

Investigation of 100 GbE Serial PMDs Based on Advance Modulation

IEEE 100GNGOPTX Study Group

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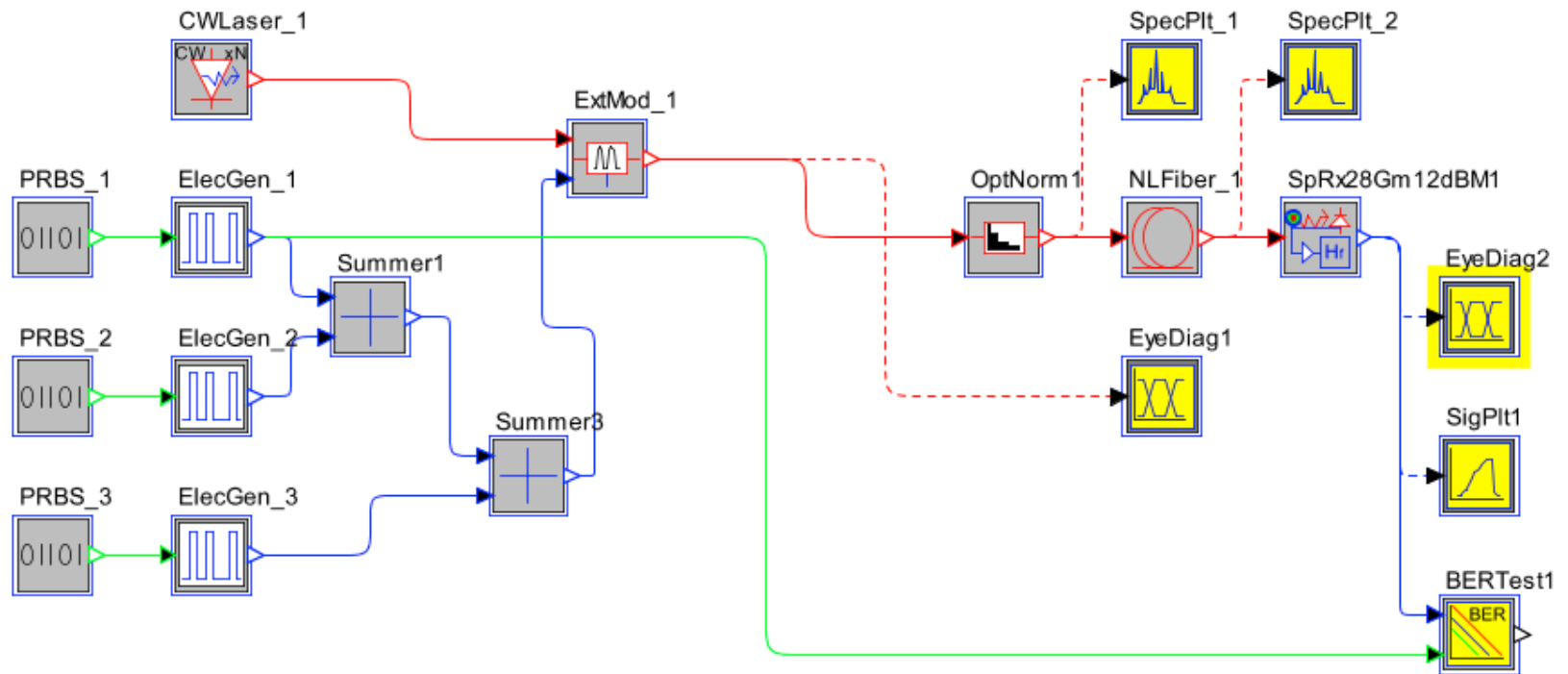
San Diego

- Simulation setup and feasibility of PAM-8 optical
 - Results presented during May interim TIA BW was actually 38 GHz instead of 28 GHz, so results for 28 GHz are added
- Simulation setup and feasibility of PAM-4 optical
 - Baseline link modPAM-2 operating at PAM-4/PAM-8 baudrate
 - PAM-2 operating 103.625 GBd
- Feasibility and performance
- Impact of rise times and jitter
- Next step

Basic Simulation Assumptions

- Modulator is MZ type
 - In case of PAM-8, 3 input signals with amplitude 1/7, 2/7, and 4/7 are linearly summed into MZ modulator
 - In case of PAM-4, 2 input signals with amplitude 1/3, 2/3 are linearly summed into MZ modulator
- Modulator Type MZ RC BW of 34 GHz zero chirp
 - Input electrical signal $V_{\pi/2}$ to limit the compression
- RIN=-150 dBm/Hz
- TX Wavelength=1280 nm
- TX DJ = 0 or 2 ps for PAM-8, 0 or 1.5 ps for PAM-4, 0 or 1 ps for PAM-2
- TX Output Power = - 3 dBm
- Optical transmitter 20-80% rise/fall 8 or 12 ps
- Data pattern=PN12
- Extinction Ratio= 7.5 dB
- Receiver BW=28 or 38 GHz PD+TZ/PostAMP with 1 k Ω
- Receiver sensitivity at -16 dBm at 1e-5

- Rsoft Schematic

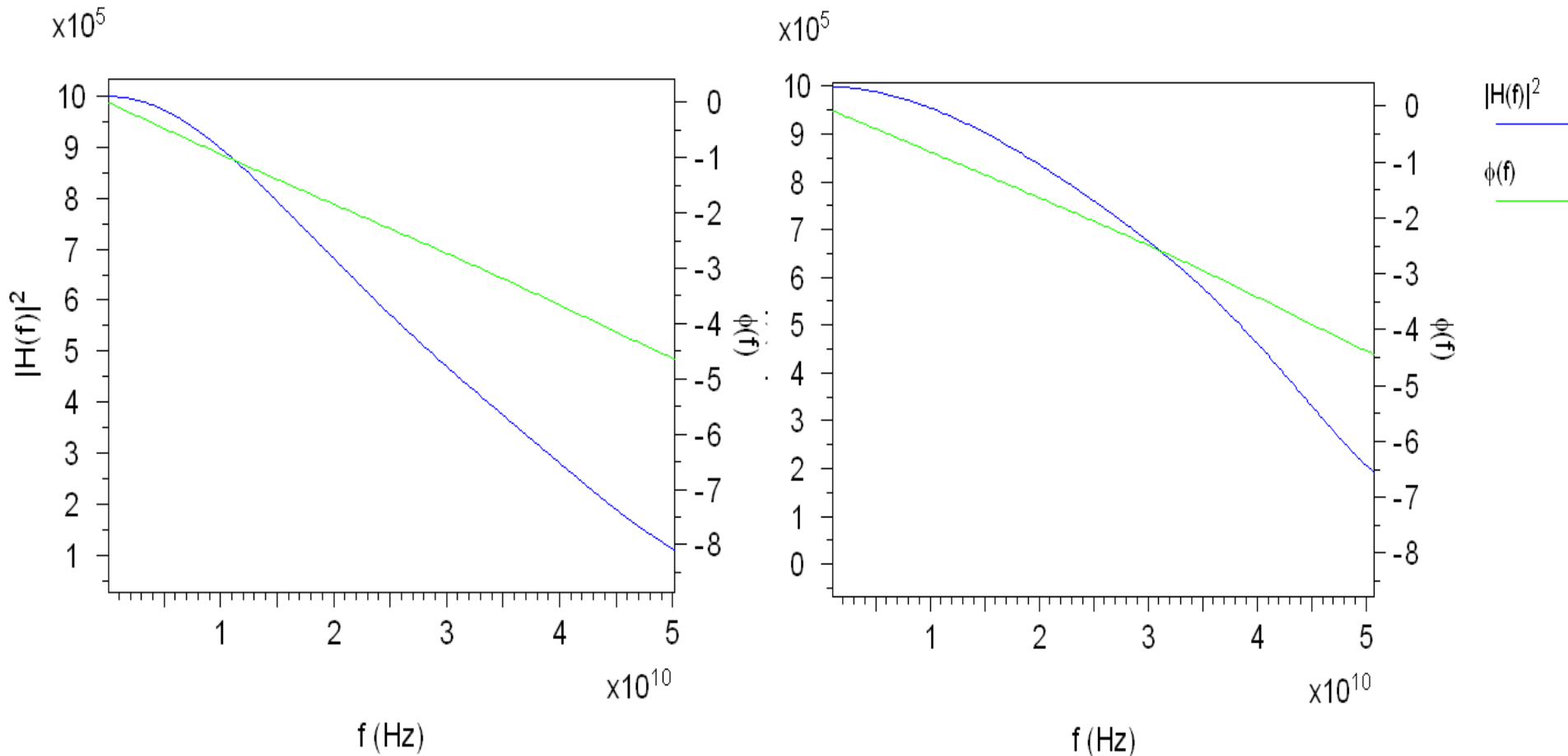


Optical Receiver Response

- Response of a realistic PD+TZ AMP with 28GHz BW as well as response of 34 GHz BT4 front end

28 GHz Receiver

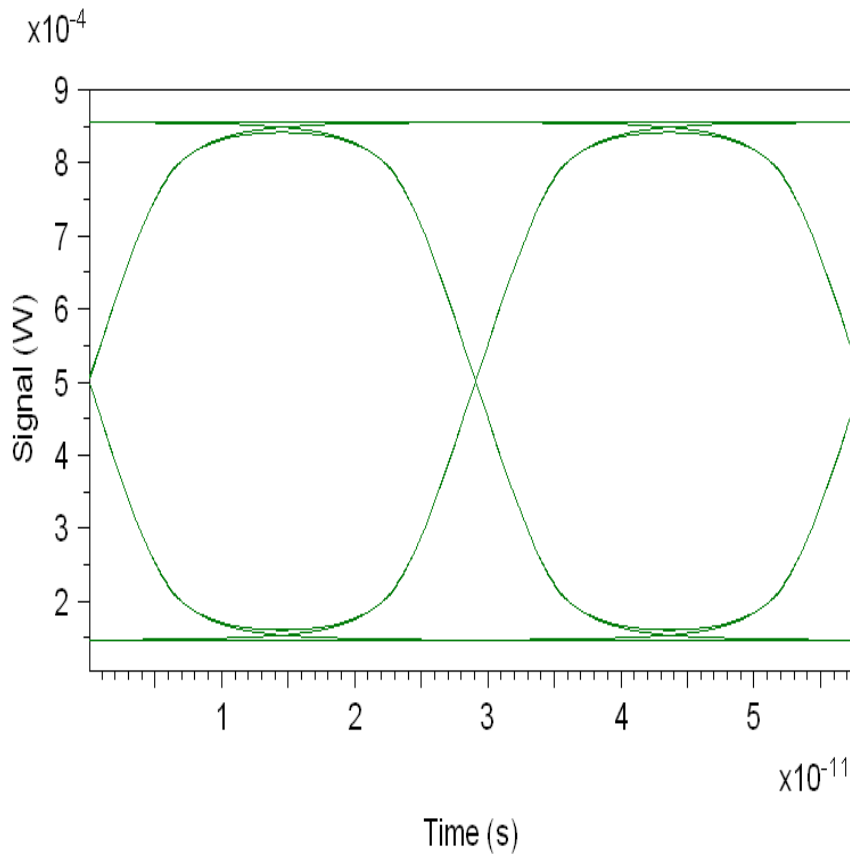
38 GHz Receiver



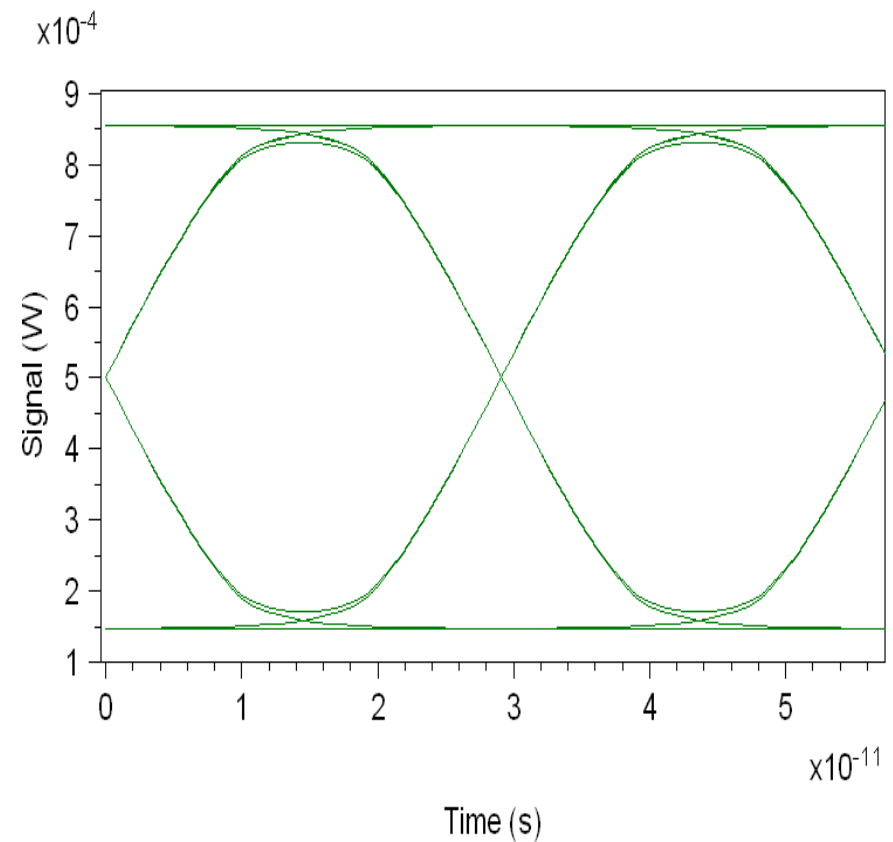
Transmitter PAM-2 Response

- Fast transmitter with 8 ps and slow transmitter with 12 ps 20-80% rise time

MZ Modulator Output for PAM2 PJ=0



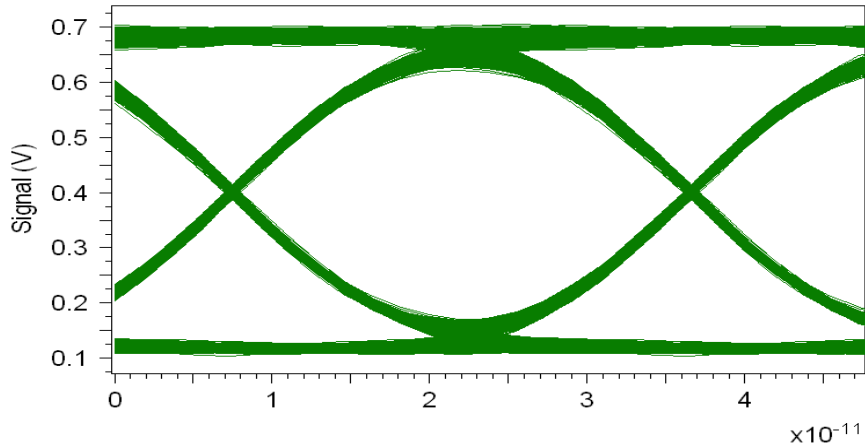
MZ Modulator Output for PAM2



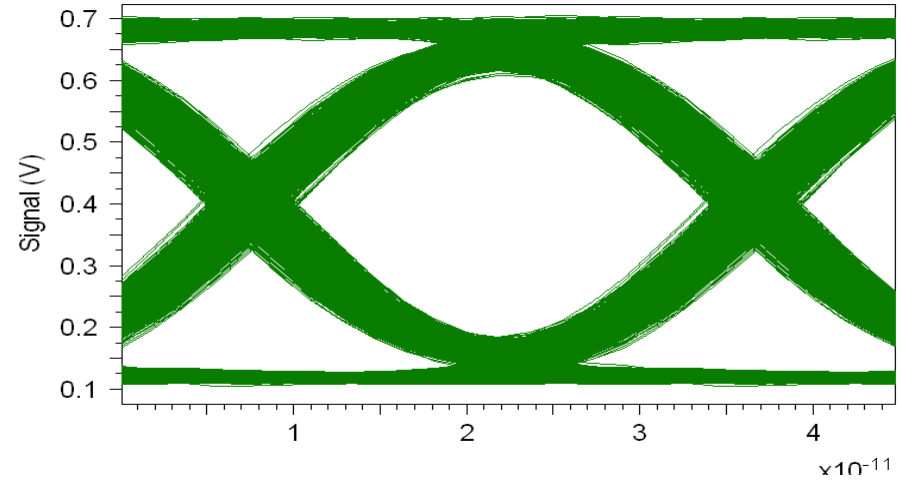
Receive Signal at 34.37GBd PAM-2 Eyes

- Receive eyes after 2 km for 28GHz PD+TZ AMP for 8 ps and 12 ps 20-80% transmitter trise with and without 2 ns of P.I

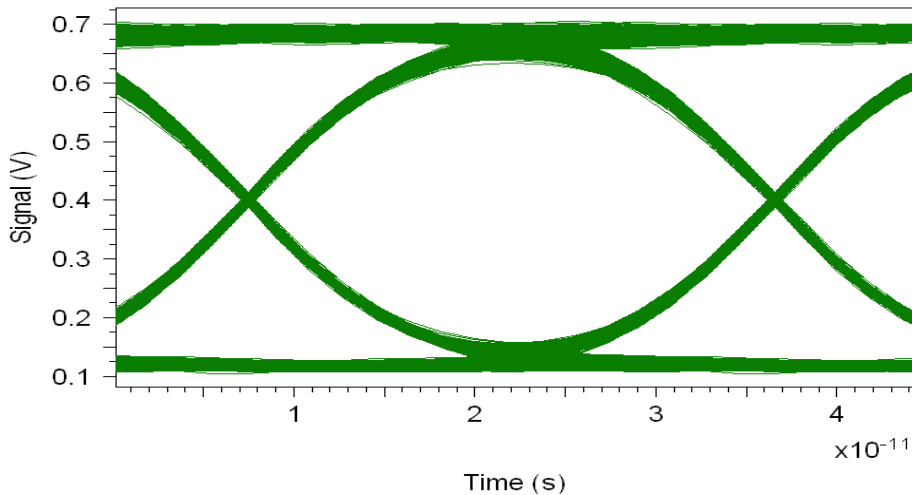
28 GHz RX TIA TR=12 ps PJ=0



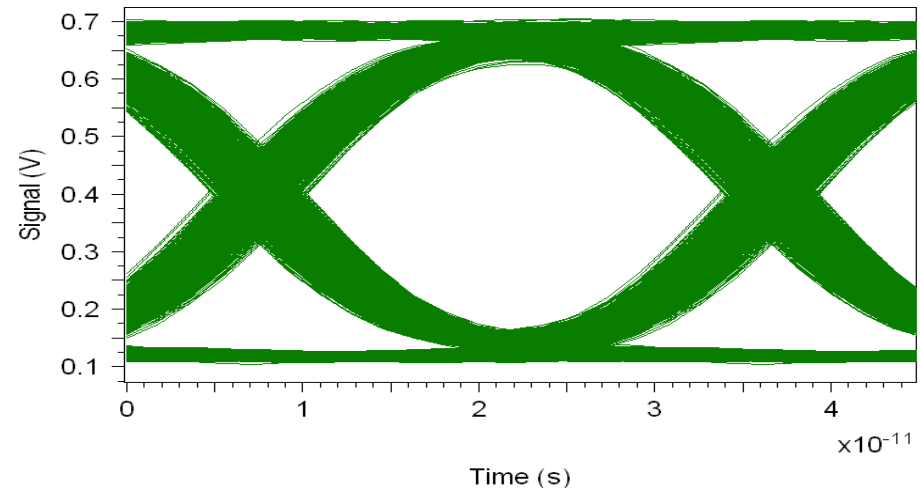
28 GHz TIA TR=12 ps PJ=2 ps



28 GHz TIA TR=8 ps PJ=0

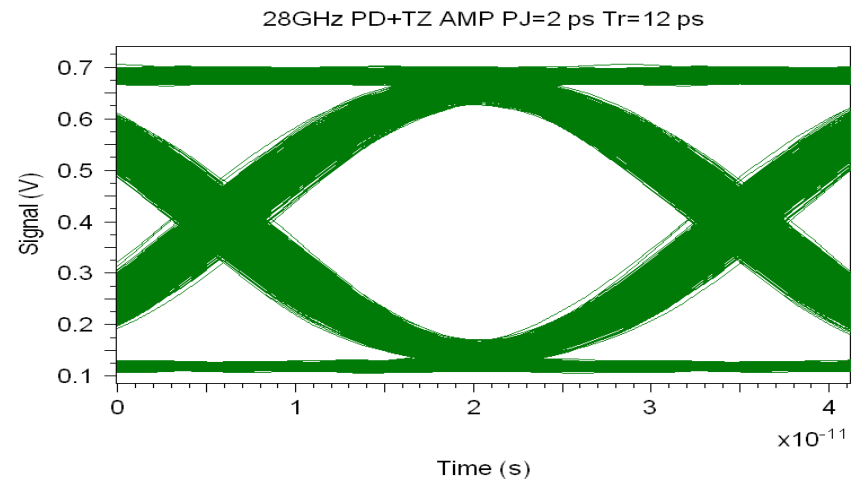
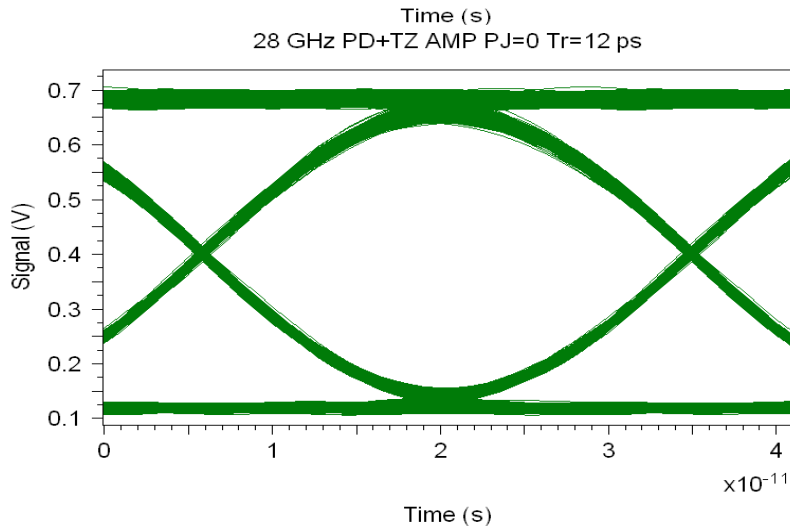
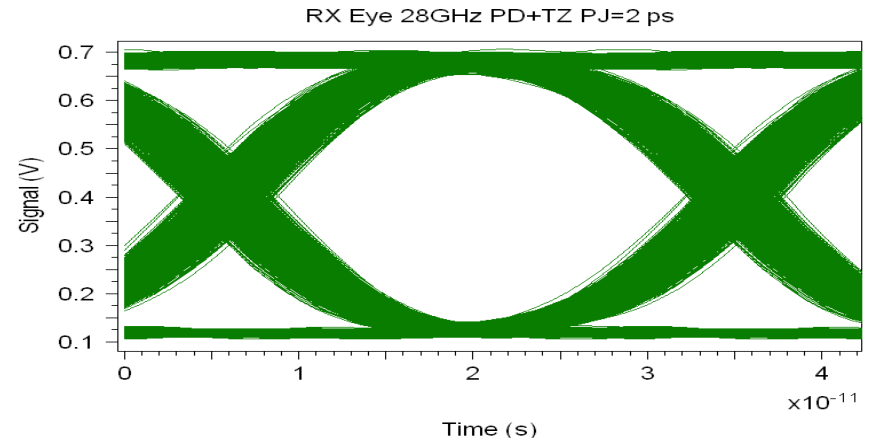
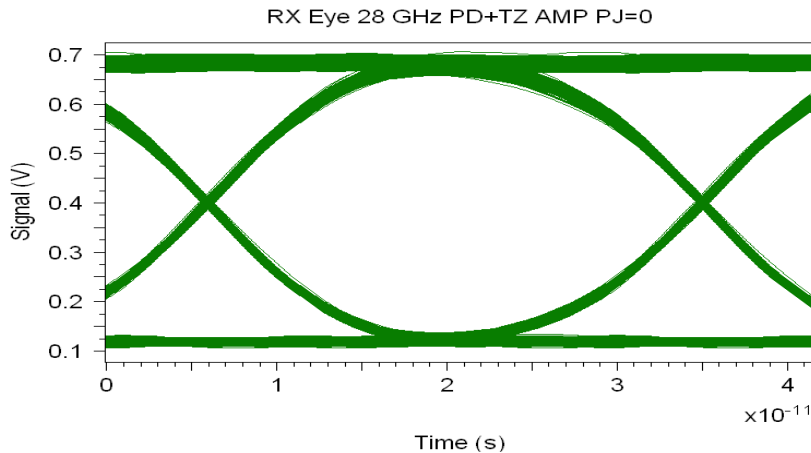


28 GHz TIA TR=8 ps PJ=2 ps



Receive Signal at 34.37GBd PAM-2 Eyes

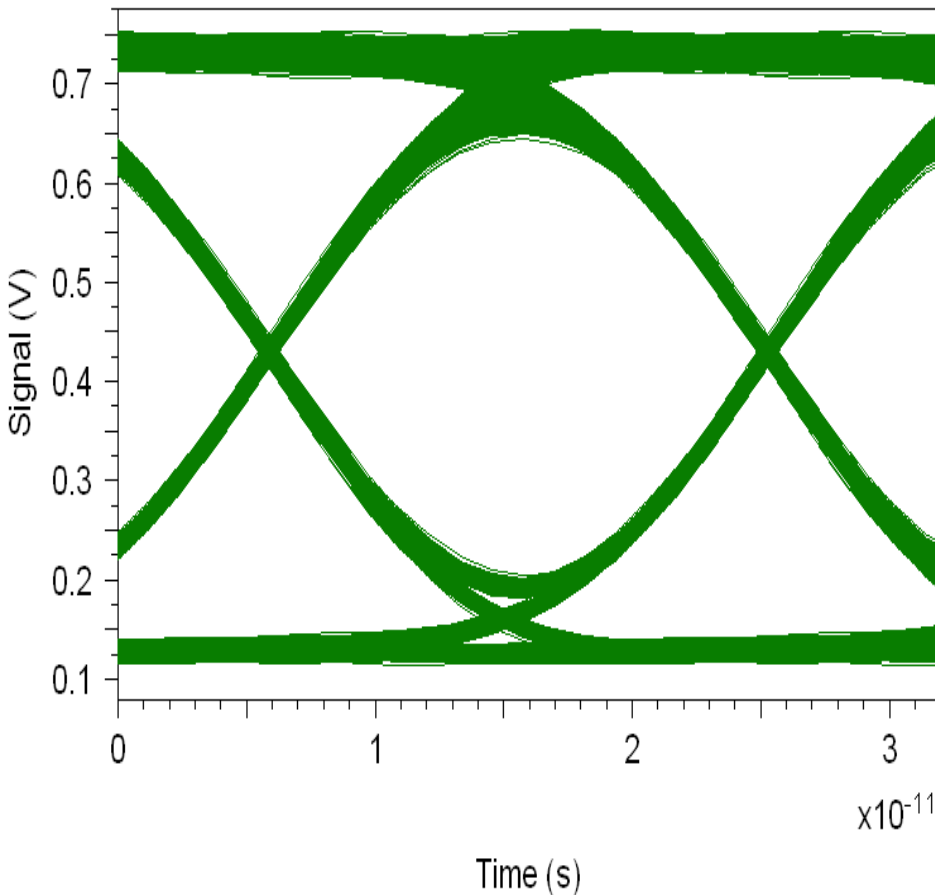
- Receive eyes after 2 km for 38GHz PD+TZ AMP for 8 ps and 12 ps 20-80% transmitter trise, with and without 2 ps of PJ.



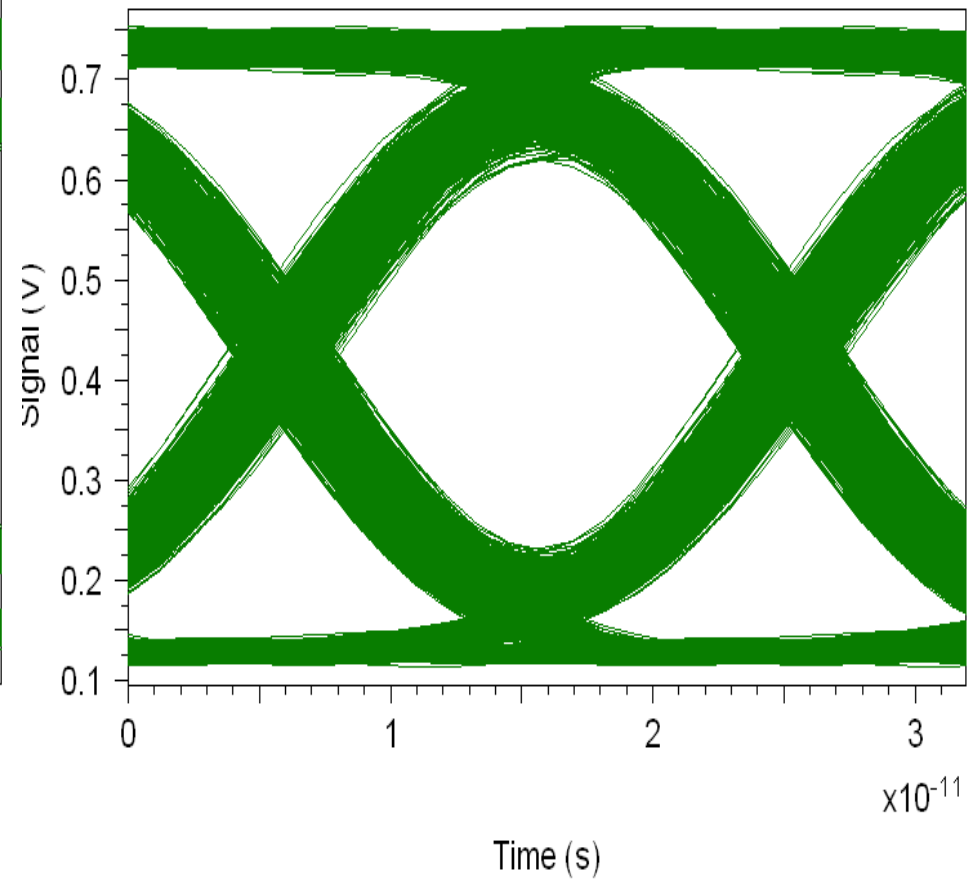
Receive Signal at 51.1625Gb/s PAM-2 Eyes

- Receive eyes after 2 km for 38GHz PD+TZ AMP for 8 ps 20-80% transmitter trise, with and without 1.5 ps of PJ.

38 GHz TIA Tr=8 ps PJ=0



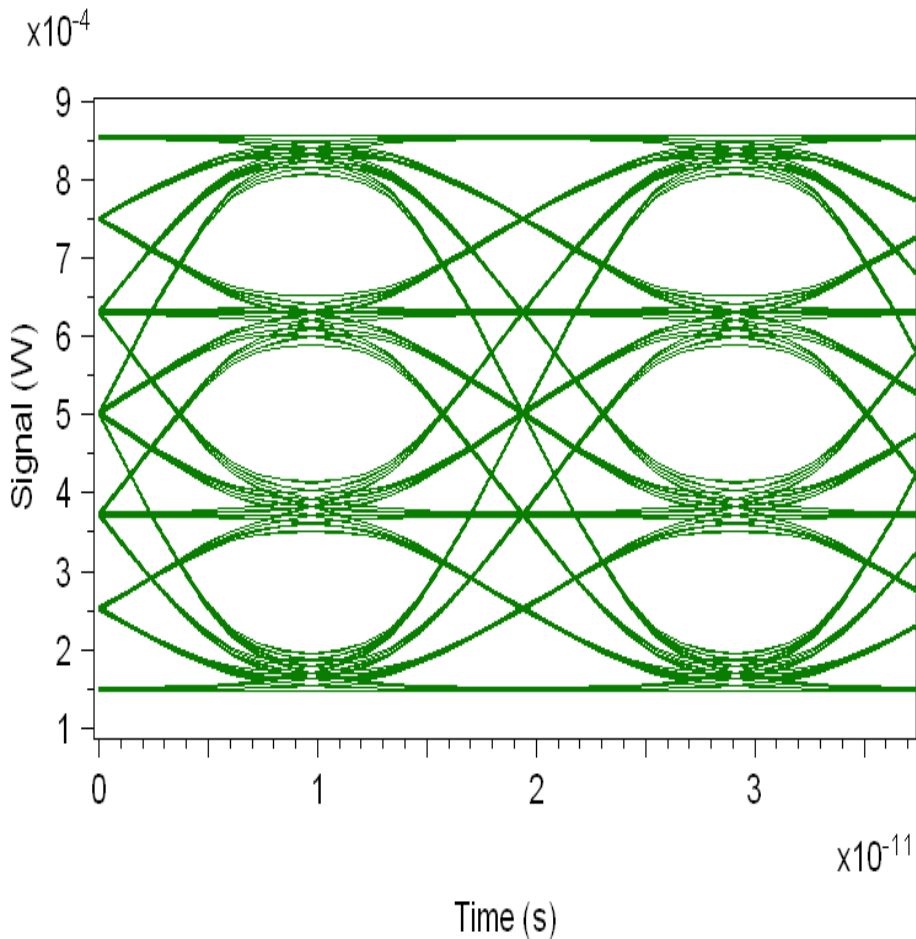
38 GHz TIA Tr=8 ps PJ=1.5 ps



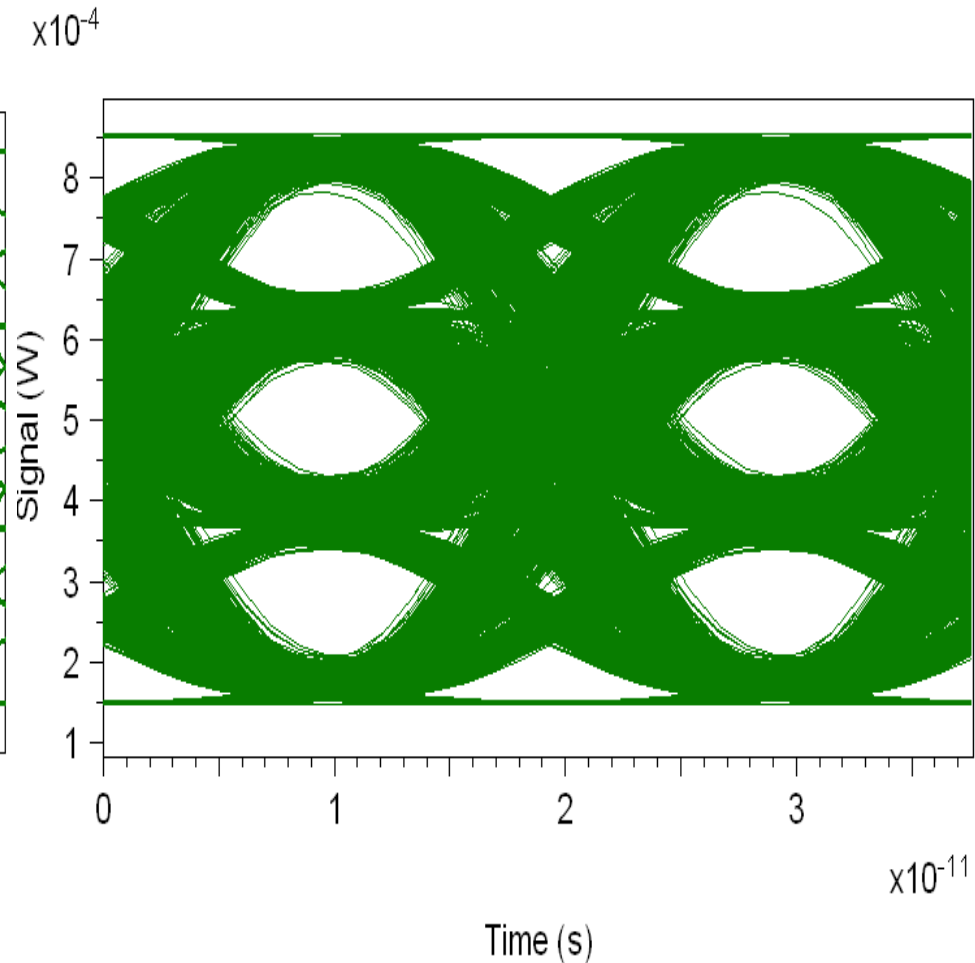
PAM-4 Transmit Optical Eyes at 51.5625 GBd

- For 8 ps 20-80% rise time optical transmitter
 - With no TX jitter and with PJ=1.5 ps

Transmitter Optical Eye PJ=0 Tr=8 ps



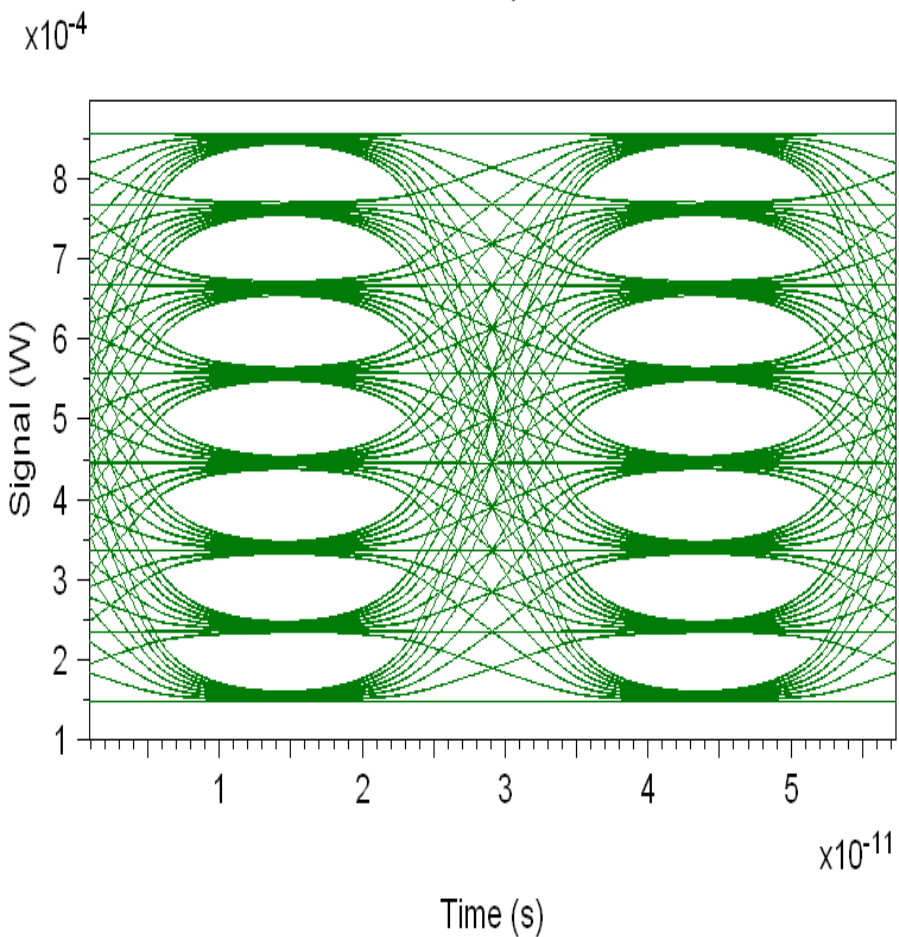
Transmit Optical Eye Tr=8 ps PJ=1.5 ps



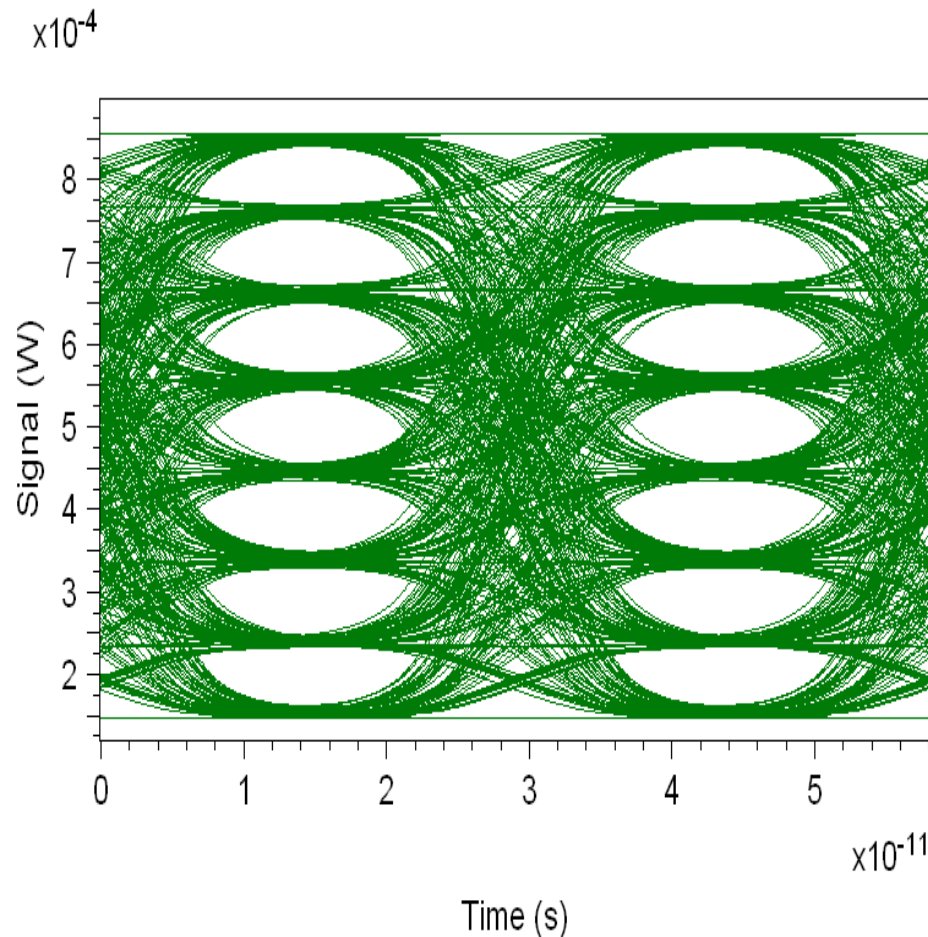
PAM-8 Transmit Optical Eyes

- For 8 ps 20-80% rise time optical transmitter
 - With no TX jitter and with PJ=2 ps

Transmit Eye PJ=0

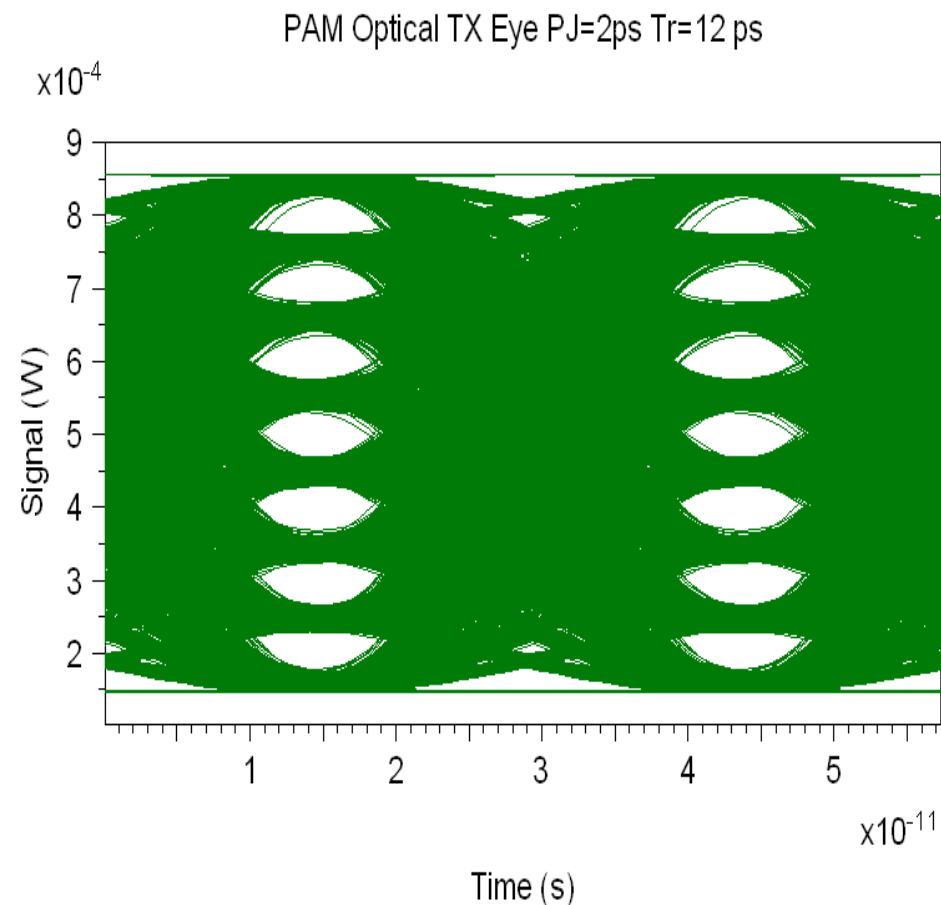
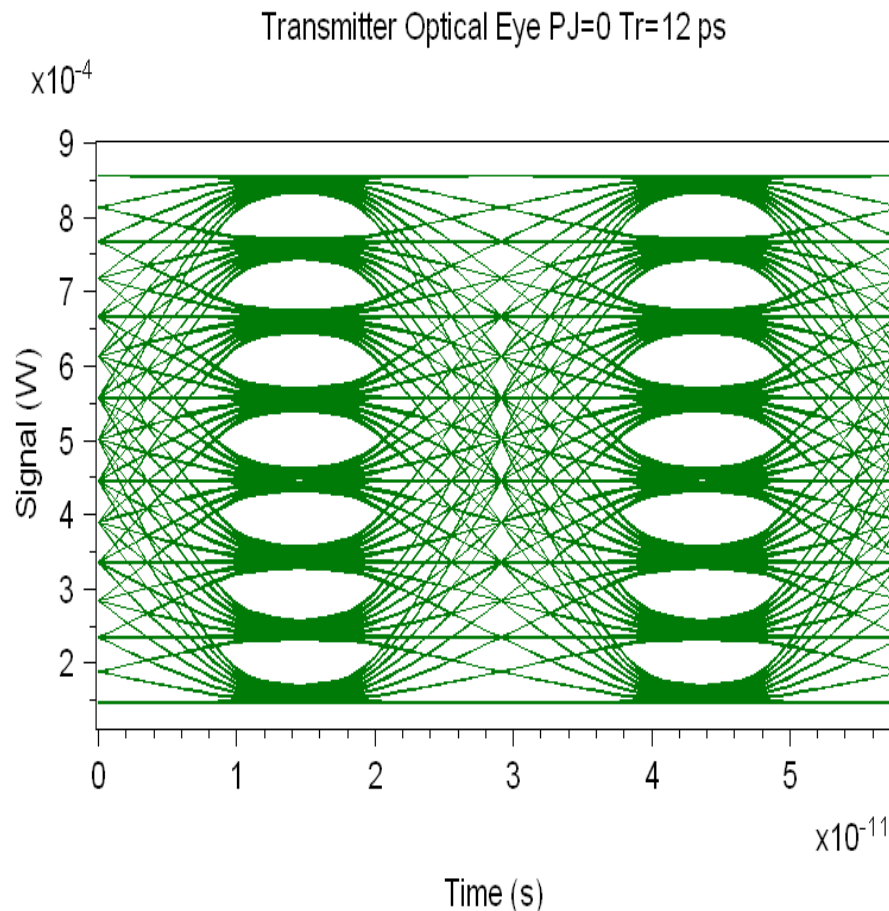


Transmit Eye with PJ=2ps



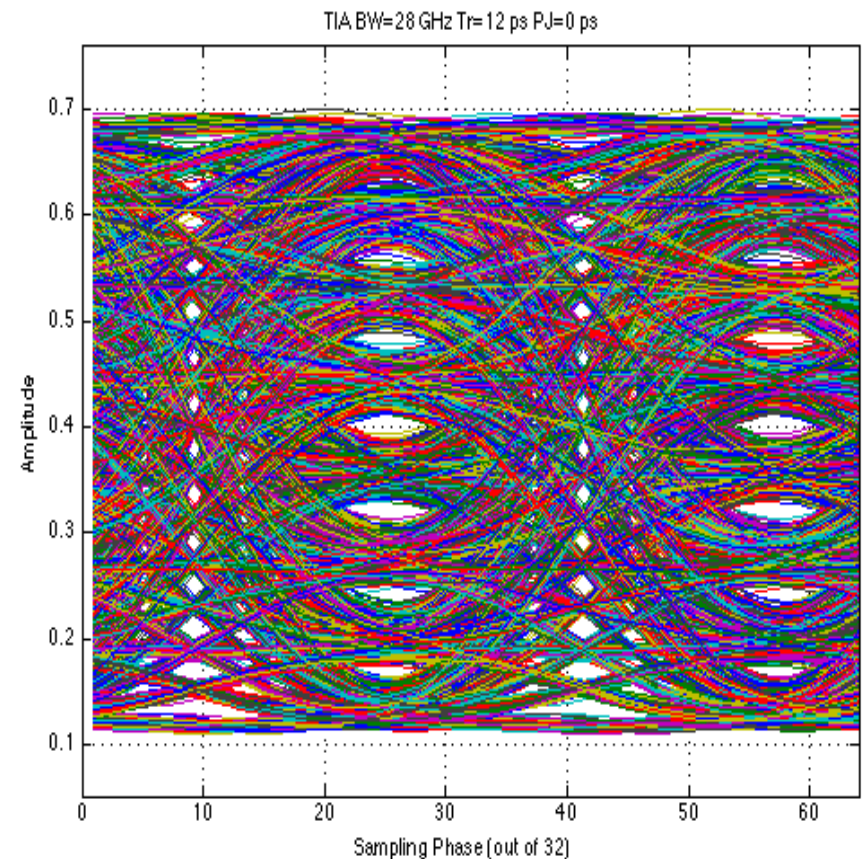
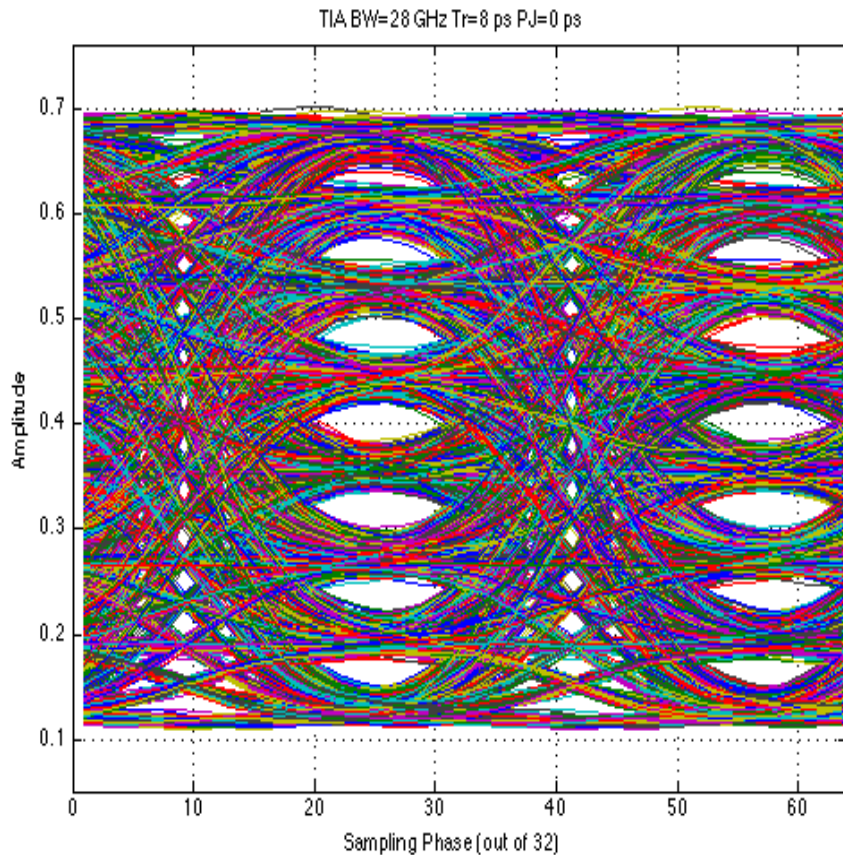
PAM-8 Transmit Optical Eye

- For 12 ps 20-80% rise time optical transmitter
 - With no TX jitter and with PJ=2 ps



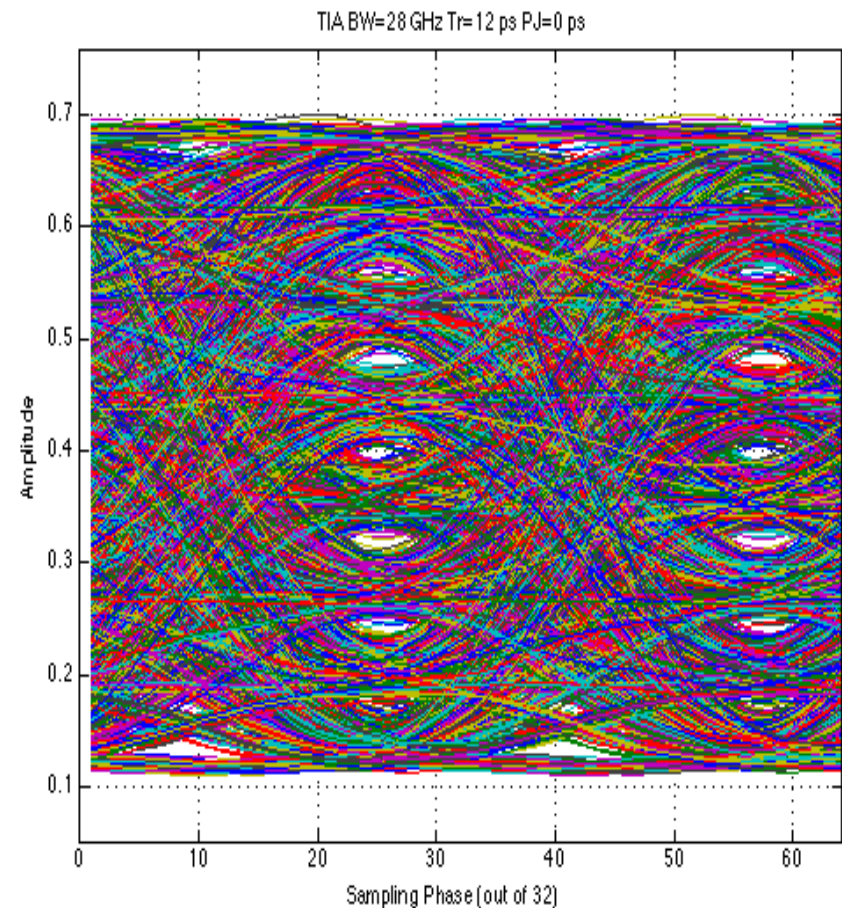
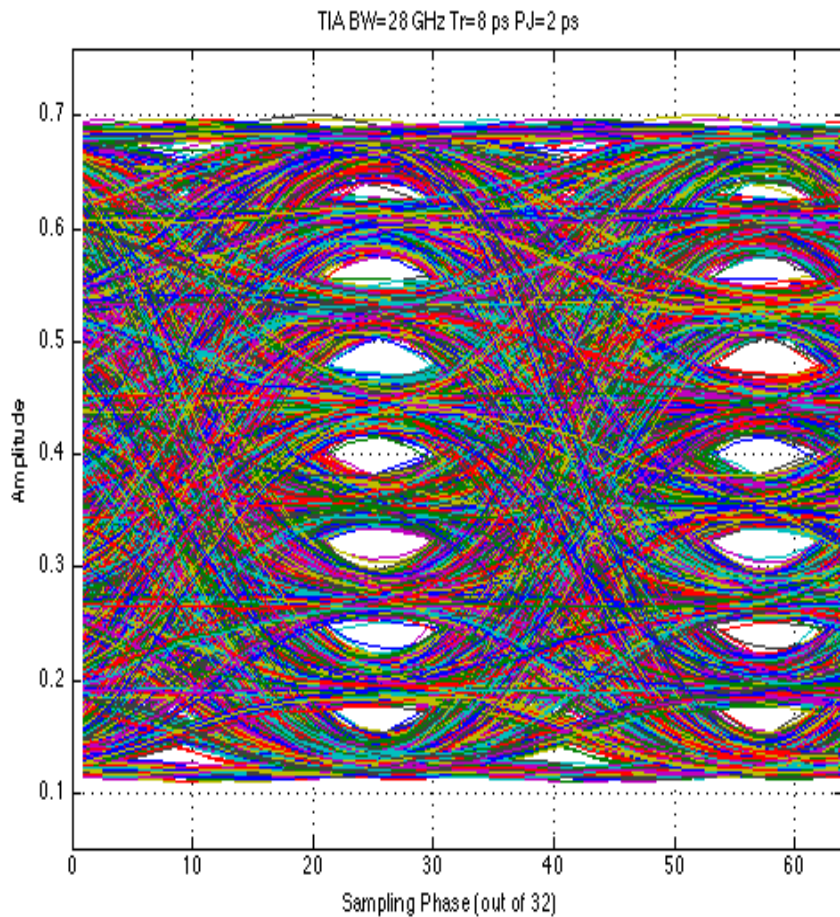
PAM-8 Receive Eye TIA BW=28 GHz

- For the 8 ps and 12 ps transmitter with PJ=0 ps
 - All simulation with 2 km of SMF28 eye is practically identical to 2m



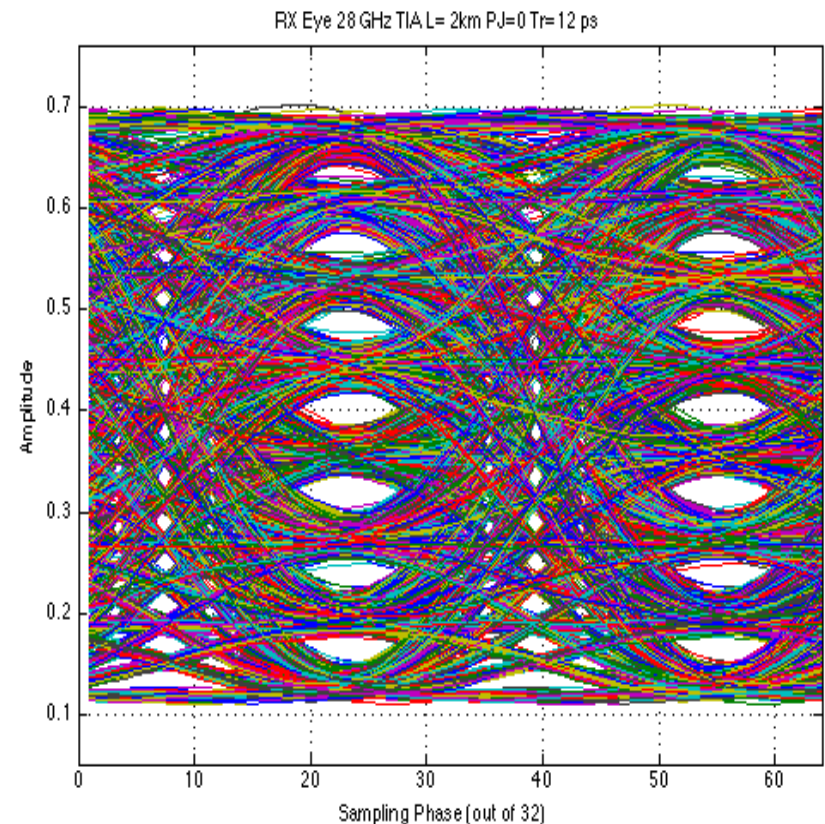
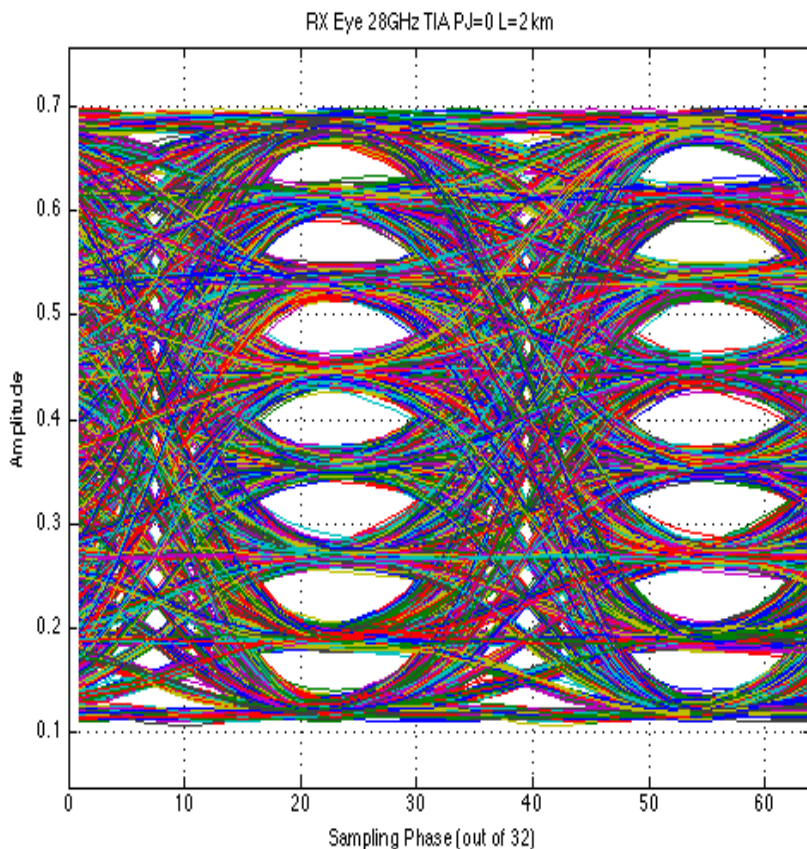
PAM-8 Receive Eye with TIA BW=28 GHz

- For the 8 ps and 12 ps transmitter with PJ=2 ps
 - All simulation with 2 km of SMF28 eye is practically identical to 2m



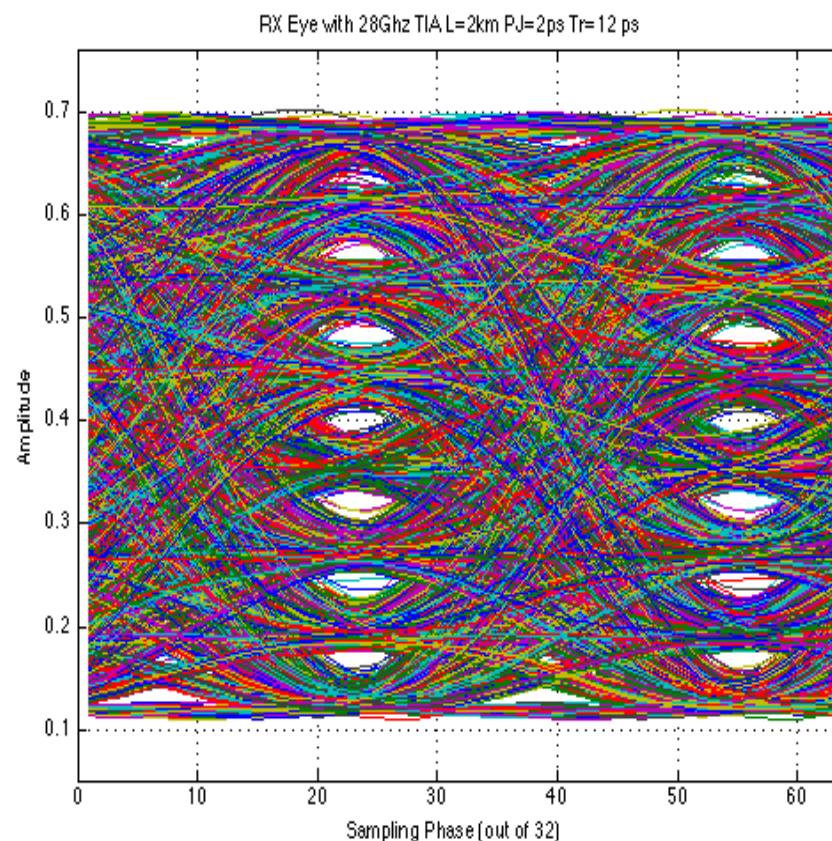
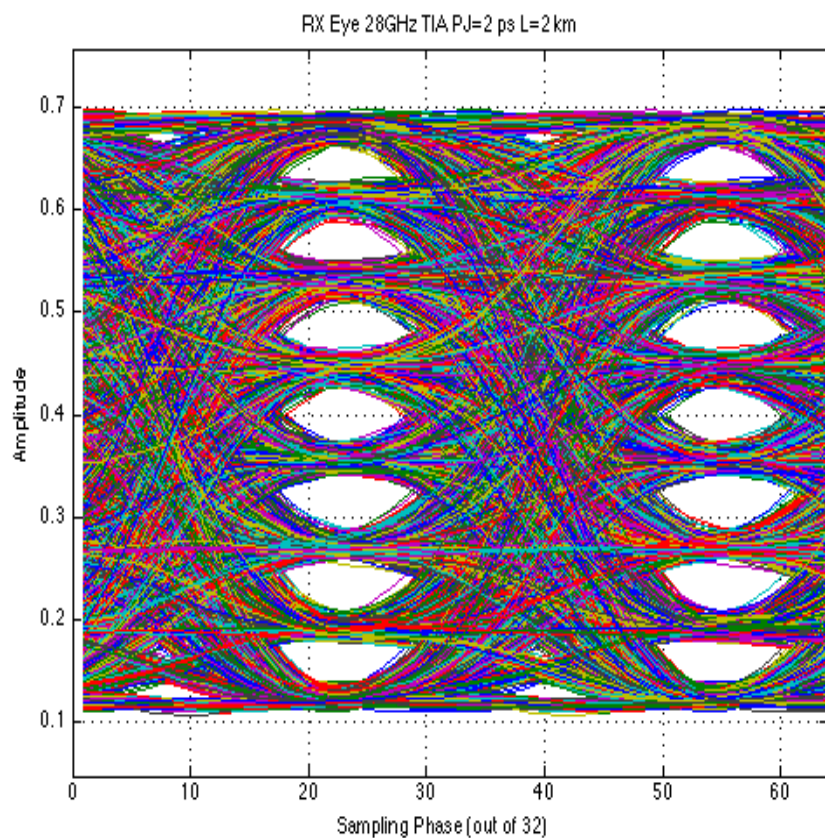
PAM-8 Receive Eye TIA BW=38 GHz

- For the 8 ps and 12 ps transmitter with PJ=0 ps
 - All simulation with 2 km of SMF28 eye is practically identical to 2m



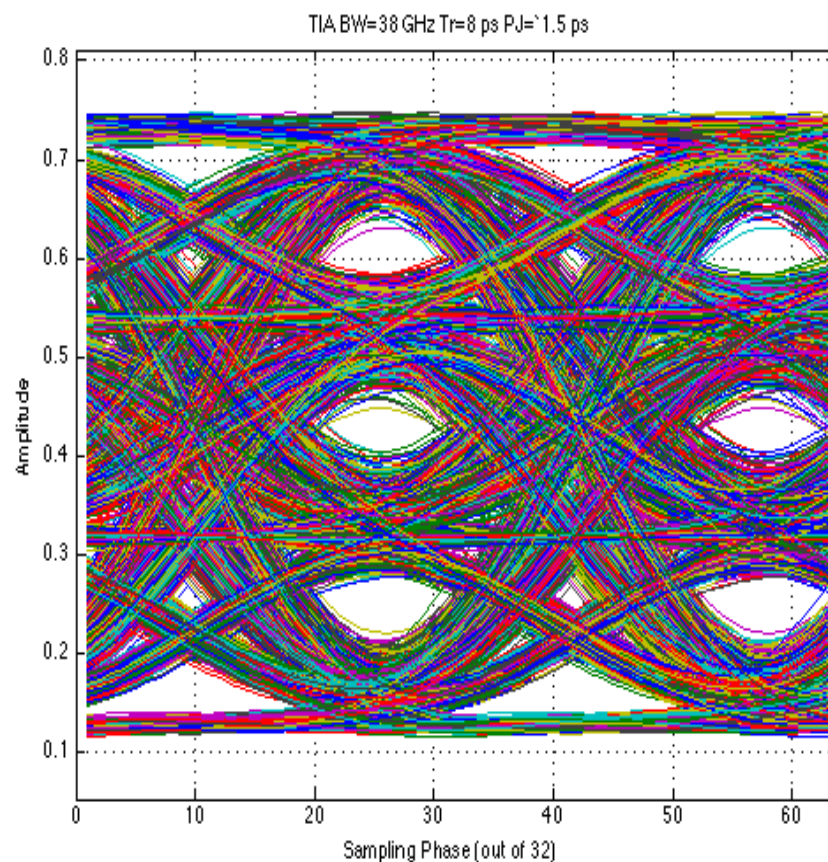
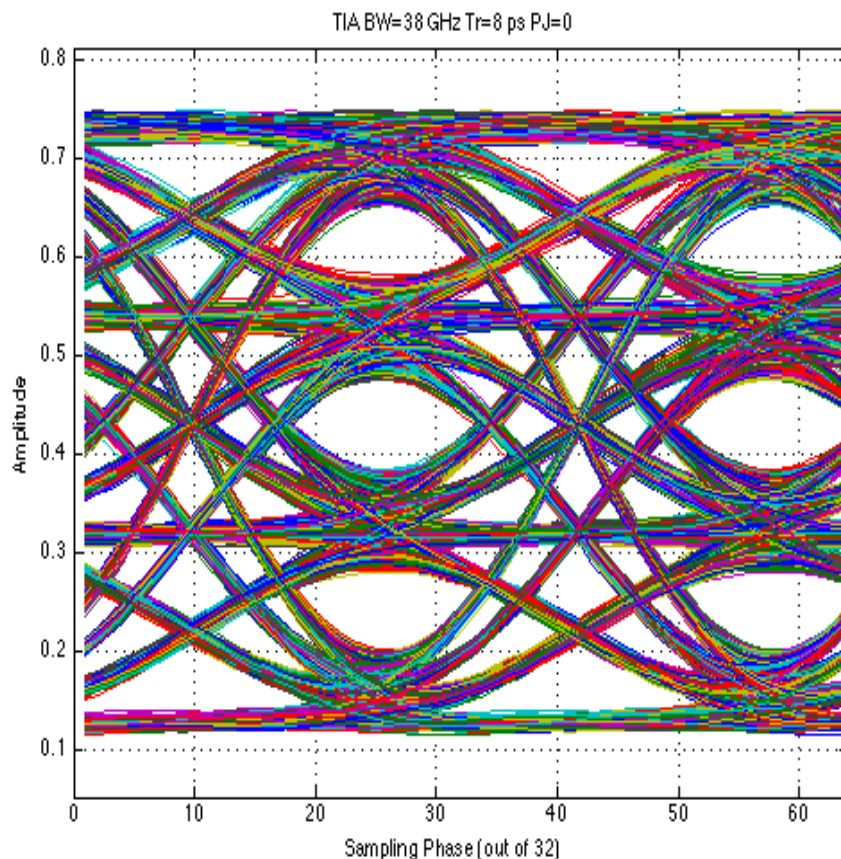
PAM-8 Receive Eye with TIA BW=38 GHz

- For the 8 ps and 12 ps transmitter with PJ=2 ps
 - All simulation with 2 km of SMF28 eye is practically identical to 2m



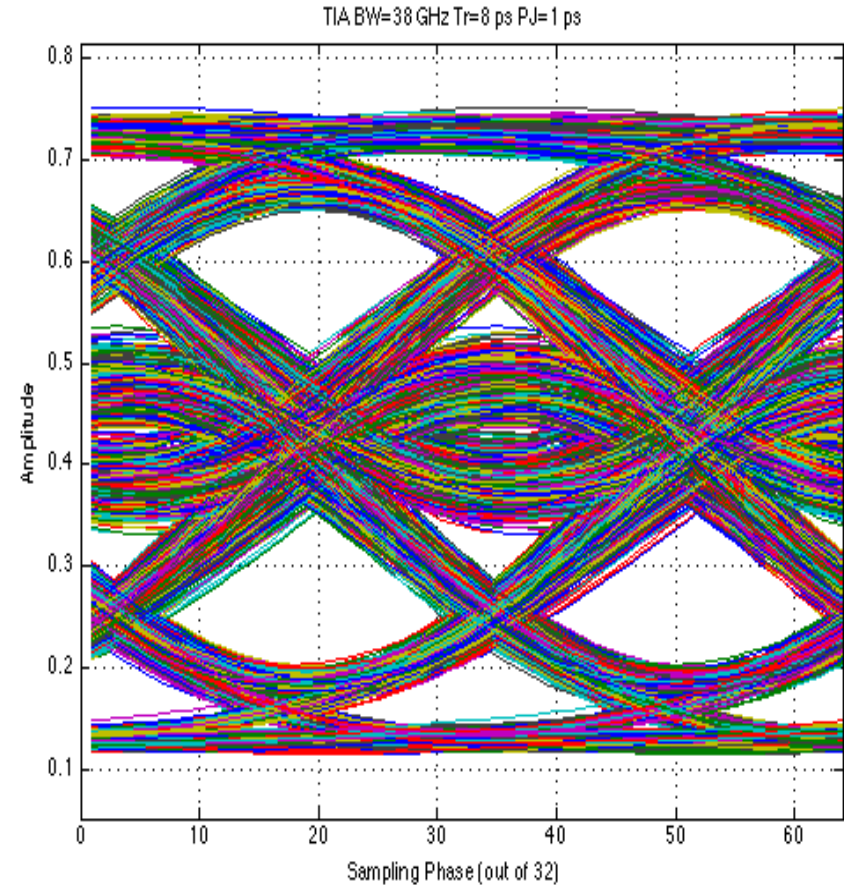
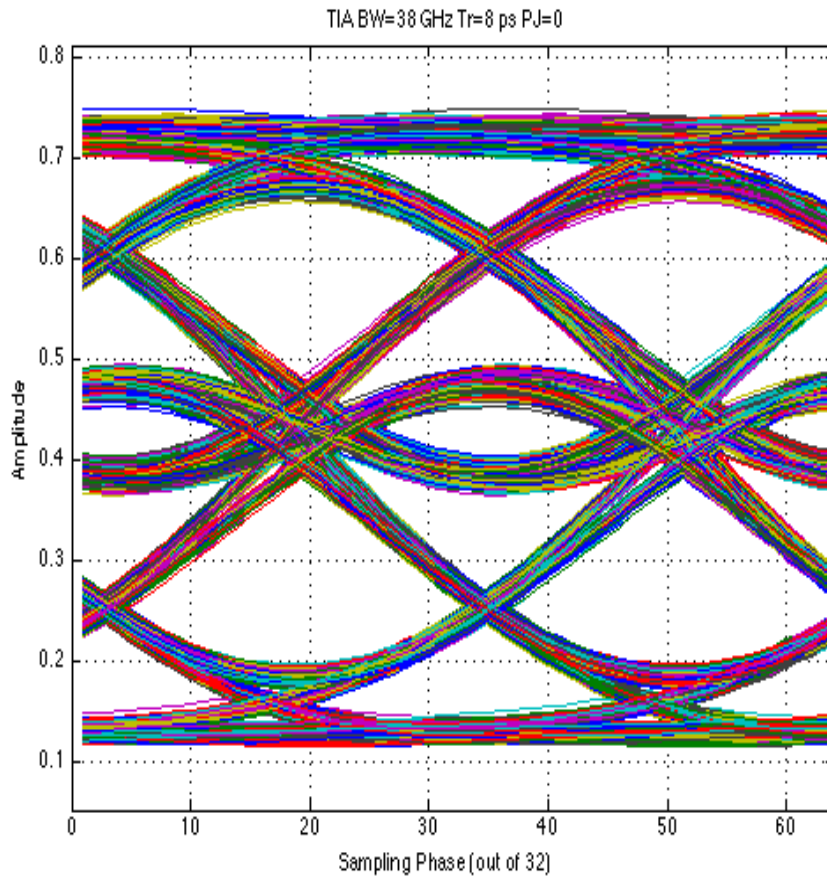
PAM-4 Receive Eye at 51.5625 GBd

- For the 8 ps transmitter rise time with PJ=0 ps and 1.5 ps
 - All simulation with 2 km of SMF28 eye is practically identical to 2 m



PAM-2 Receive Eye at 103.625 GBd

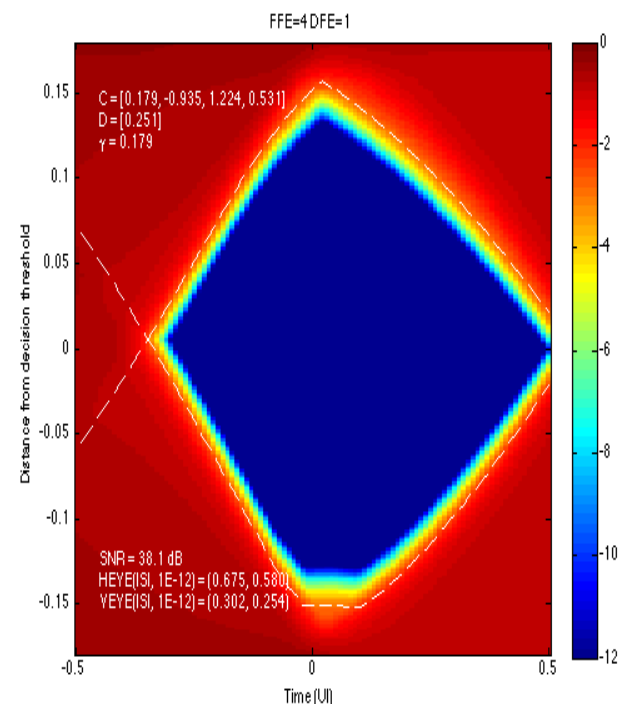
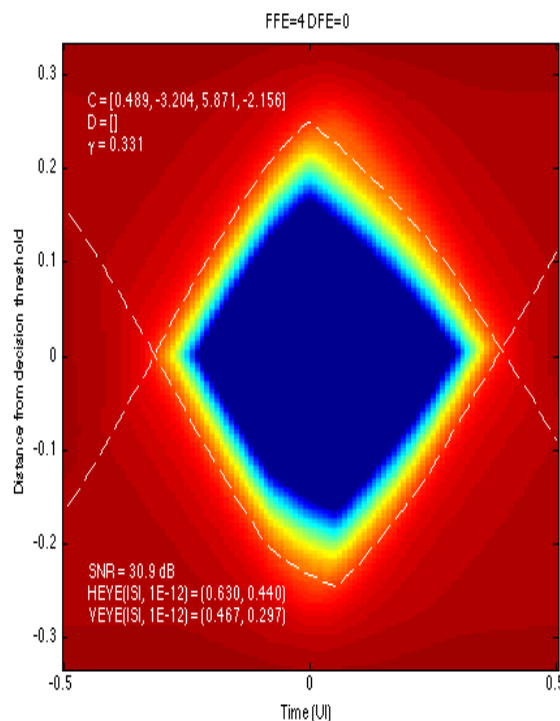
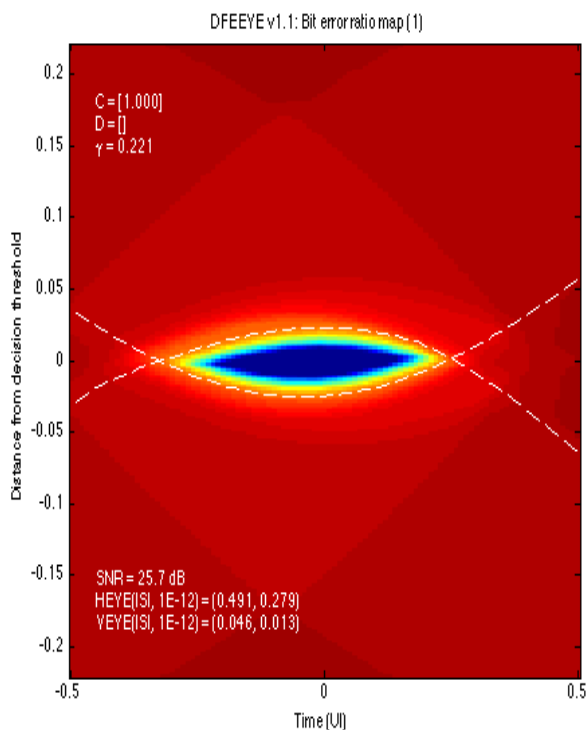
- Receive eyes after 500 m for 38GHz PD+TZ AMP for 8 ps 20-80% transmitter trise, with and without 1.0 ps of PJ.



Equalized PAM-2 Receive Eye at 103.625 GBd



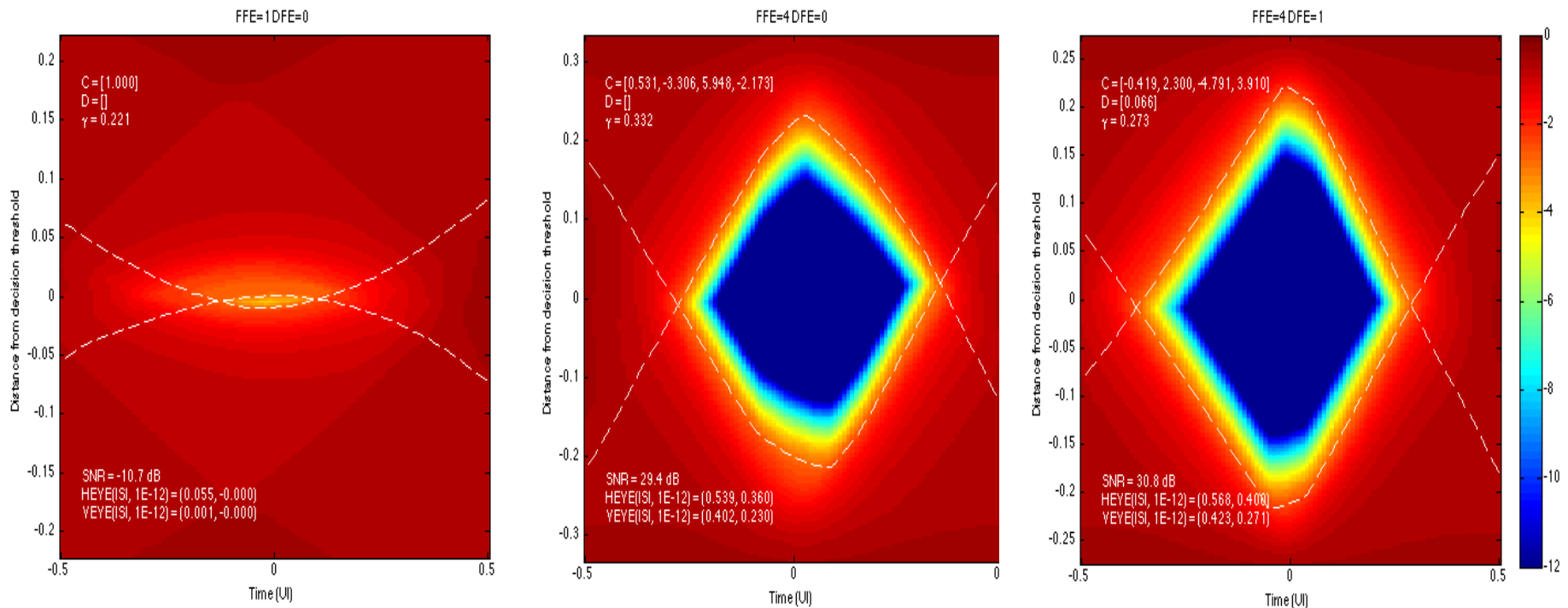
- Receive eyes after 500 m with PJ=0 for FFE=1DFE=0, FFE=4DFE0, and FFE=4DFE1



Equalized PAM-2 Receive Eye at 103.625 GBd



- Receive eyes after 500 m with PJ=1 ps for FFE=1DFE=0, FFE=4DFE0, and FFE=4DFE1



- RSOFT time domain simulation include realistic driver, transmit jitter, MZ modulator with 34 GHz RC BW
 - Model include all optical effect with exception of MPI
 - The receiver has realistic front end as well as noise power spectral density resulting in -16 dBm sensitivity for PAM-2
 - Model include realistic jitter and driver rise time
 - Increasing transmit optical rise time from 8 ps to 12 ps does significantly close the PAM-8 eyes and PJ of 2 ps to lesser extend
- Based on the suggestions during May interim PAM-4 as well as PAM-2 simulation are added
 - Overall PAM-4 operating at 51.5625 GBd has the largest eye opening without any equalization
 - PAM-8 eyes 34.37 Gbd are closed and would require equalized receiver for signal recovery
 - PAM-2 eyes at 103.5625 GBd are nearly closed but a modest 4 tap T/2 equalizer is sufficient to open the eye
- Next step is to investigate if moderate equalizer can compensate PAM-8 receive eye degradations as well looking into other advance modulation such as CAP-16 and QAM-16.

Thank You