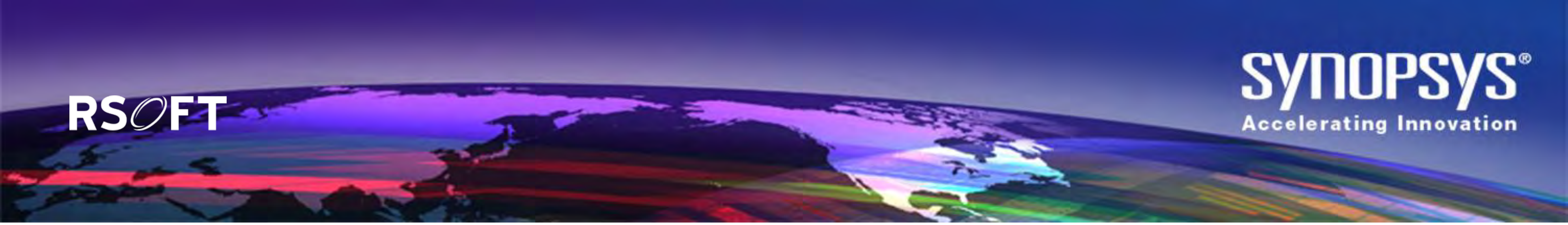

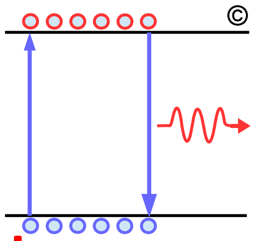

Tool for Simulating 400 GbE Optical PMDs

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IEEE 802.3bs Task Force

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Background

- **Historically IEEE 802.3 has relied on various tool for link modeling or compliance**
  - 802.3z (1 GbE) 1st Hanson, Cunningham, Dawe developed the IEEE spreadsheet
  - 802.3ae (10 GbE) Enhanced version of the IEEE spreadsheet introduced
  - 802.3aq (10 Gb/s LRM)
    - Cambridge defined the 81 fiber index profile "LRM Channel Model"
    - ClariPhy developed TWDP Matlab code for transmitter compliance and receiver calibration
  - 802.3ap (10G-KR) backplane S-parameters provided by Intel, Molex, Xilinx, etc
  - 802.3bj (100G-KR4) backplane and/or Cu cable S-parameters provided by TE, Molex, IBM, etc
  - 802.3ba (40, 100 GbE) 802.3ae spreadsheet was further enhanced
- **What are the options for 802.3bs to model channel including HOM (Higher Order Modulation)**
  - Realistic measured results is the best but might be difficult produce
  - Lack of tools that can accurately model 400 GbE PMDs would be as if trying to hit a target in darkness
- **Using OptSim* we show example simulation of 400 GbE PMDs based on the time domain simulation including multi-path interference (MPI).**

*** OptSim is an example tool that this author has extensively used and is not commercial endorsement.**

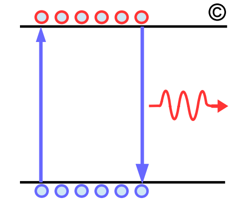
802.3bs Modeling Requirements

- **Support modulation format PAM and DMT**
- **In case task force defines PMD based on 50 Gb/s SR8**
  - Then VCSEL spatial rate equation model and spatial fiber models will be required but the methodology for this type of simulation already established

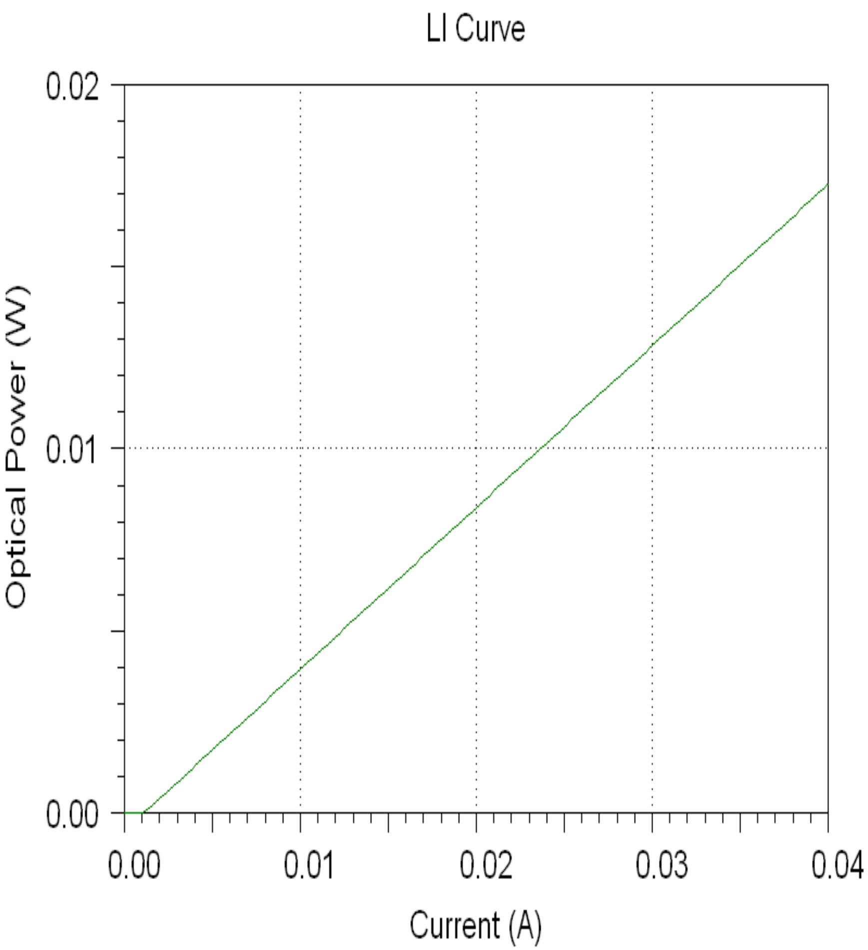
  http://www.ieee802.org/3/100GNGOPTX/public/mar12/plenary/ghiasi_02_0312_NG100GOPTX.pdf
- **Transmitter should support**
  - Support rate equation DFB-DML, MZM Modulator,
  - Introduction of transmitter jitter, noise, reflections
  - Non-linear driver
  - RIN and laser linewidth
- **Fiber and connector**
  - SMF non-linear fiber
  - MMF spatial fiber as well as offset launch
  - Dispersion
  - Connectors
  - MPI (Multi-path interference)
- **Receiver should support**
  - Thermal and shot noise
  - TIA response as well as any compression

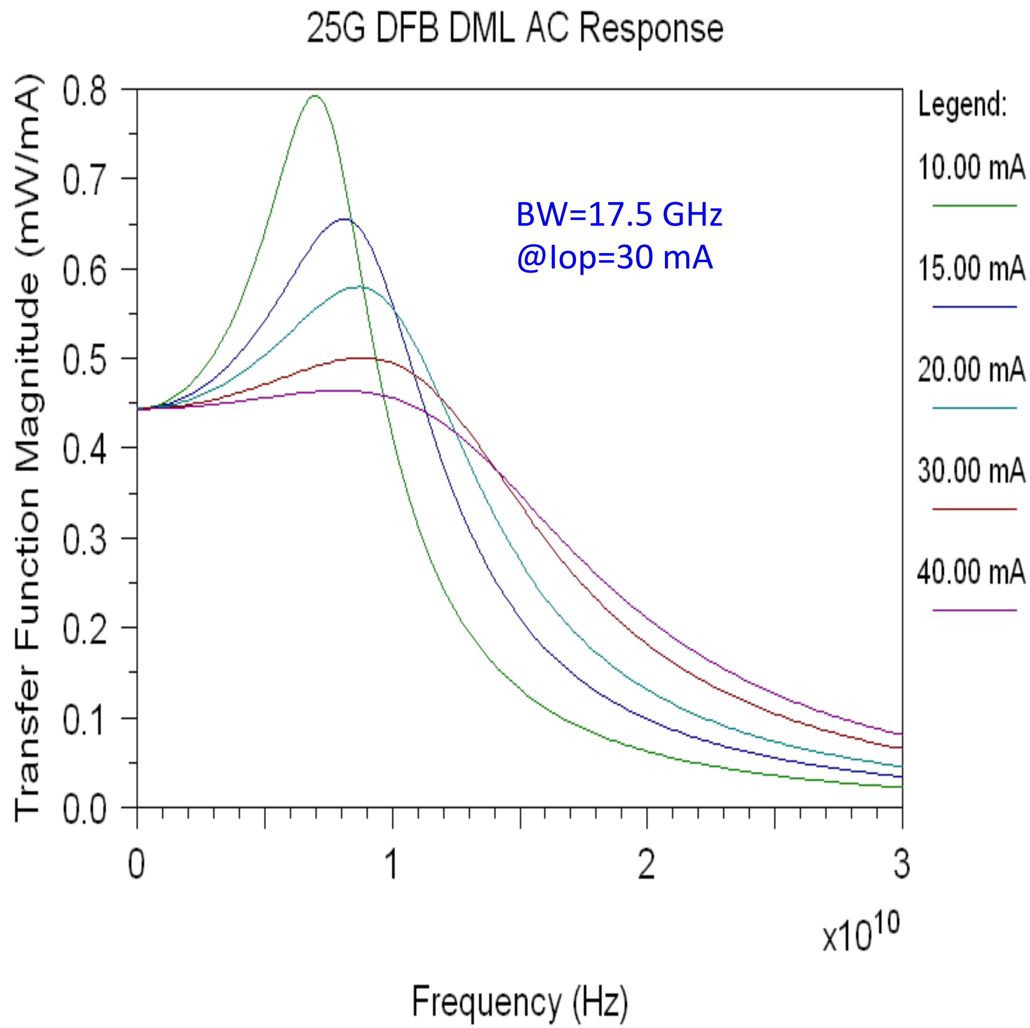
Basic Simulation Assumptions

- **Transmitter specifications**
  - Electrical driver 12 ps 20-80 rise/fall
  - Transmitter DJ =2 ps
  - Electrical driver SNR=21 dB
  - Optics based on DFB-MZM or DFB-DML
  - To generate PAM-4, 2 input signals with amplitude 1/3, 2/3 are linearly summed to drive the optics
  - MZM had RC BW=17.5 GHz
  - DFB DML had BW =17.5 GHz
  - RIN=-135 dB/Hz
  - Extinction ratio= 6dB
  - TX Wavelength=1270 nm and linewidth 100 MHz
  - TOSA RL = 26 dB unless otherwise specified
- **Receiver specifications**
  - BW=19 GHz
  - Sensitivity -13 dBm AOP @ 1E-5
  - ROSA RL = 26 dB
- **Data pattern=PN9 by 8x repeated**
- **Connector and fiber specifications**
  - Non-linear SMF fiber model
  - Connector loss = 0.5 dB
  - Connector return loss = 26 dB.

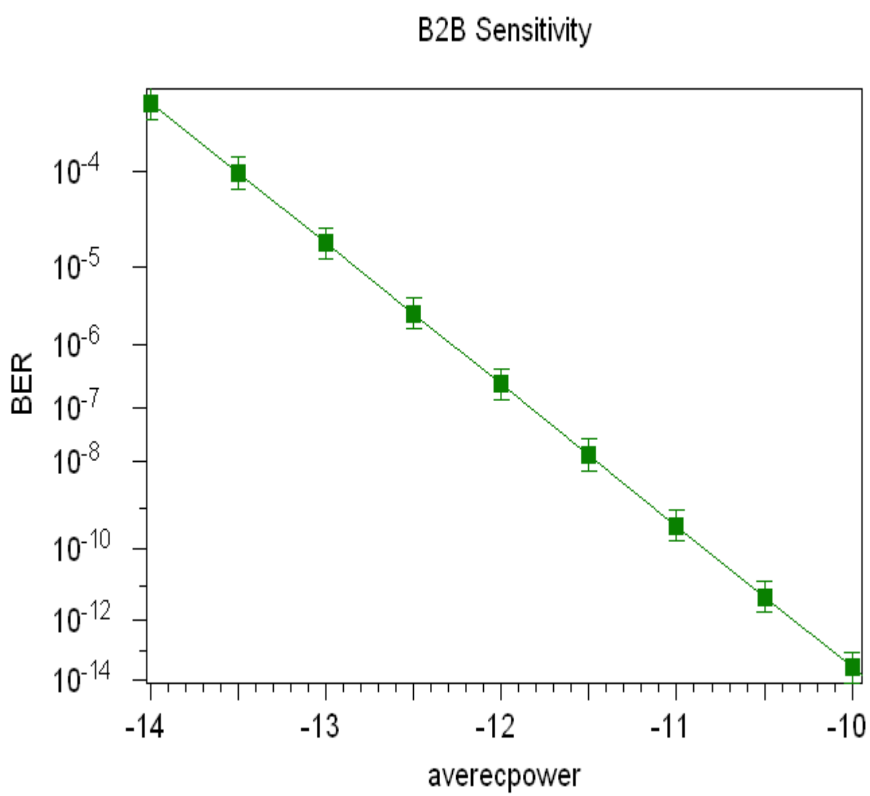


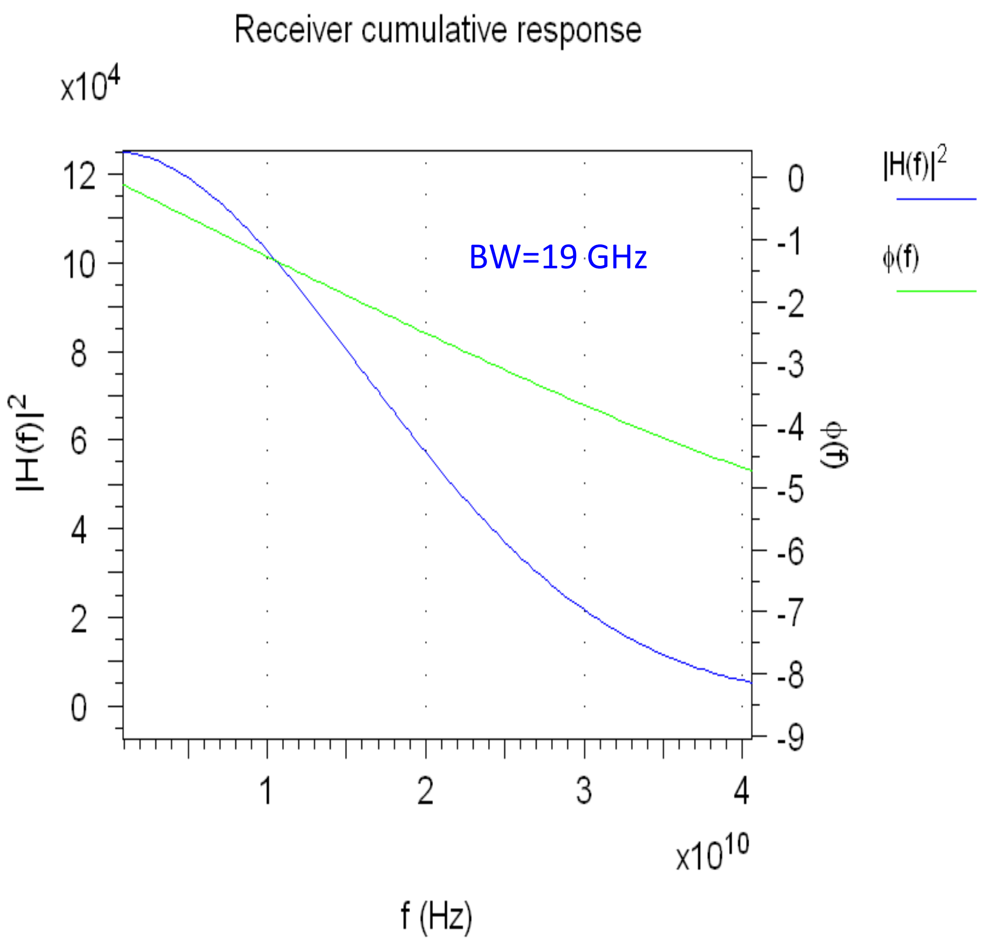
25G DML-DFB DC and AC Responses





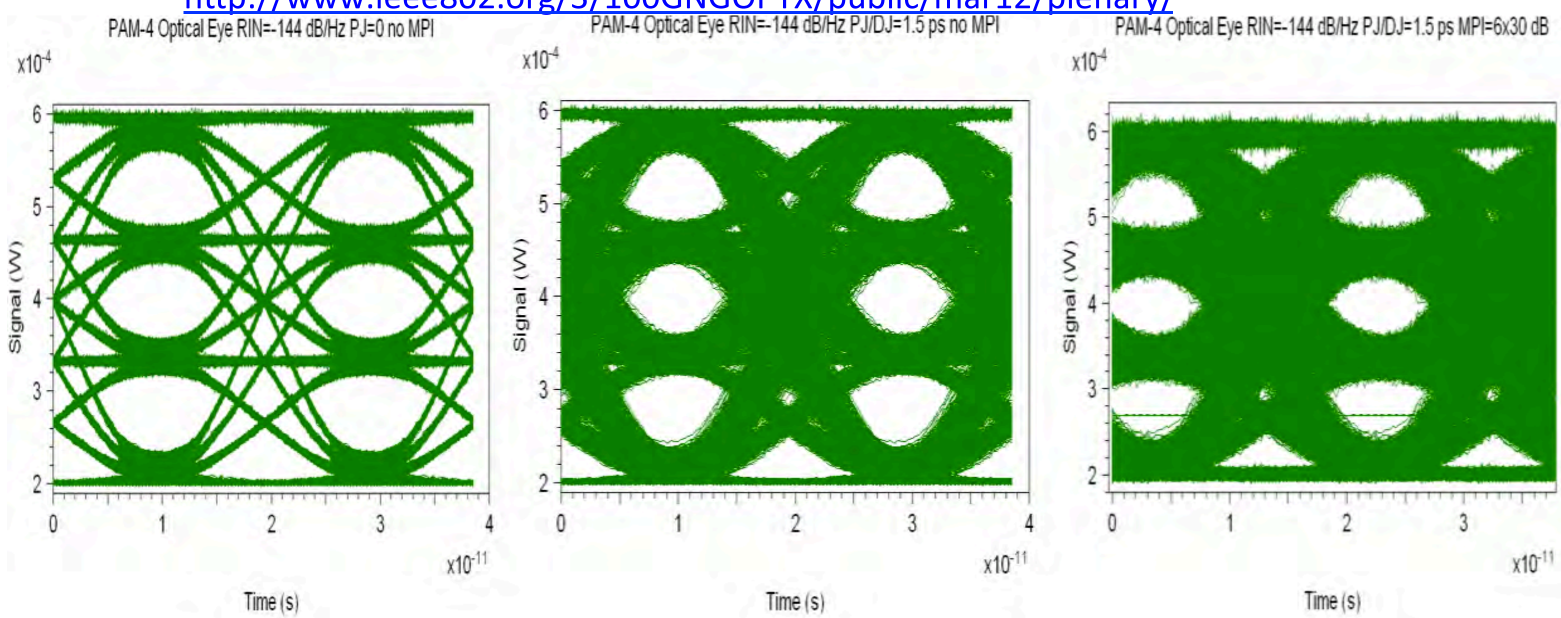
Reference 25G Receiver Response



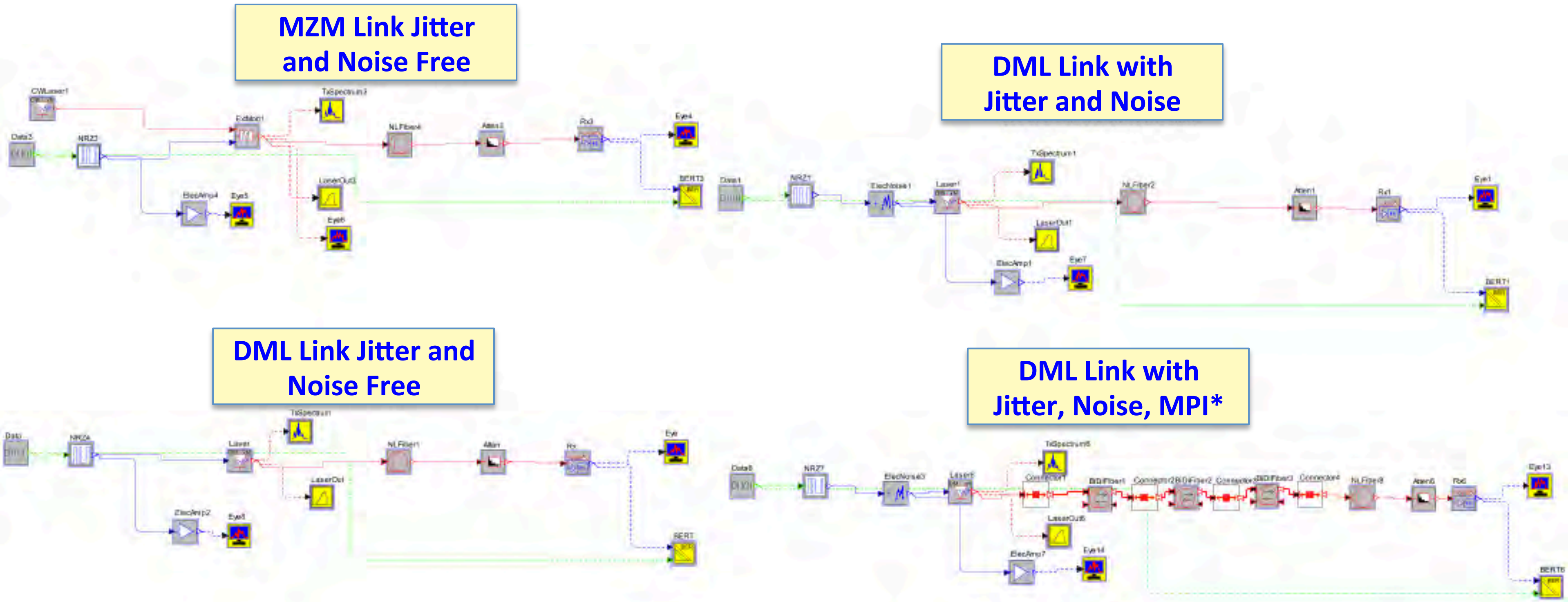


MPI Simulation with Optical Filter

- **Previously shown MPI simulation was based on optical filter “Etalon” in OptSim**
  - New improved simulation result are based on bi-directional fiber propagation and connector return loss to accurately simulation MPI
  - http://www.ieee802.org/3/bm/public/nov12/ghiasi_01a_1112_optx.pdf using OptSim
    - 6 connectors were reduced into a single Etalon based on analytic analysis given below: http://www.ieee802.org/3/100GNGOPTX/public/mar12/plenary/

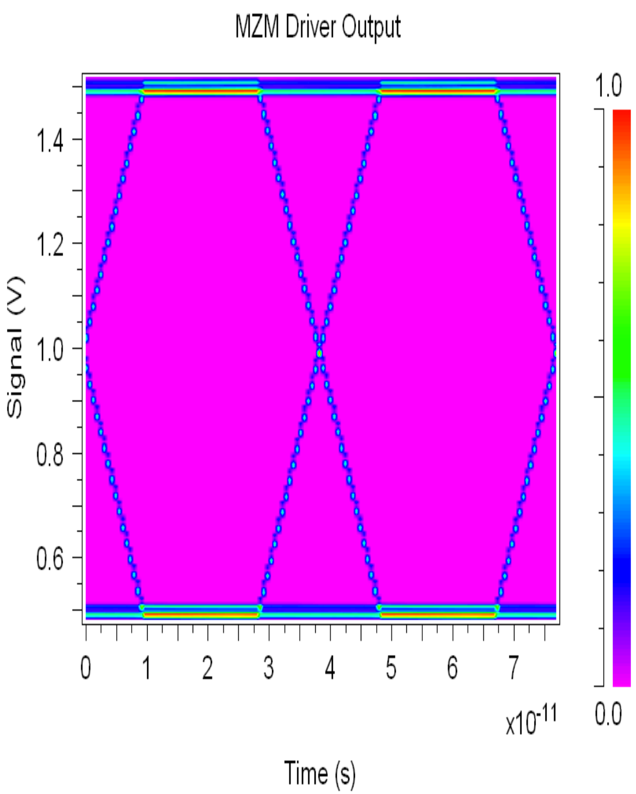


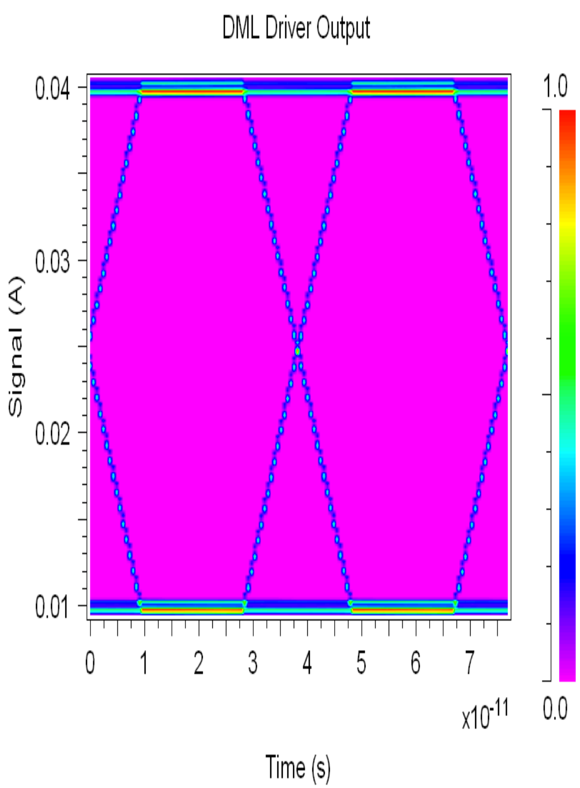
Schematic from Simplified MZM to More Realistic DML Links

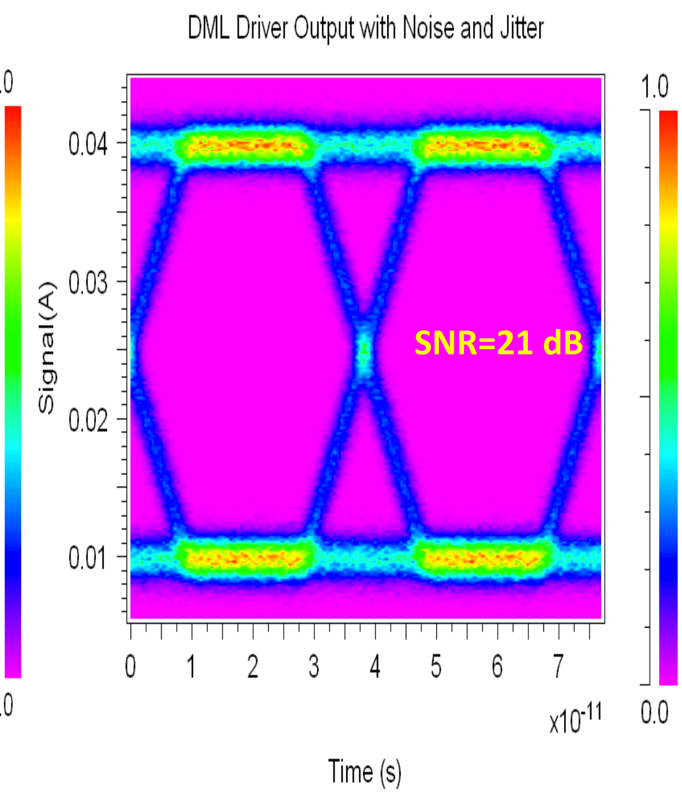


* TOSA/ROSA at RL of -26 dB with 2 mid-span connector at -26 dB

Electrical Drivers

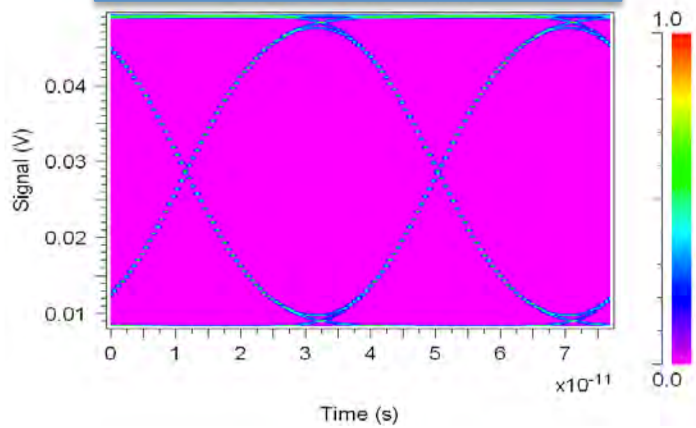




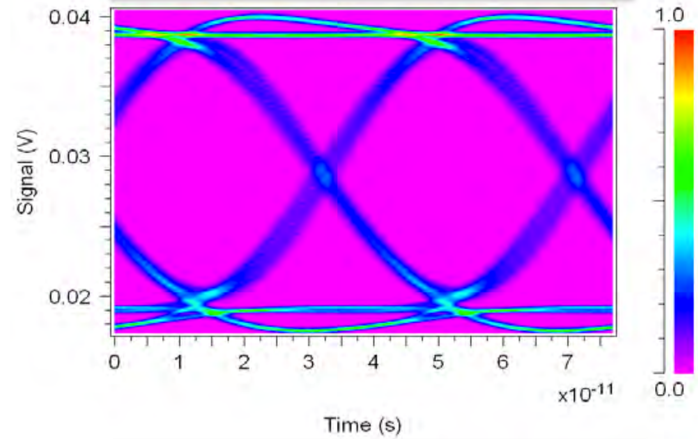


Simulation Result from Simplified MZM to More Realistic DML Links

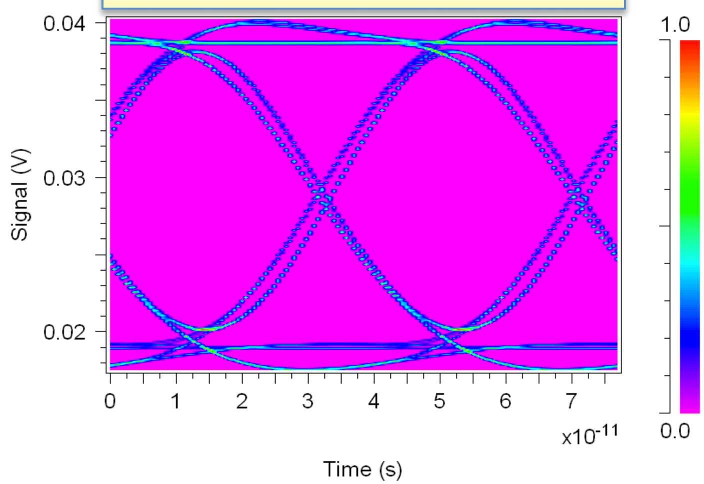
MZM Link Jitter and Noise Free



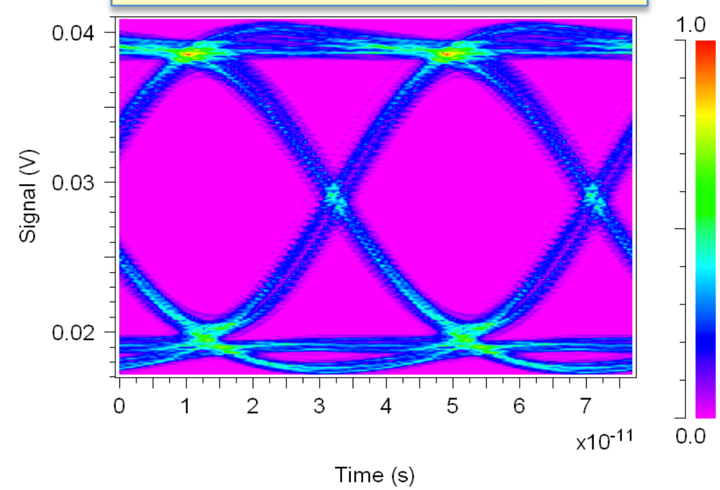
DML Link with Jitter and Noise



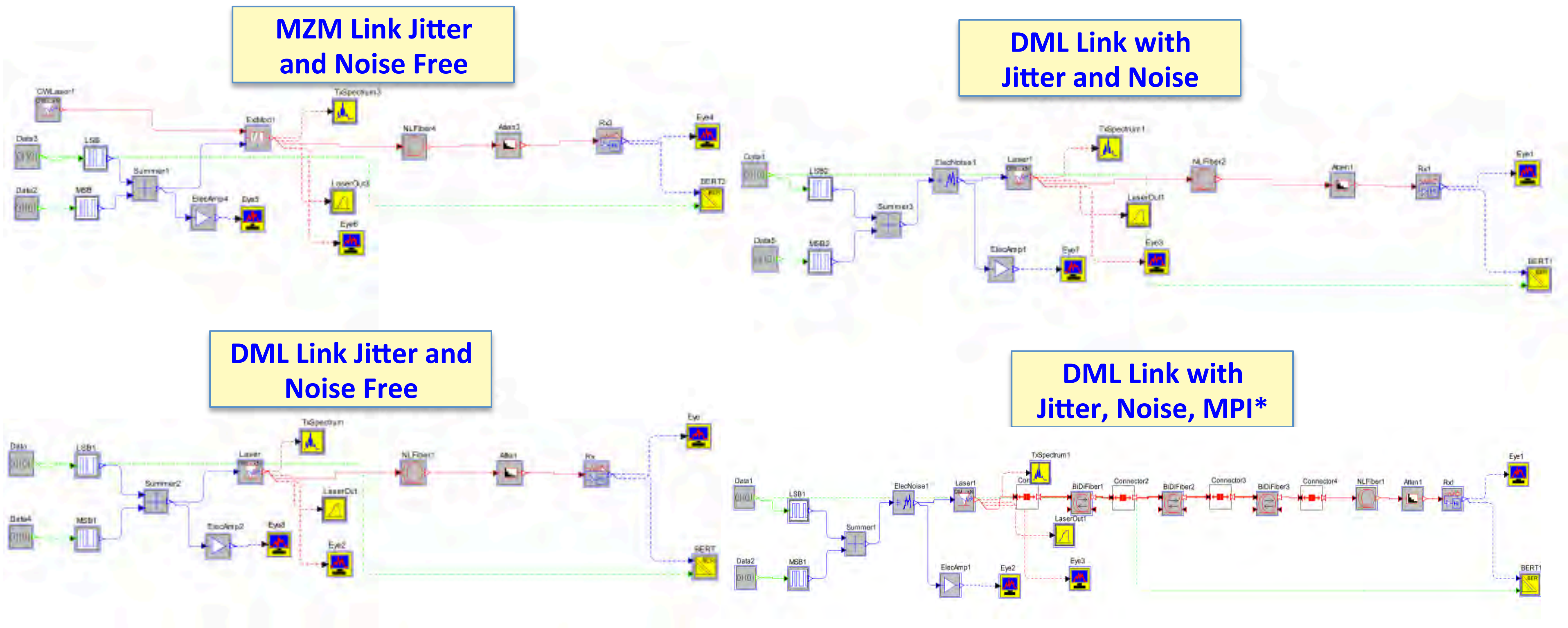
DML Link Jitter and Noise Free



DML Link with Jitter, Noise, MPI

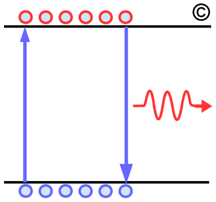


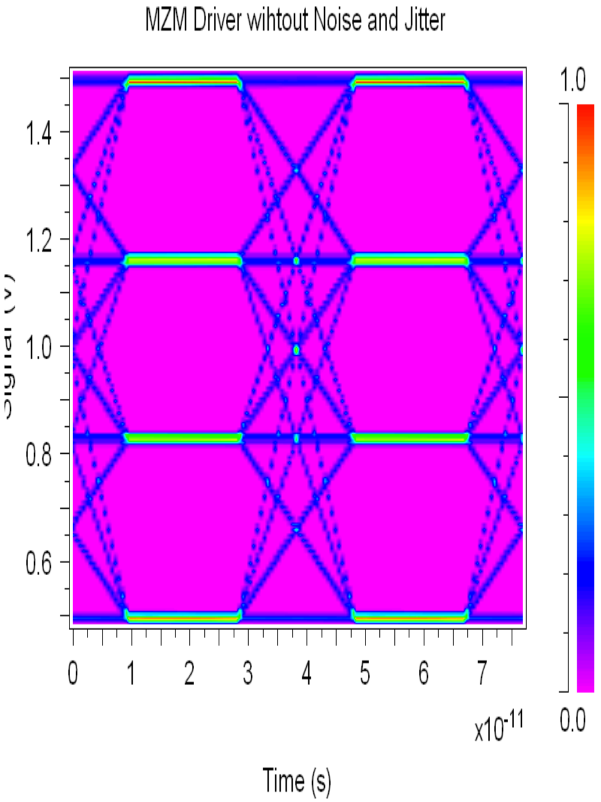
Schematic from Simplified MZM to More Realistic DML PAM4 Links

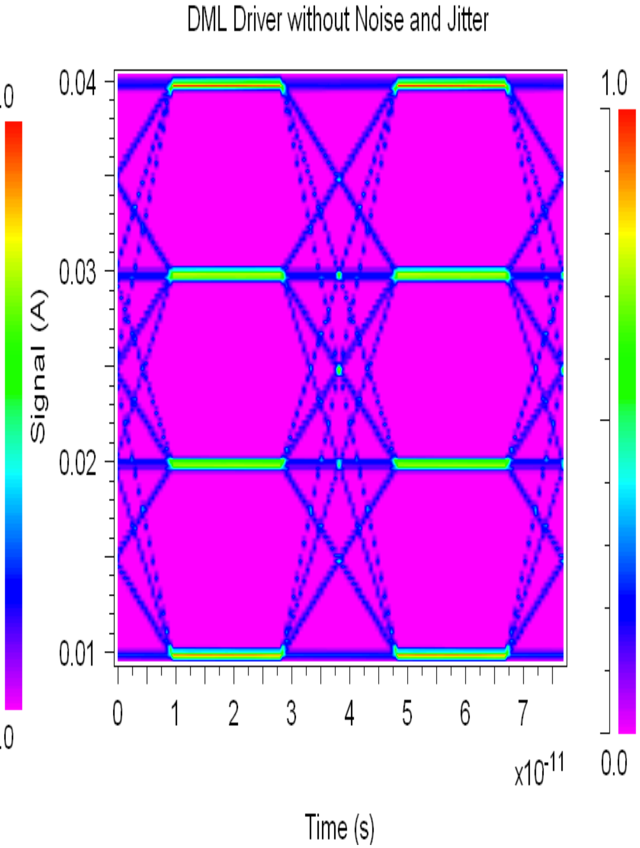


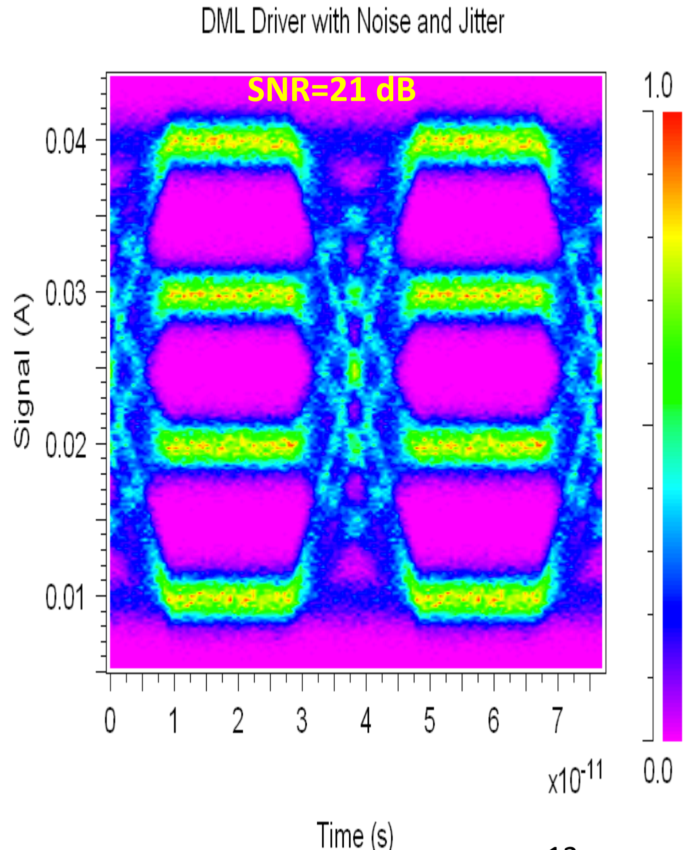
*** TOSA/ROSA at RL of -26 dB with 2 mid-span connector at -26 dB**

PAM4 Electrical Drivers



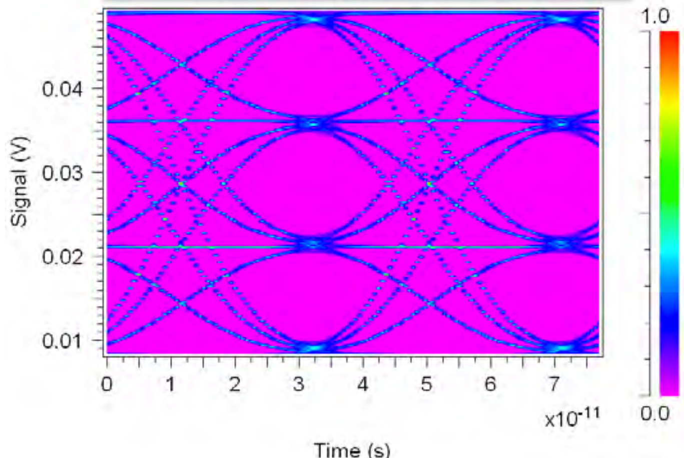




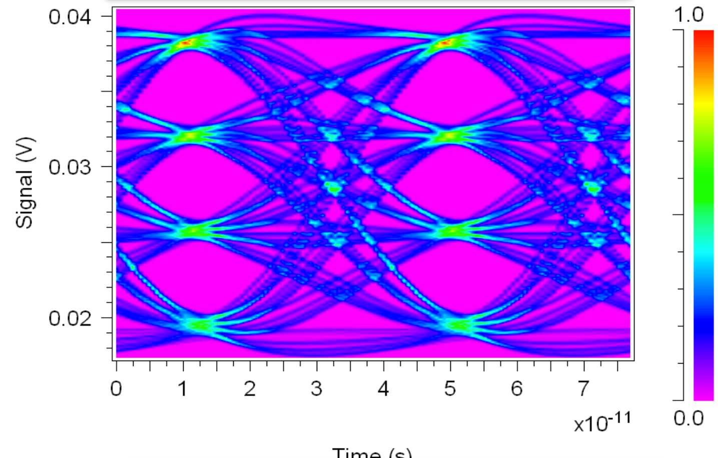


Simulation Result from Simplified MZM to More Realistic DML PAM4 Links

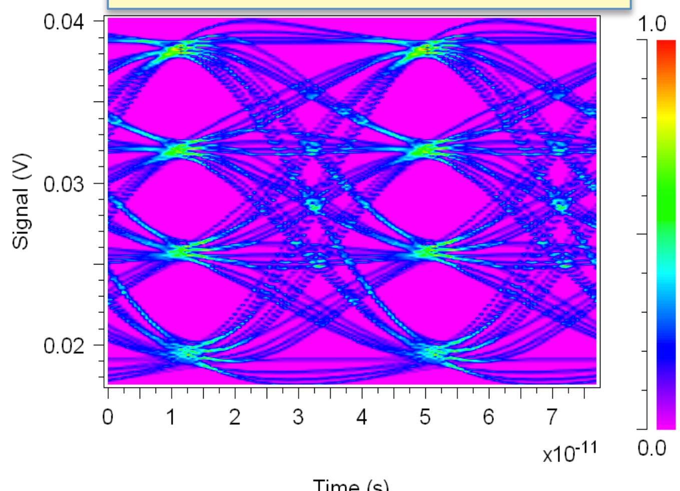
MZM Link Jitter and Noise Free



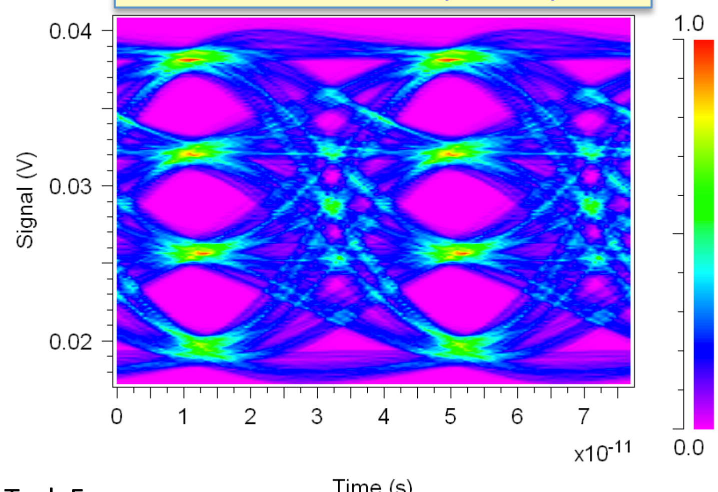
DML Link with Jitter and Noise



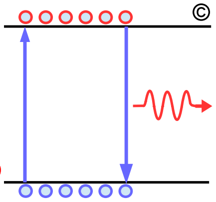
DML Link Jitter and Noise Free

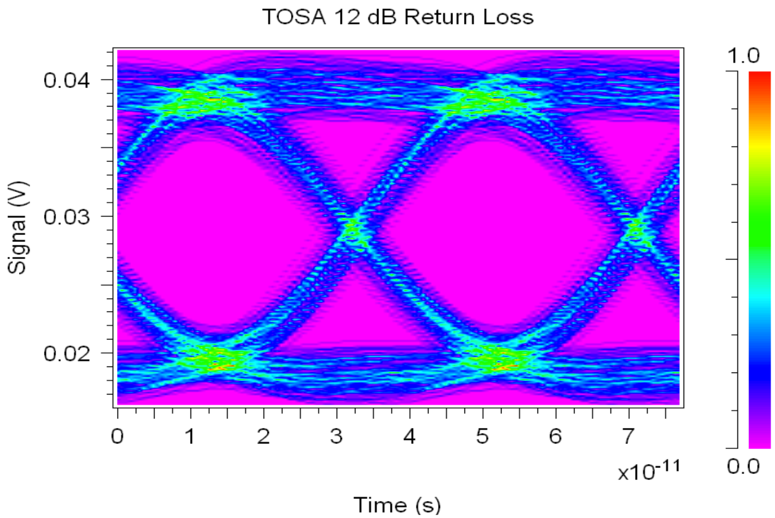


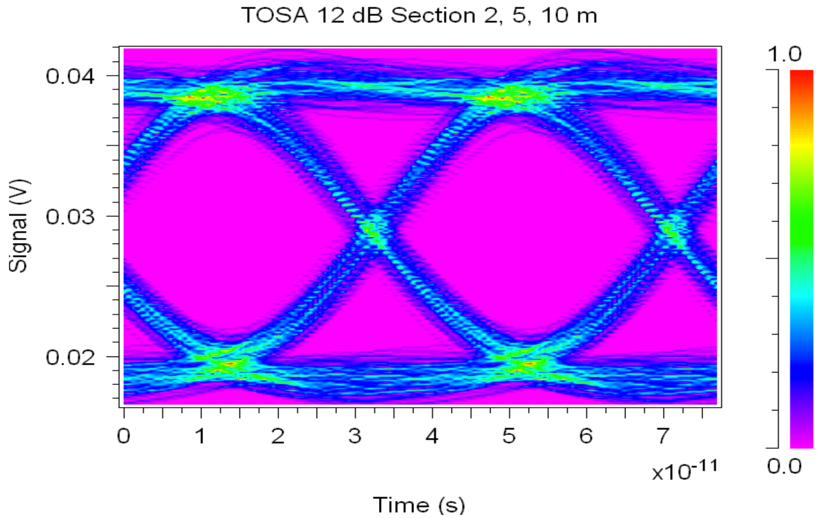
DML Link with Jitter, Noise, MPI

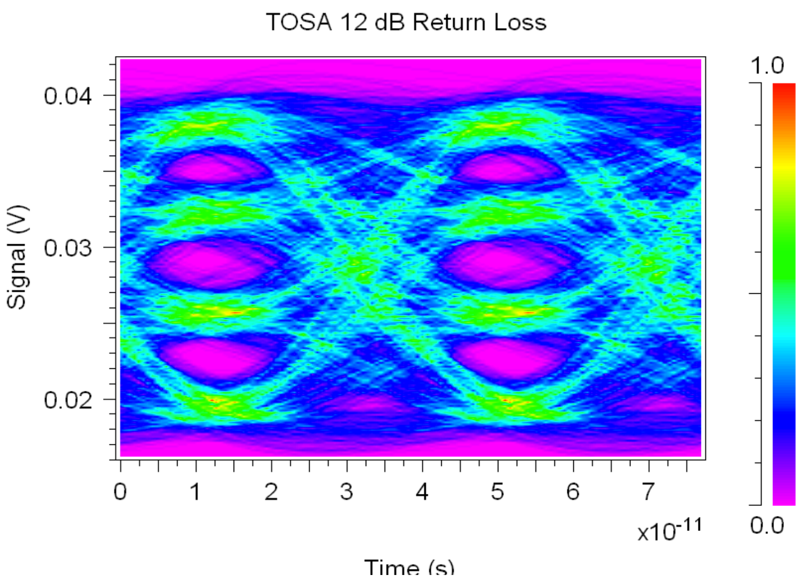


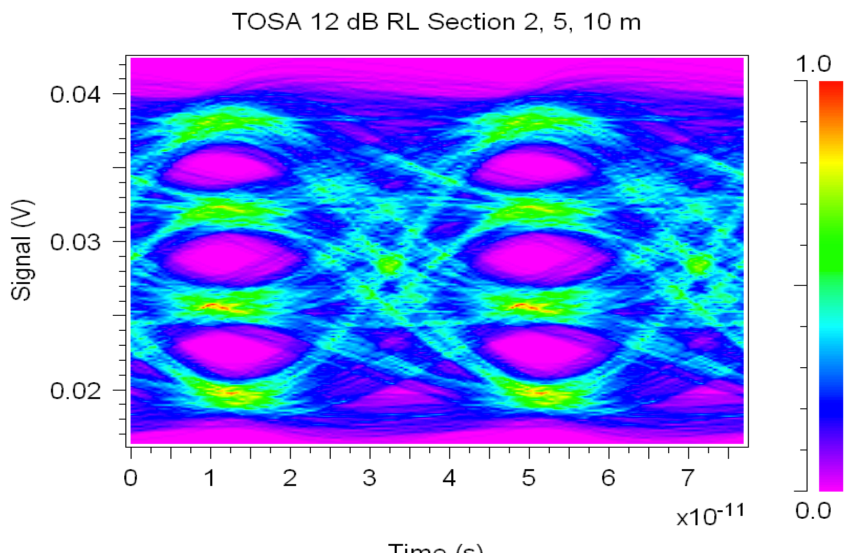
MPI Simulations for 12 dB TOSA RL with Equal 2 m sections and 2, 5, 10 m Sections











Summary

- **This presentation illustrates how electrical and optical parameters could impact the link margin**
  - As we move from NRZ to HOM the link becomes more sensitive and requires more realistic models to simulate impairments
  - A simple MZM model is not a representative of rate equation model of DFB-DML or VCSEL
  - We show MPI penalty based on actual link physical parameters (fiber length, connector loss, and connector return loss)
- **A key obstacle in defining and comparing potential PMDs in 802.3bs will be lack of channel models**
  - If there is interest a sub-set of channel waveform over-sampled at like 32x could be provided to IEEE 802.3bs by the authors
  - To keep the effort at manageable level some level consensus on the parameters must be reached first
- **Results shown here are sample simulation of NRZ and PAM4 link**
  - With more time results for other modulation format such as DMT could have been provided as well.