Measurements Results of 25.78 GBd VCSEL Over OM3 with and without Equalization

IEEE 100GNGOPTX Study Group

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Overview

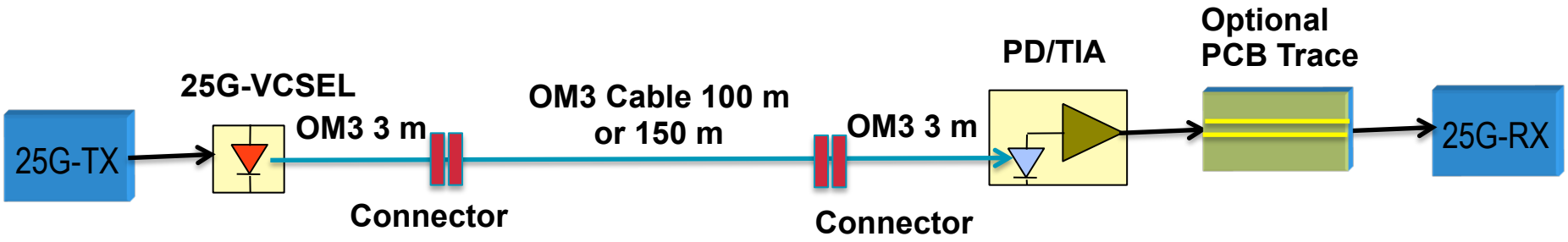
- Test setup
- Measured and simulated eye diagrams
- Calculated WDP and pulse response
- BER plot
- Example FFE implementation

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.

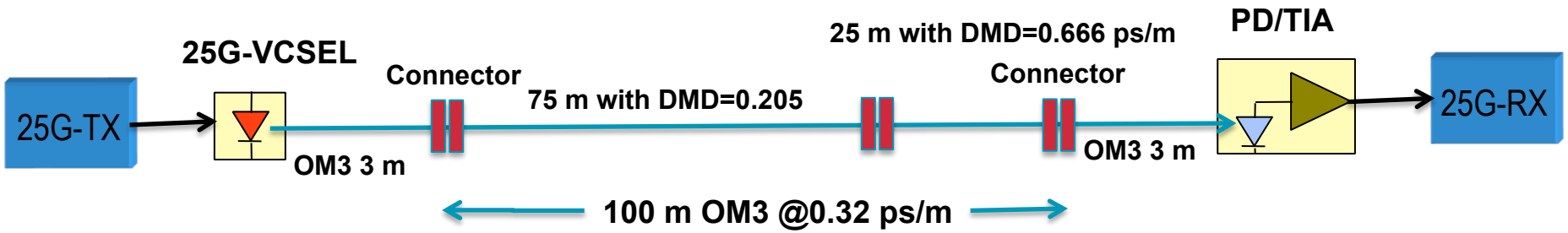
Basic Test Setup

- 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



Creating Worst Case OM3 Fiber

- Worst case OM3 fiber has an average DMD of 0.32 ps/m
- The OM3 fiber previously used had an average DMD of 0.205 ps/m with EMBW of 2930 MHz.km
- An out of spec OM3 fiber was located with average DMD of 0.66 ps/m with EFMB of 1057 MHz.km
- The nominal length of the previously used OM3 fiber and the out spec OM3 fiber were combined to have an average DMD of 0.32 ps/m at the specified length
  - Example below show how the two fiber were combined to get 100 m.

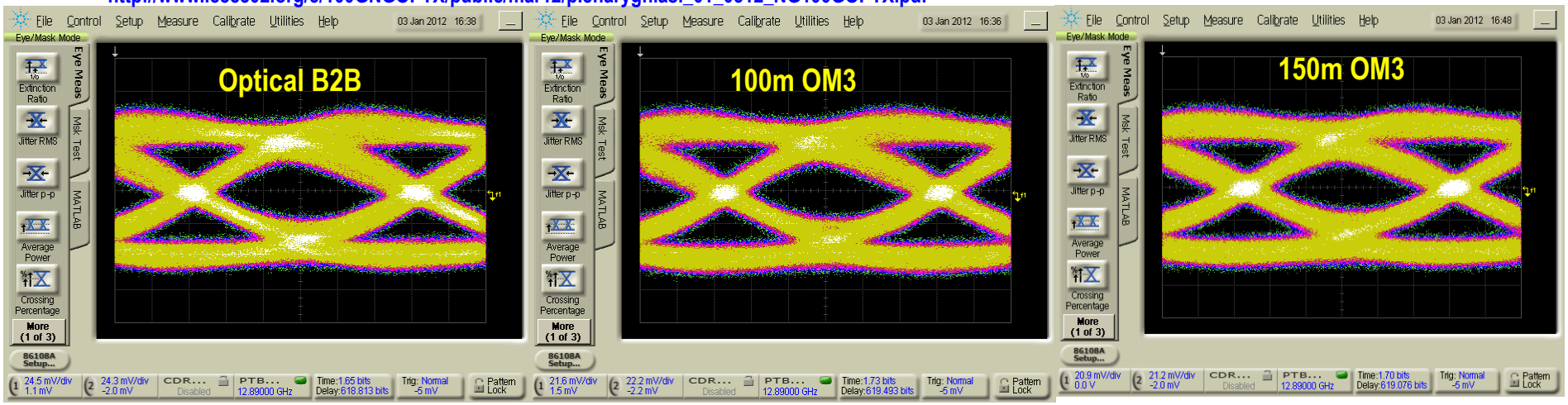


PRBS31 Eye Diagram at 25.78 GBd

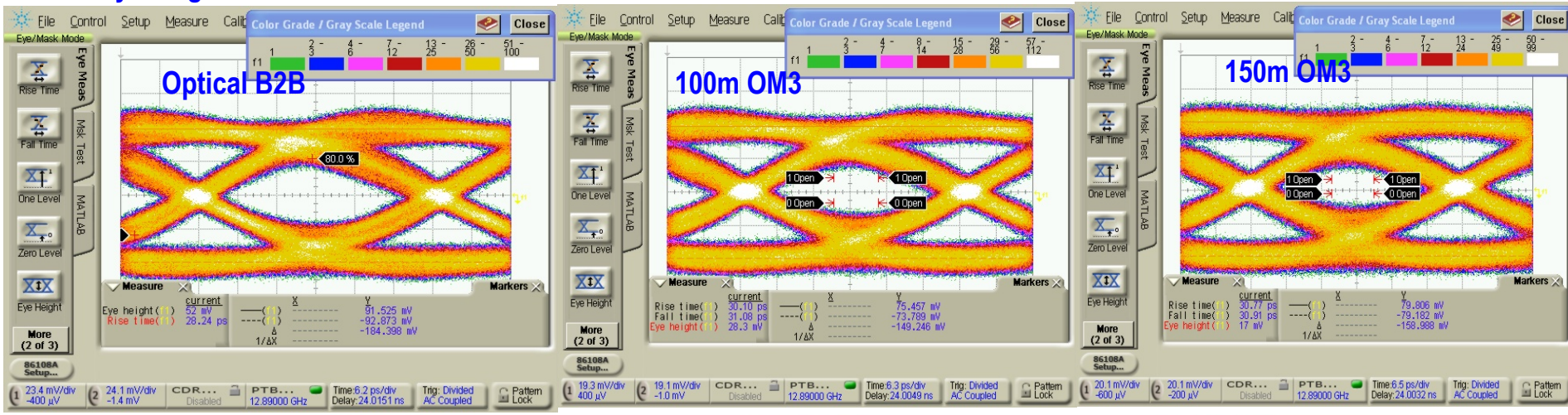
- Response for 150 m typical OM3 is comparable to worst case 100 m

Eye Diagram with typical OM3 fiber as shown

http://www.ieee802.org/3/100GNGOPTX/public/mar12/plenaryghiasi_01_0312_NG100GOPTX.pdf

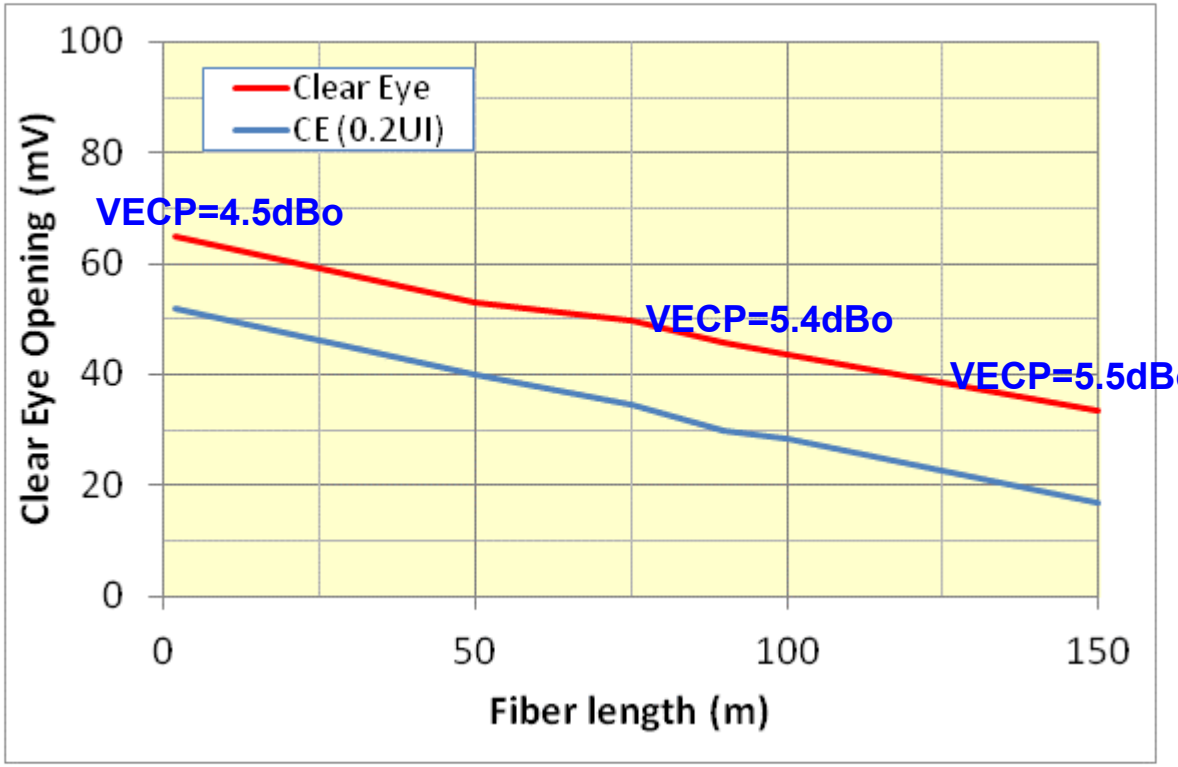


Eye diagram for worst case OM3 fiber



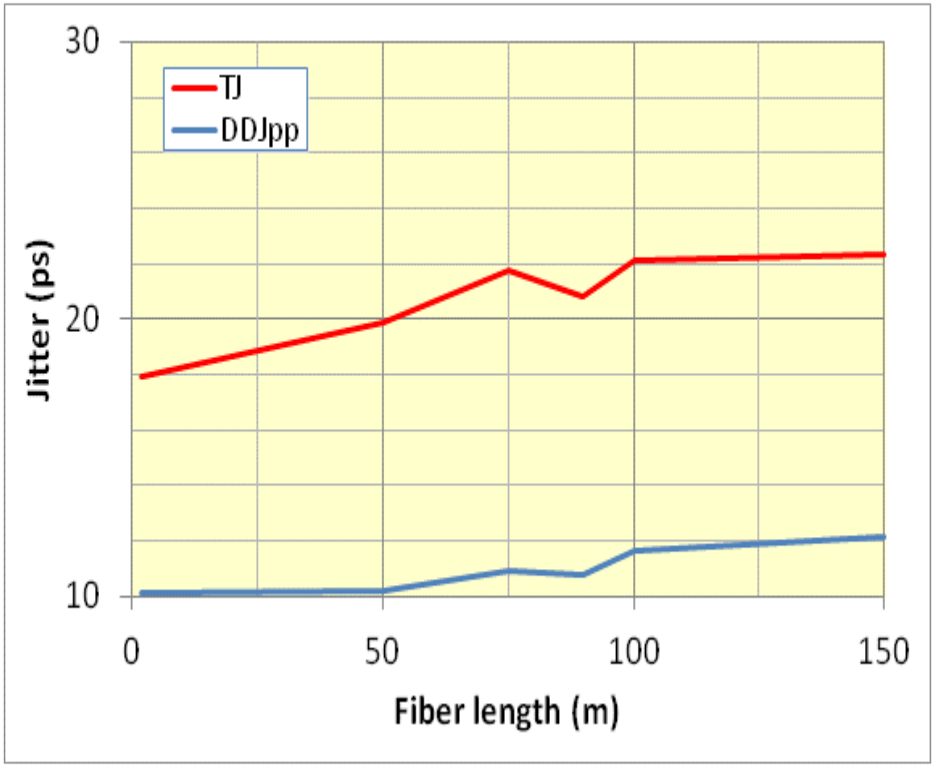
Clear Eye Opening Worst Case OM3

- Fiber is OM3 with varying lengths
- Clear Eye measured at center of the eye, CE (0.2UI) measured within +/- 0.1UI from center of the eye
- No indication of penalty cliff!



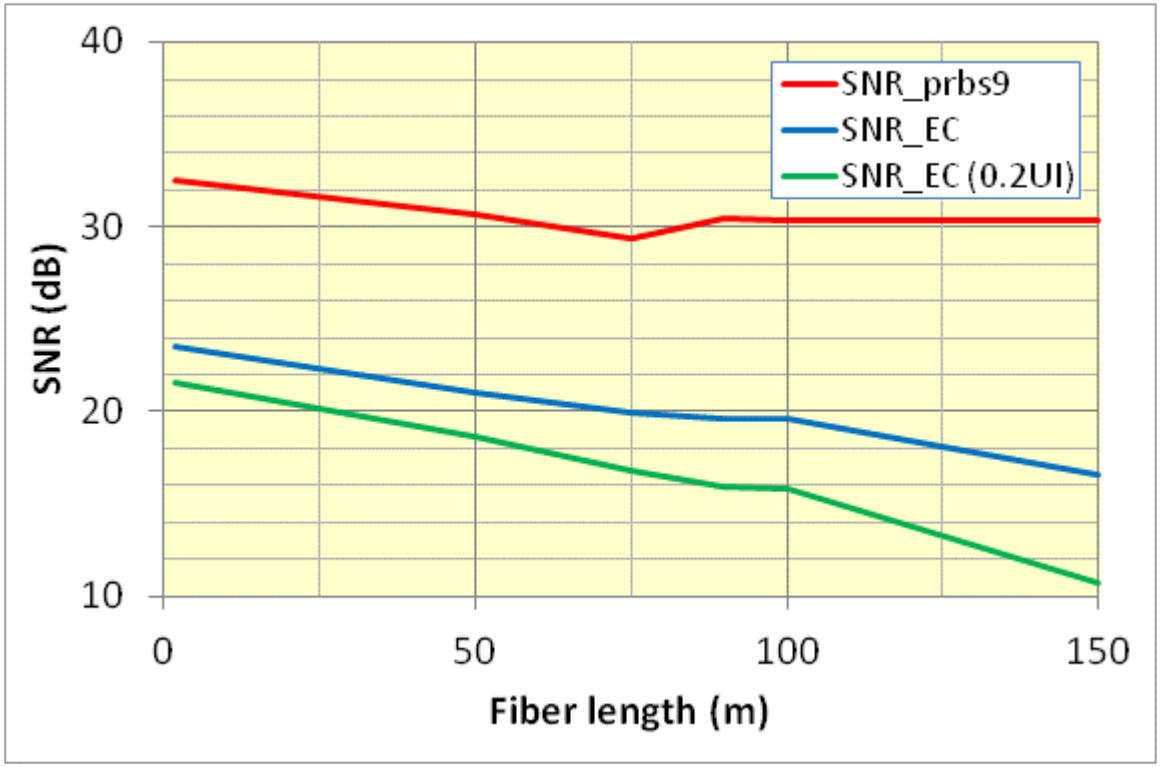
Worst Case OM3 Jitter

- Fiber is OM3 with varying lengths
- TJ & DDJ specified at 1e-12 BER



Unequalized Link SNR for Worst Case OM3

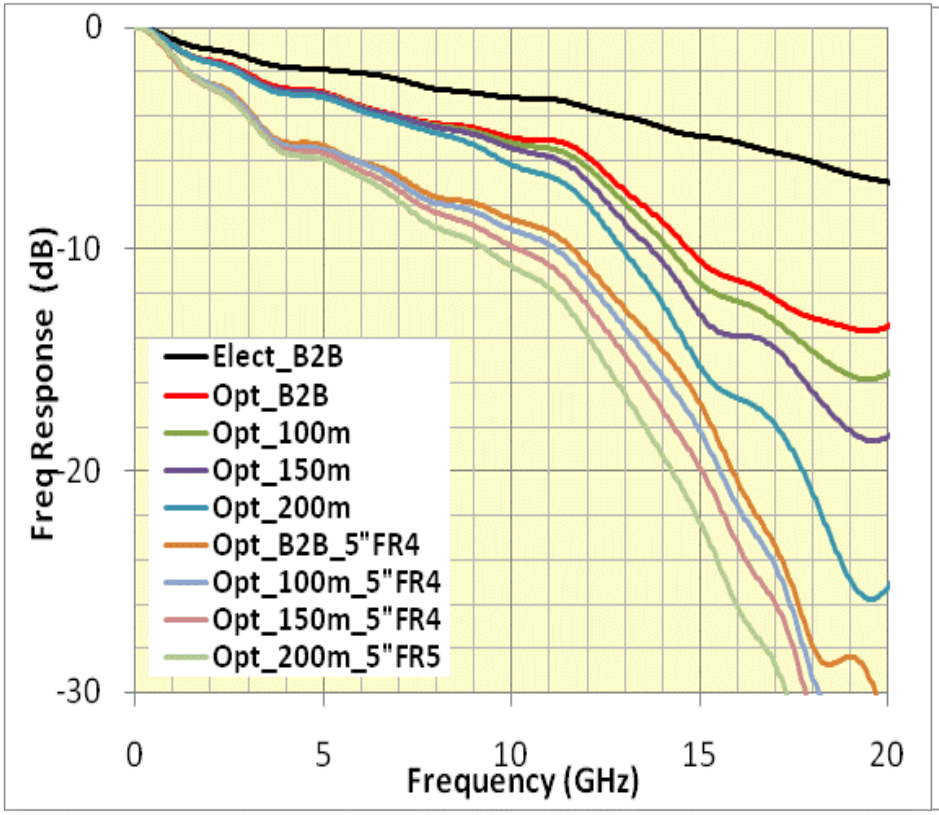
- SNR_prbs9 is measured at long ones and zeros at beginning of pattern
- SNR_EC is defined by minimum eye opening at center of eye
- SNR_EC (0.2UI) is defined by minimum eye opening within +/- 0.1UI from center of eye



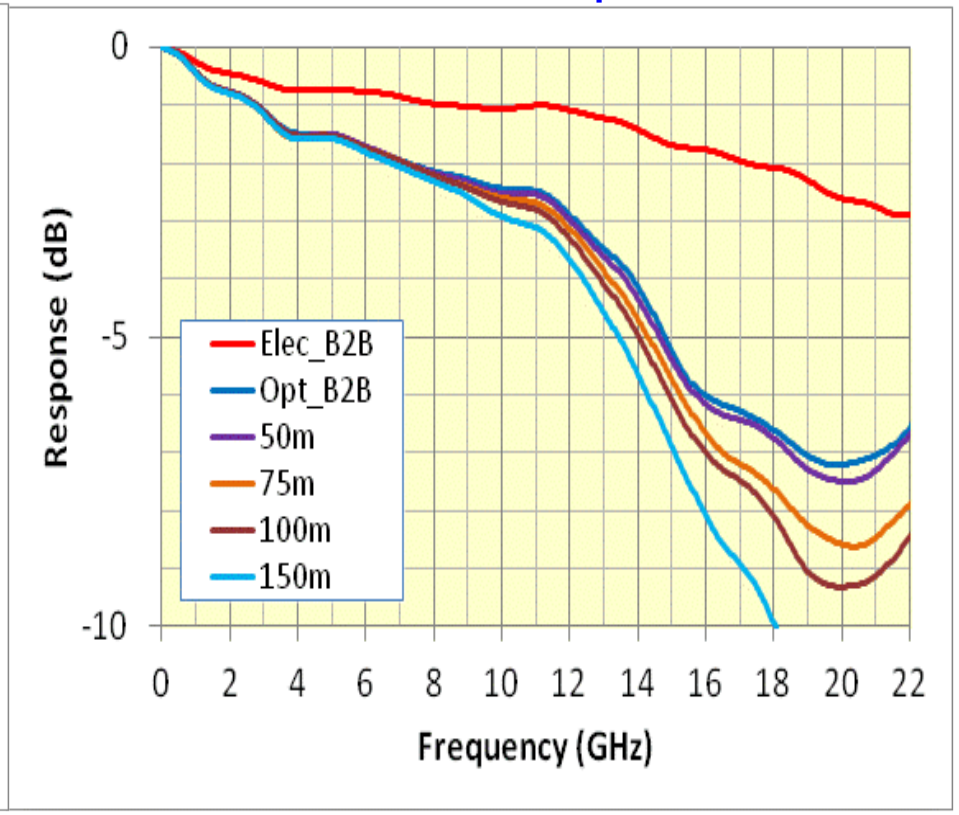
OM3 Fibers Frequency Response

- For nominal OM3 fiber and worst case

Fiber DMD=0.205 ps/m

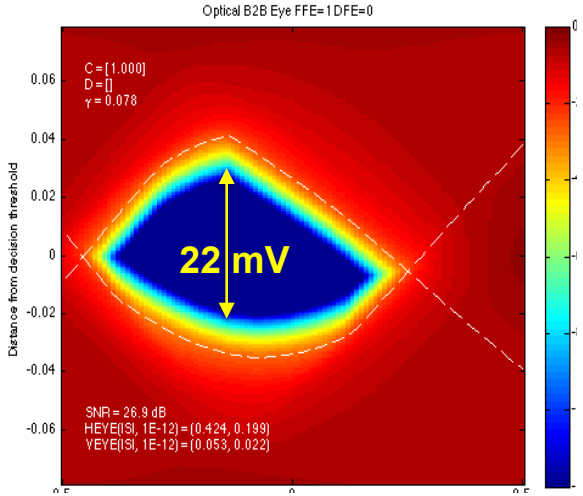


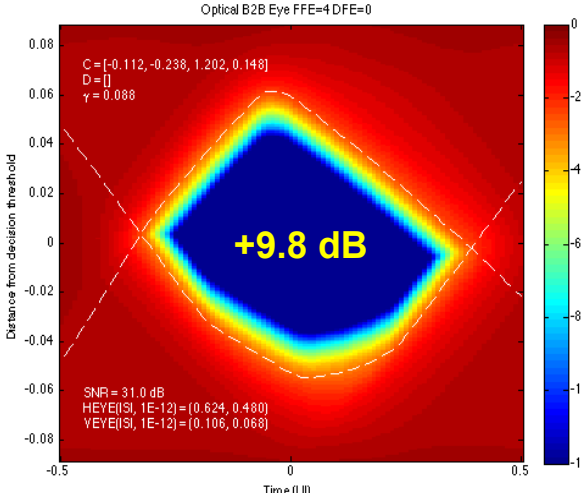
Fiber DMD=0.32 ps/m

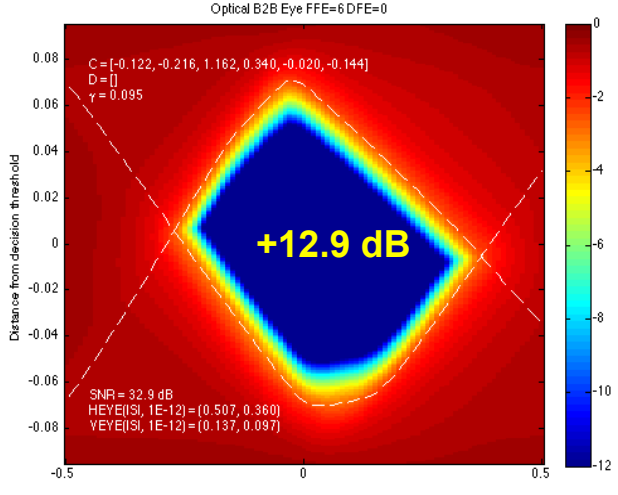


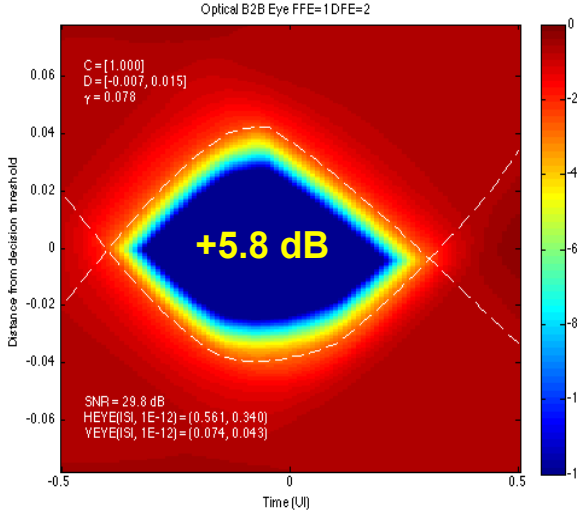
25.78 GBd Eye diagrams for nominal OM3 fiber

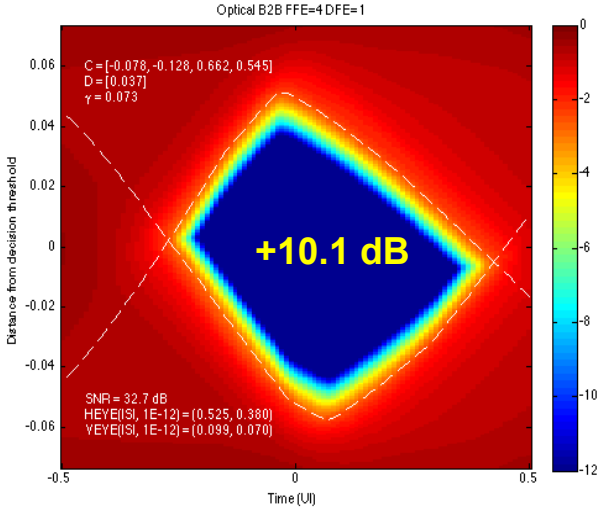
- Equalized eye after 6 m of OM3 fiber
  - Relative equalized eye opening gain for various equalizer shown

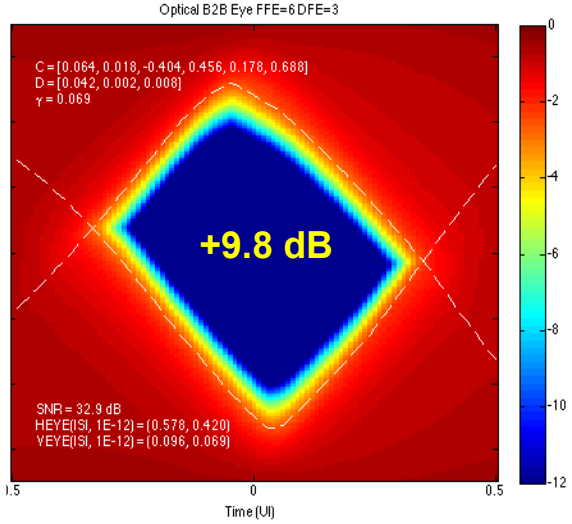






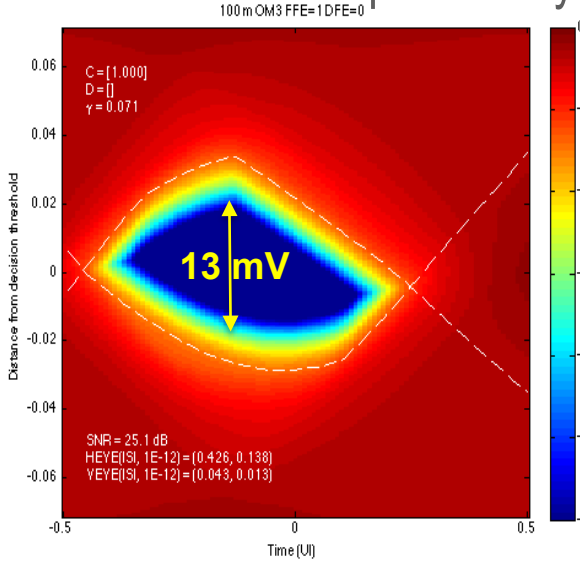


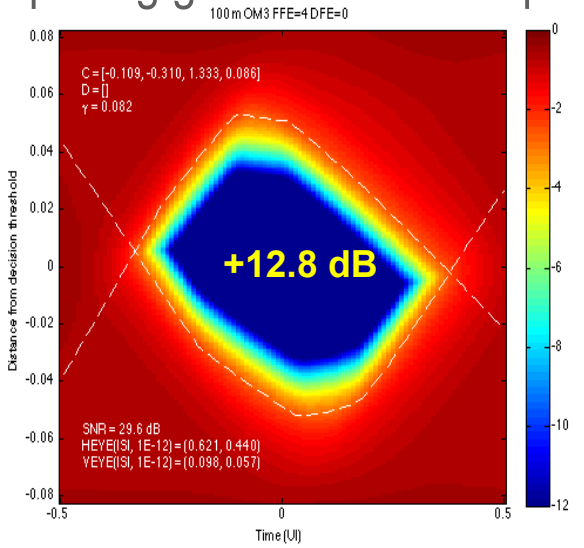


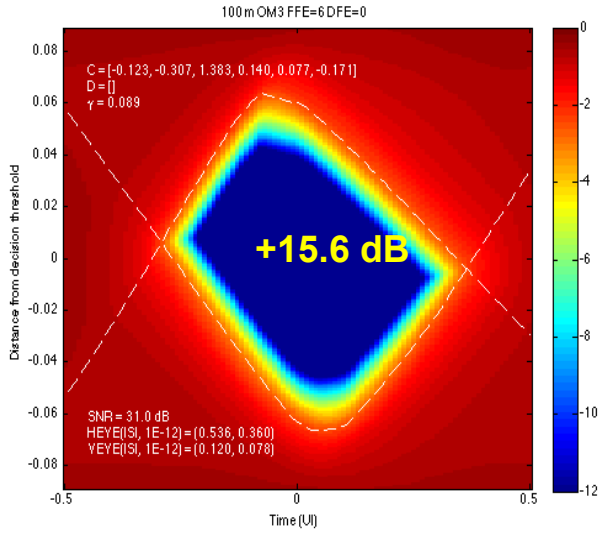


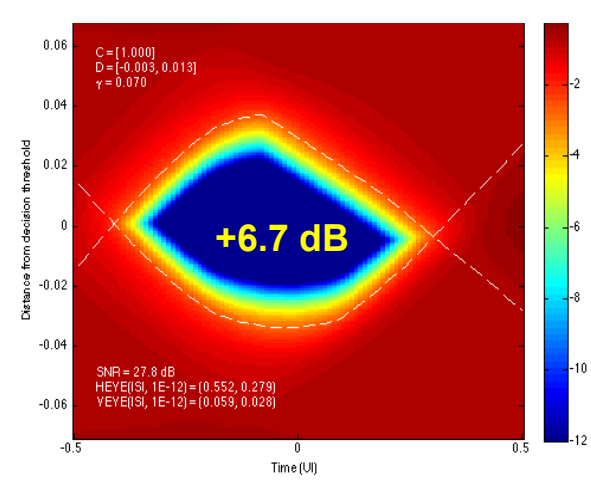
25.78 GBd Eye diagrams for nominal OM3 fiber

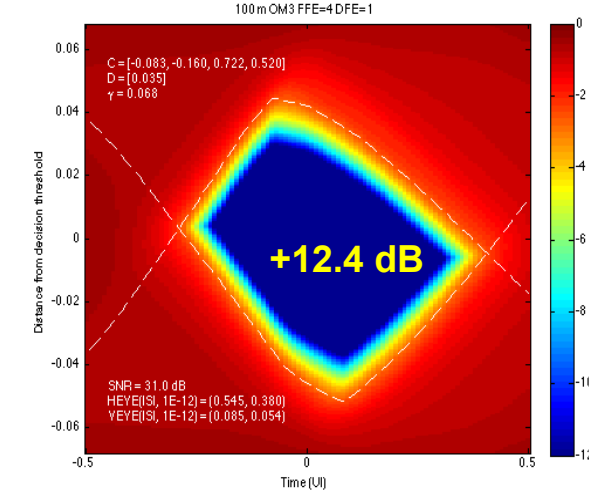
- 100 m of nominal OM3 + 6 m of nominal OM3 fiber
  - Relative equalized eye opening gain for various equalizer shown

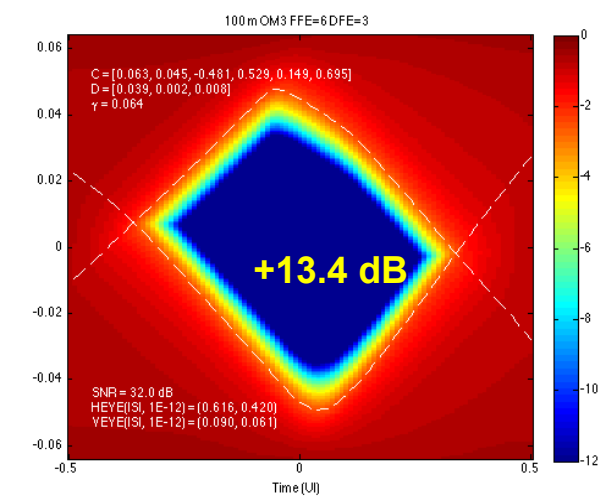






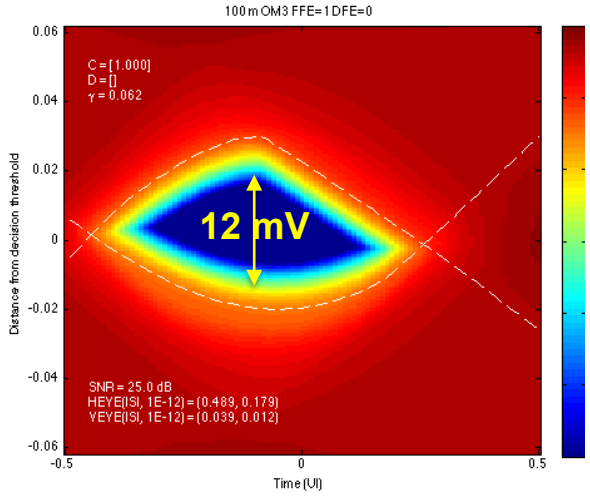


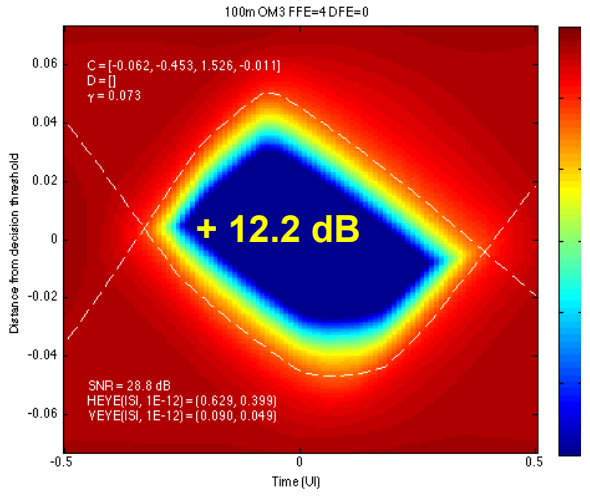


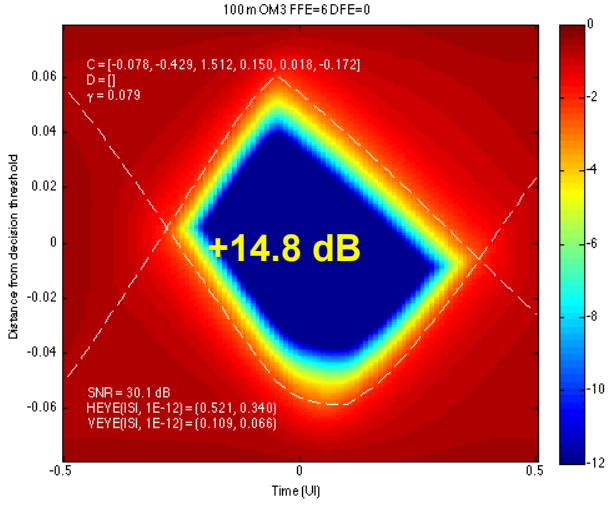


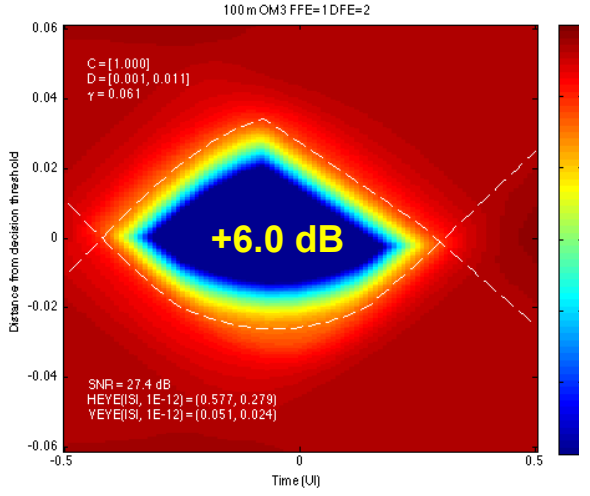
25.78 GBd Eye Diagrams for Worst Case OM3 Fiber

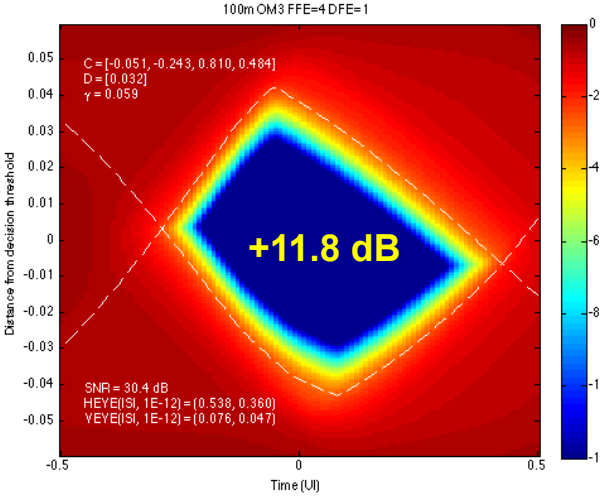
- 100 m of worst case OM3 + 6 m of nominal OM3 fiber
  - Relative equalized eye opening gain for various equalizer shown

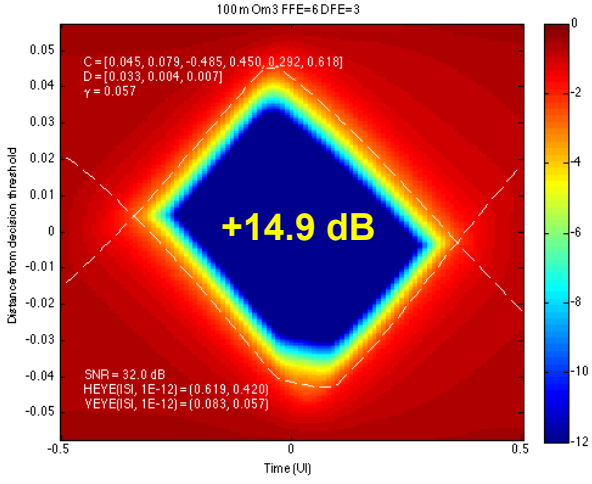






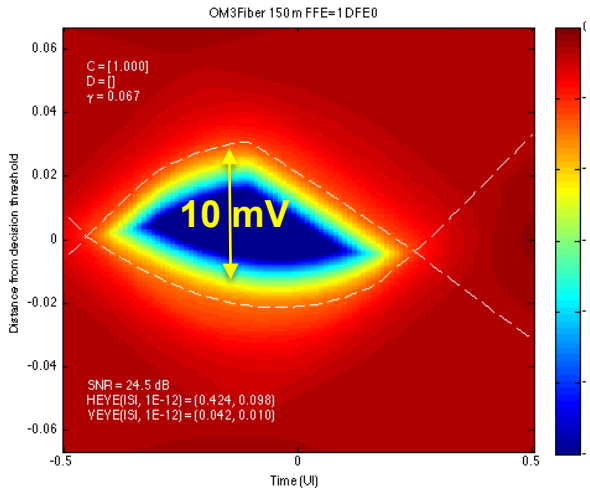


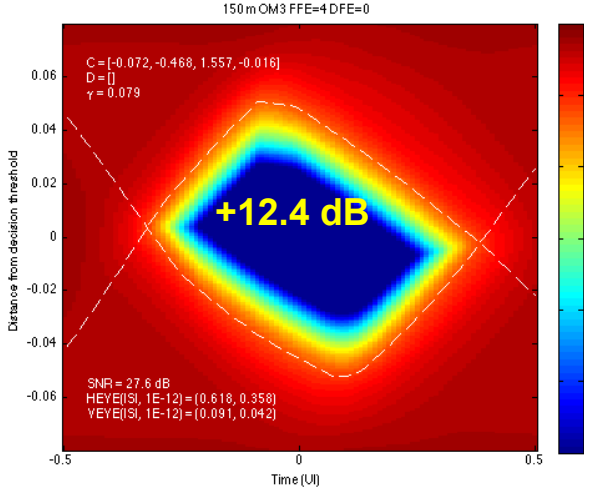


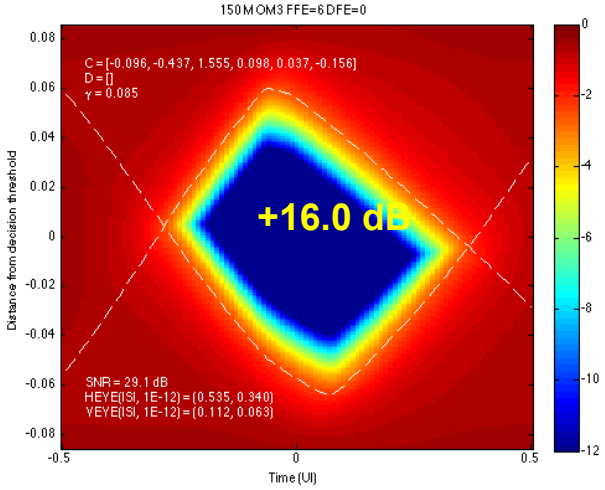


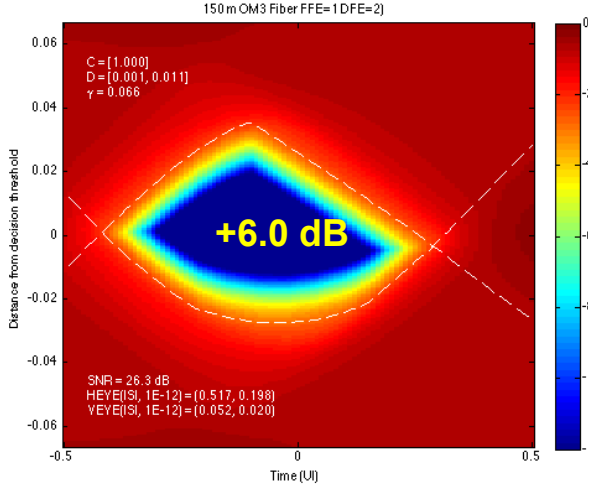
25.78 GBd Eye diagrams for nominal OM3 fiber

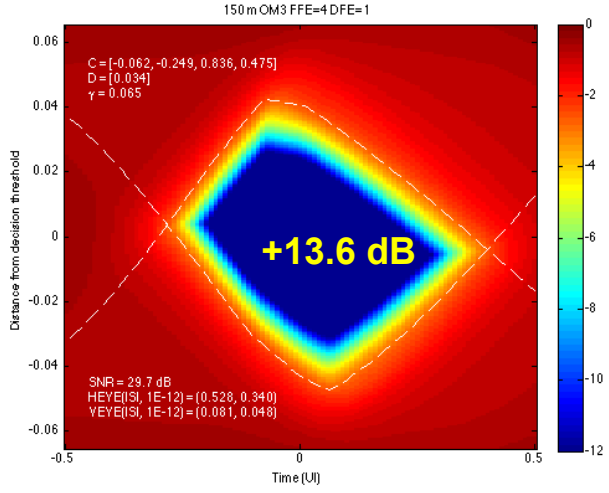
- 150 m of nominal OM3 + 6 m of nominal OM3 fiber
  - Relative equalized eye opening gain for various equalizer shown

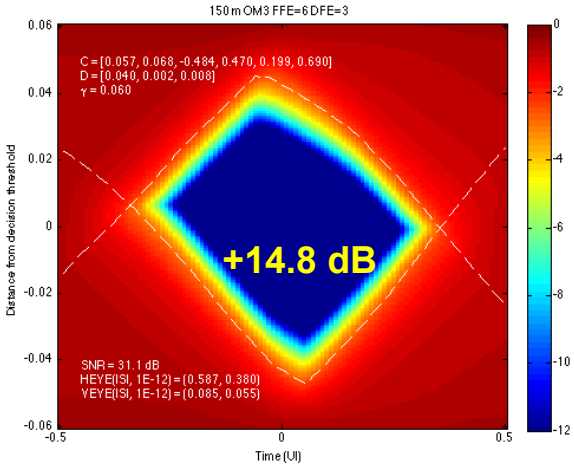






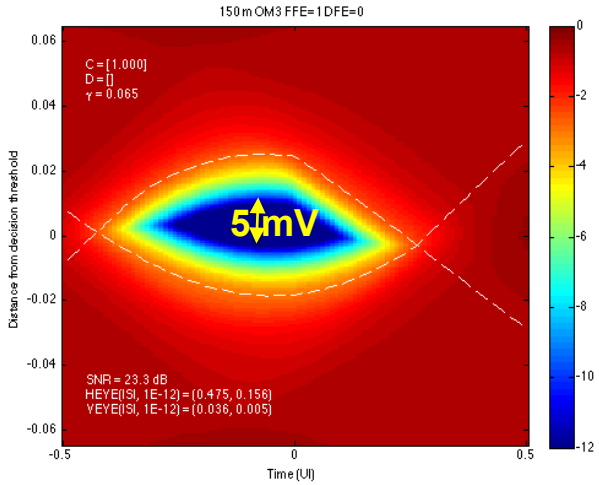


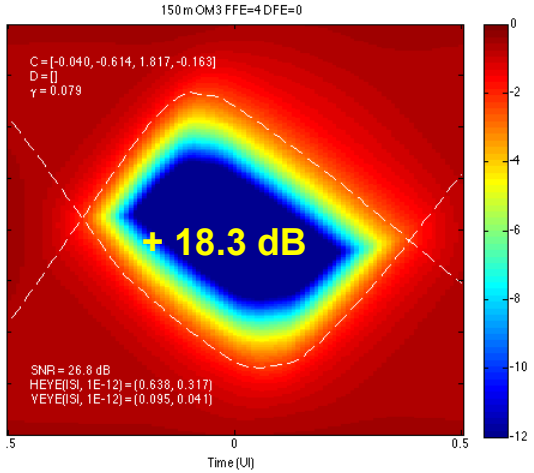


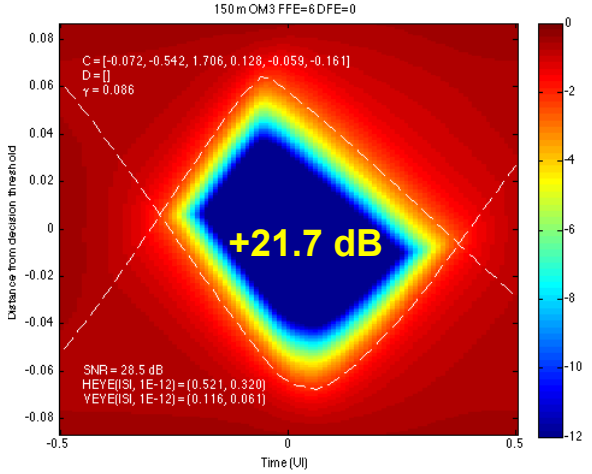


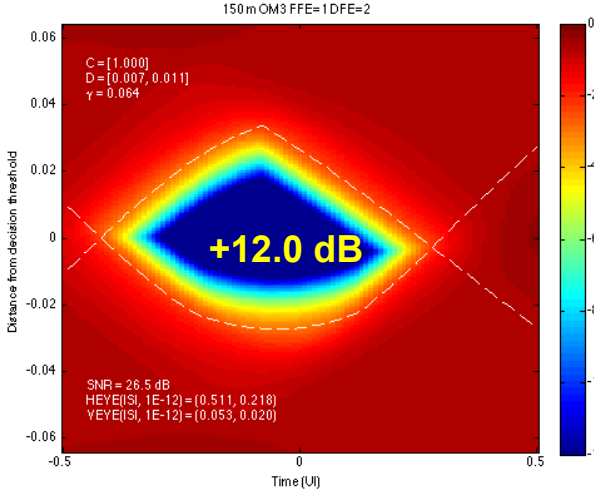
25.78 GBd Eye Diagrams for Worst Case OM3 Fiber

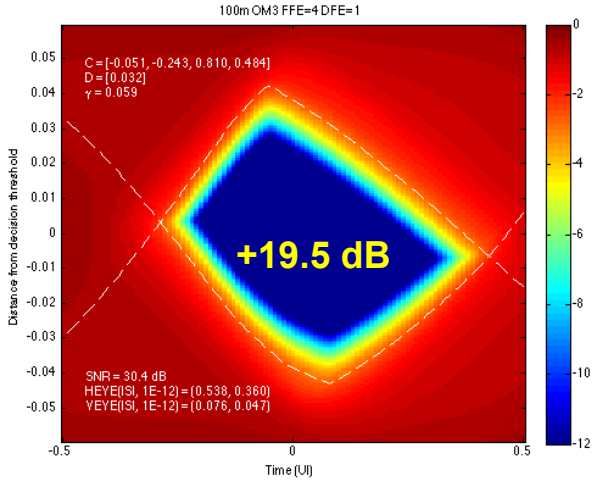
- 150 m of worst case OM3 + 6 m of nominal OM3 fiber
  - Relative equalized eye opening gain for various equalizer shown

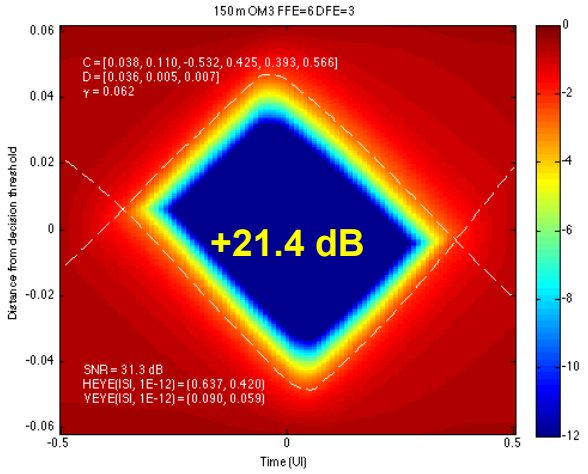












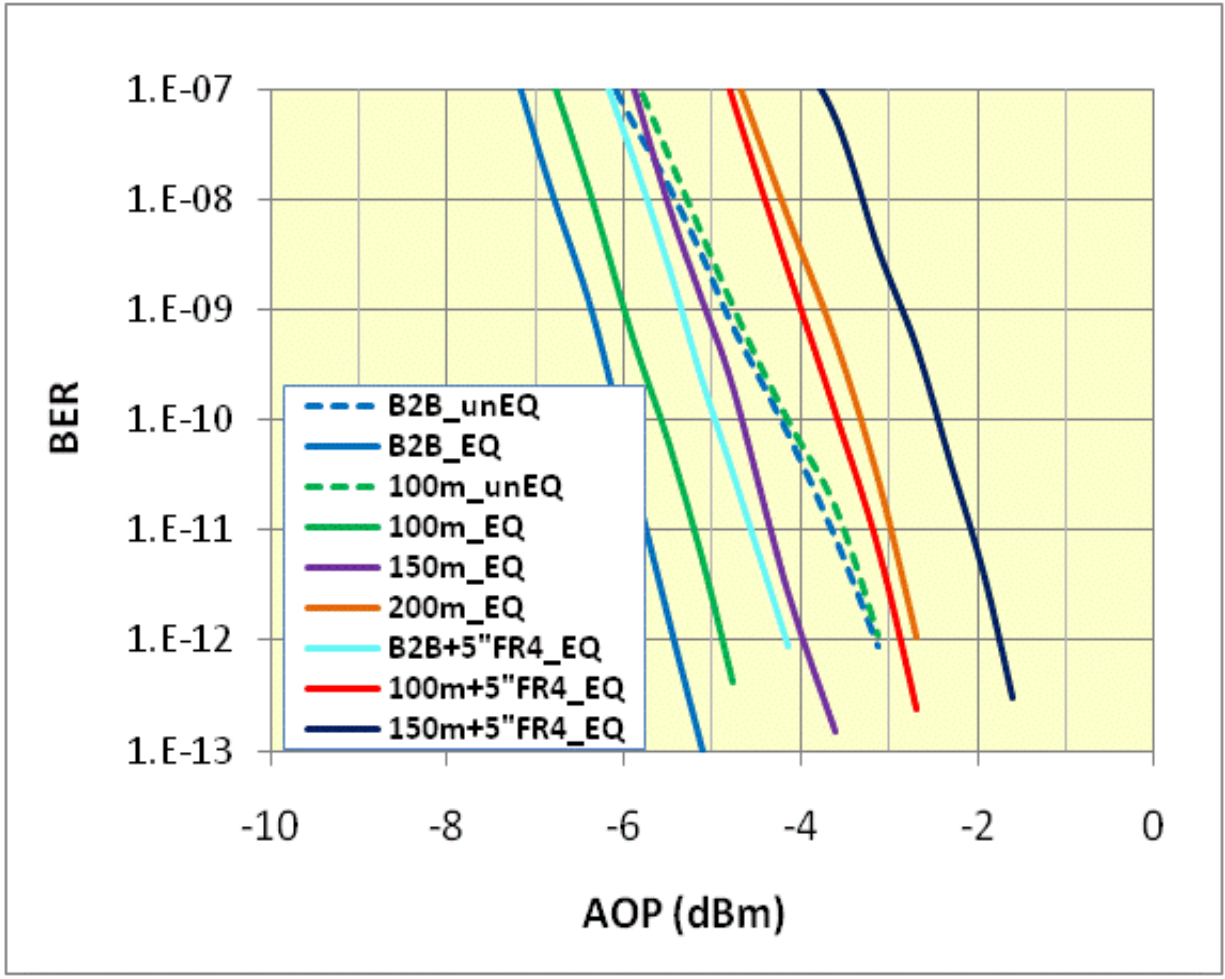
Summary of Vertical Eye Openings @ 1E-12

- Unequalized eye opening at 106 m drops almost by half from 6 m
- Unequalized eye for worst case OM3 at 150 m is half the nominal fiber eye opening but equalized eye not that different
- Moderate size equalizer improve the eye opening in every case!

Fiber Type	No-EQ (mV)	FFE4 DFE0 (mV)	FFE6 DFE0 (mV)	FFE1 DFE2 (mV)	FFE4 DFE1 (mV)	FFE6 DFE3 (mV)
6 m OM3 Nominal	22	68	97	43	70	69
100 m OM3 Nominal + 6 m Patchcord	13	57	78	28	54	61
100 m OM3 Worst Case + 6 m Patchcord	12	49	66	24	47	57
150 m OM3 Nominal + 6 m Patchcord	10	42	63	20	48	55
150 m OM3 Worst Case + 6 m Patchcord	5	41	61	20	47	59

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

- Measured results with worst case OM3 fiber having DMD of 0.32 ps/m does show more degradation
  - The penalty from a nominal 150 m OM3 fiber is comparable to the worst case OM3 with length of 100 m
  - With a modest equalizer there is very little difference between worst case fiber and nominal fiber
- VCSEL and PIN/TIA are the dominant sources of penalty but a modest equalizer can reduce these inherent penalty which exist even for B2B
- 25.78 GBd test chip which has both CTLE and 1-DFE was used as receiver
  - 1 tap DFE receiver has gains of 2.5 dBo and the nominal 150 m OM3 link runs error free for 4 days with <1E-15 @ 99.98 confidence level!
- Spreadsheet model predicts at 100 m of OM3 we should see an error floor
  - Up to 150 m of worst case OM3 fiber the eye opening and SNR drops only gradually and no error floor yet has been observed!

Thank You