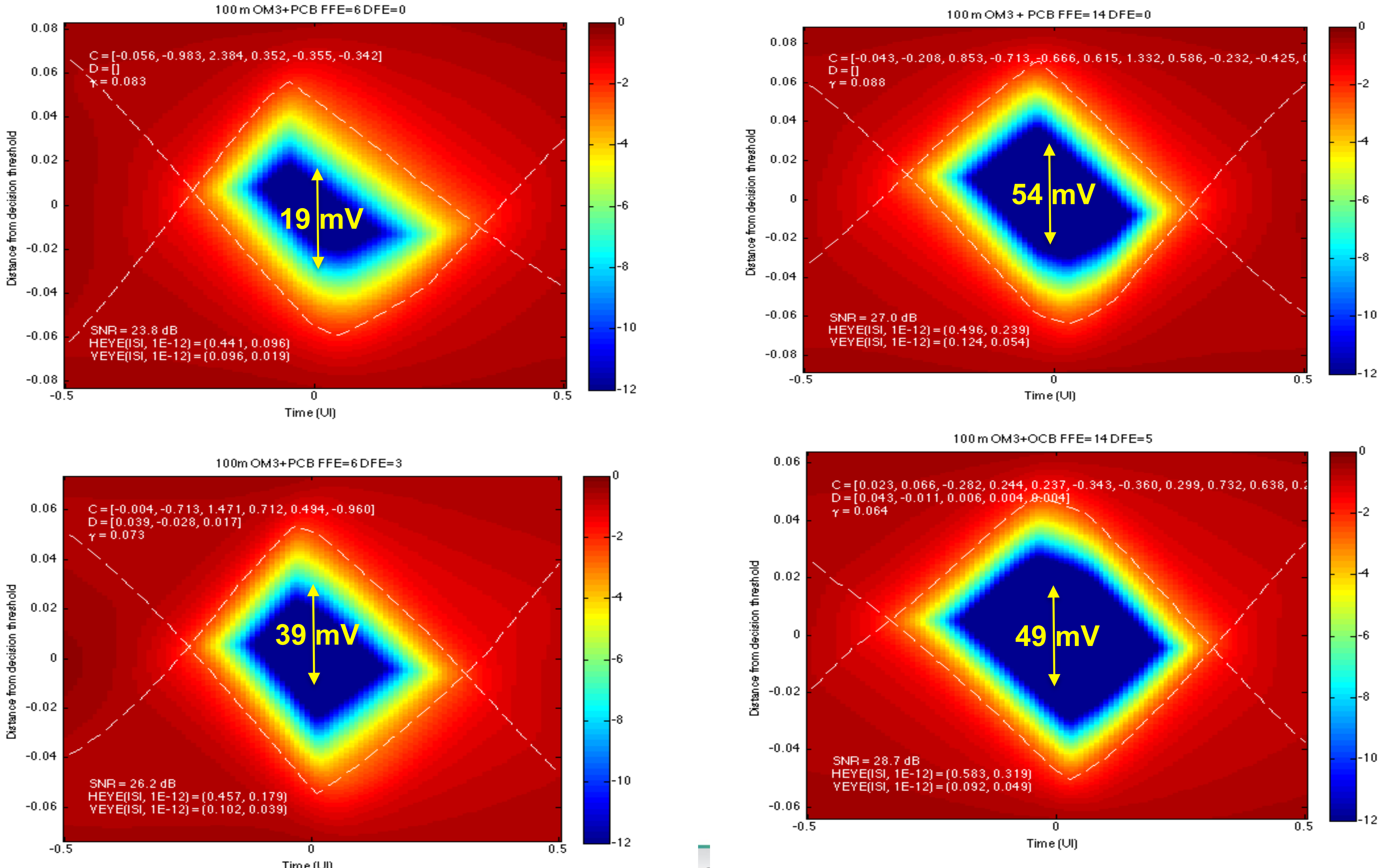
Equalized Eye Diagram at 25.78 GBd with 106 m of OM3 fiber

- The unequalized eye of just 13 mV likely too small for error free operation



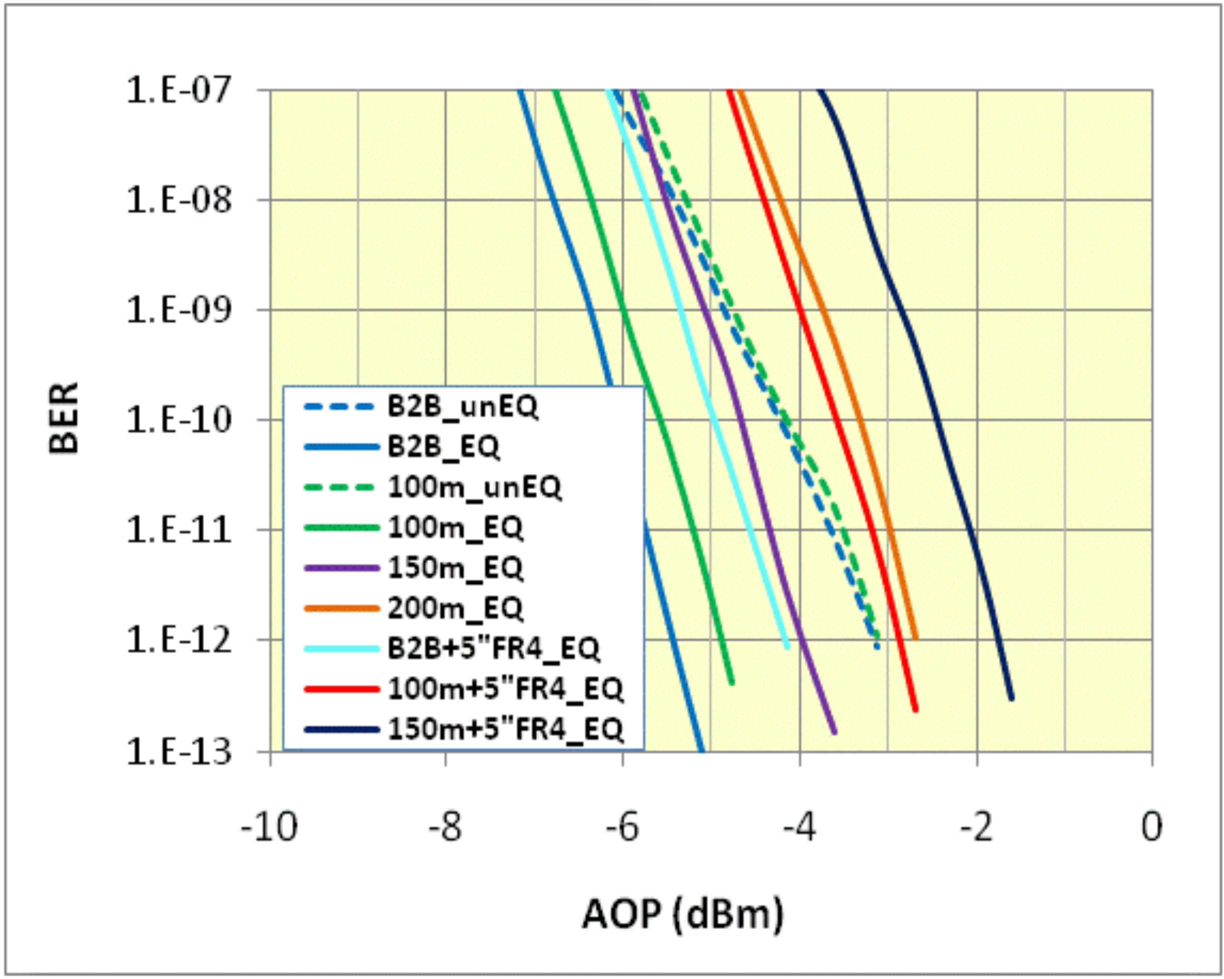
Equalized Eye Diagram at 25.78 GBd with 106 m of OM3 + 4” PCB

- Assuming min target slicer opening of 30 mV a FFE6+DFE3 is sufficient



BER Results For Nominal OM3 Fiber

- Results are with and without 1 tap DFE
- B2B unEQ still is about -3 dBm
- B2B sensitivity with EQ improves by 1 dBm from previous results
- B2B sensitivity with EQ and without EQ improves by 2.5 dBm
- 150m OM3 long term BER → 99.98% EF conf level at 1E-15
- 100m OM3 + 5“ PCB no longer has an error floor



Summary

- To make transmitter meeting DDPWS and J2 requirements the cPPI-4 channel would have to be ~ 7 dB instead of 10.5 dB CAUI-4 budget
  - Should leave about 4 dB which equates to ~5" on Megtron-6
  - Unretime TP1a would require better laser, one option is to start half retime as the process improves eliminate the TX retimer
- To make limiting module receiver work
  - About 0.1 UI of additional margin host SerDes
  - The extra margin could come by having shorter fiber or receiver with improved sensitivity
- To make linear module receiver work
  - Crosstalk does add some penalty but the fact one the host can now equalize for the fiber/Laser there is net gain
  - This interface DFE as result of MTTFPA the interface require at least FEC encoder and we might as well turn on
- FEC definitely can help both limiting as well as linear interface and not as much on the transmitter.

Thank You