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*Fiber Optic Solutions
for High-Speed Networks*

The Ultimate Archetype 100 GbE per Lambda Technology



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OIDA and Ethernet Alliance

100GbE per Lambda for Data Center Workshop

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Outline

- ◆ Archetype 100 GbE per Lambda System Architecture
- ◆ Digital Modulation Techniques
- ◆ 100 GbE per Lambda for WDM Single-Mode Fiber Systems
- ◆ 100 GbE per Lane for Parallel Multi-Mode Fiber Systems
- ◆ Conclusions

100GbE per Lambda System Design Space

- ◆ Device Technology: InP, SiP
- ◆ Transmitter: DML, EML, MZM
- ◆ Baud Rate: 25, 50, 100 Gbaud
- ◆ Modulation: PAM, DMT, QAM, CAP, etc.
- ◆ Impairments: Thermal Noise, Laser RIN, DAC/ADC Quantization, Nonlinearities, RF Imperfections, Dispersion
- ◆ Equalization: CTLE, FFE/DFE, FFT/IFFT, MLSE
- ◆ FEC: Coding Gain, Latency, Power
- ◆ Engineering Tradeoffs: Cost, Power, Density, Reach



How to proceed?

Who Is Your Archetype?

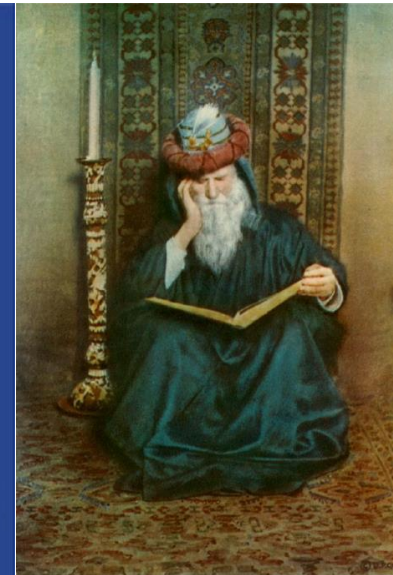
Hero

Ruler

Magician

Rebel

Sage



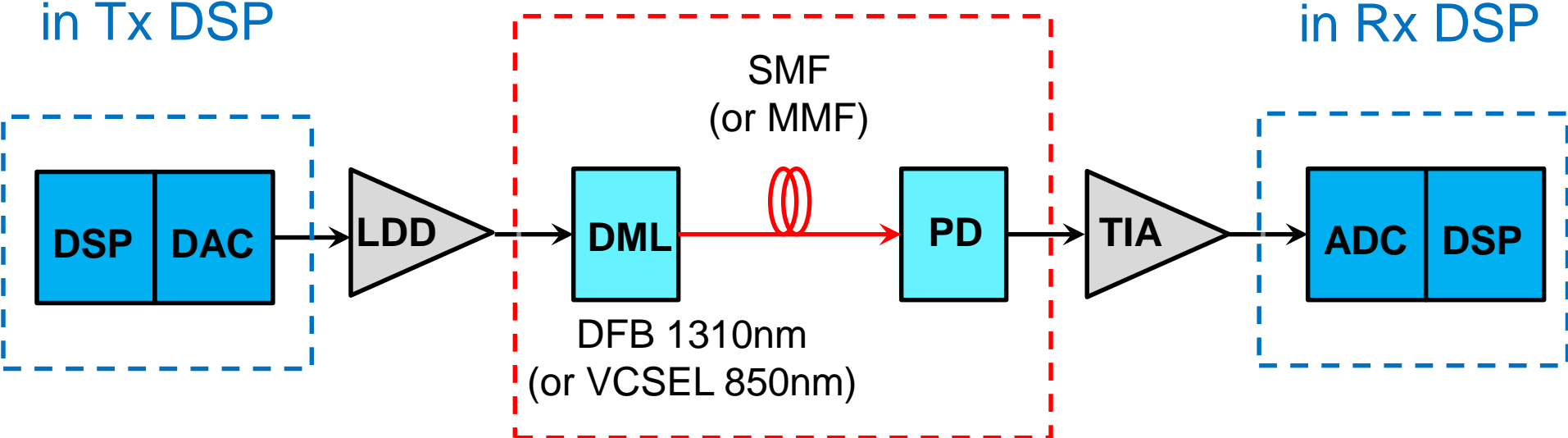
Source: http://www.soulcraft.co/essays/the_12_common_archetypes.html

Archetype 100 GbE per Lambda System Architecture

Complexity
in Tx DSP

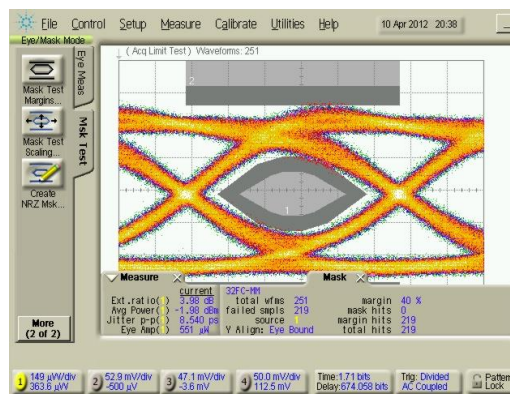
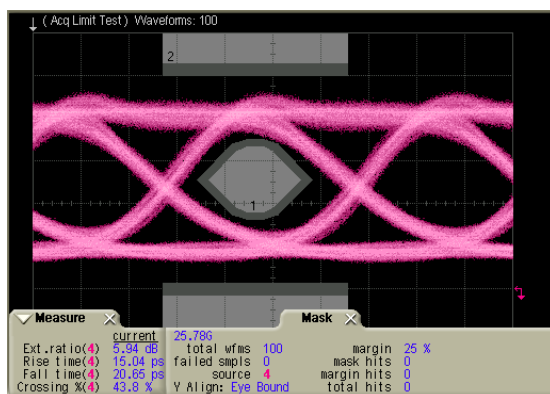
Simple Efficient Optics

Complexity
in Rx DSP

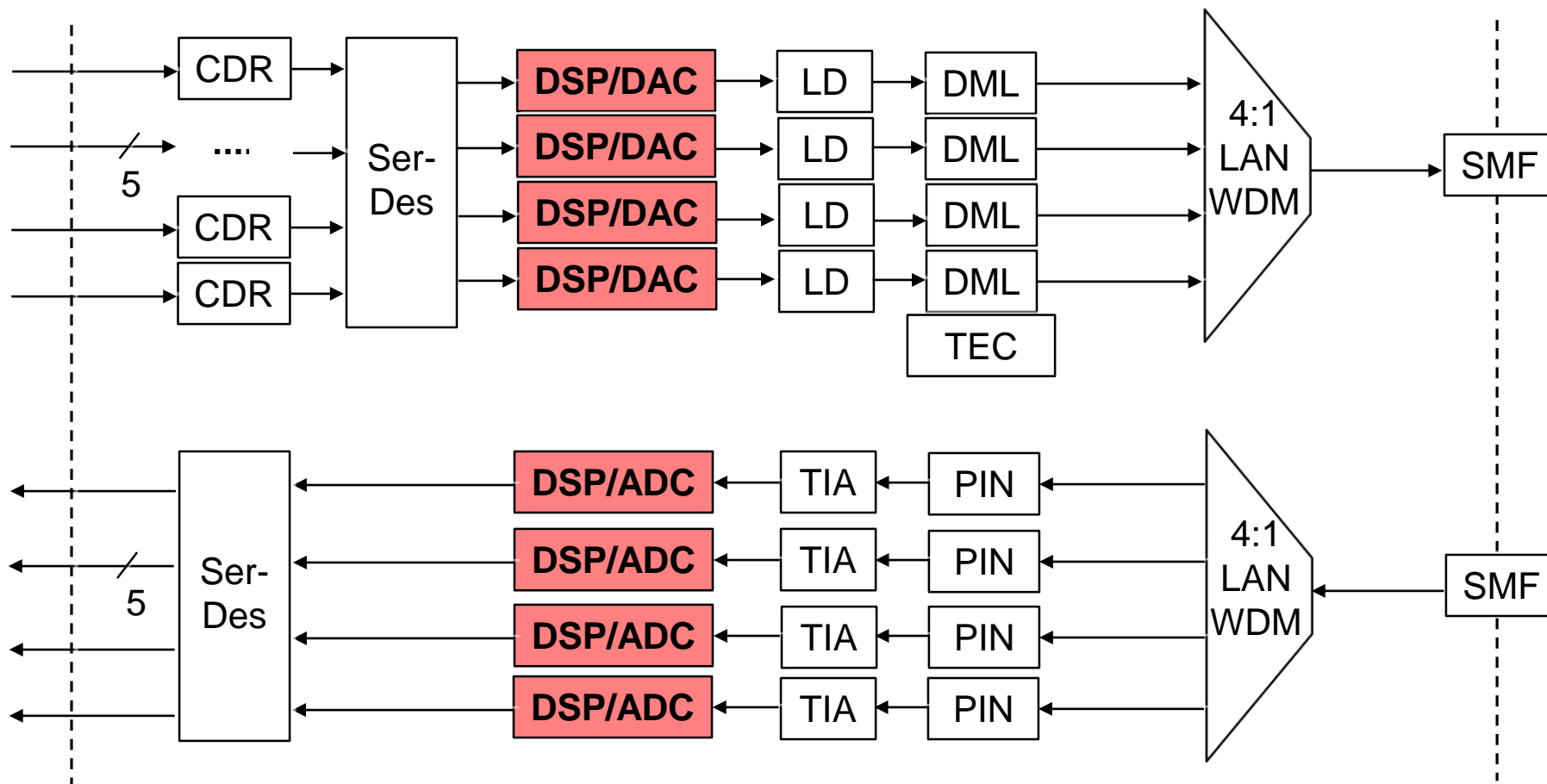


25.8 Gb/s DFB

28 Gb/s VCSEL



400GbE 4-Lambda SMF Module Concept



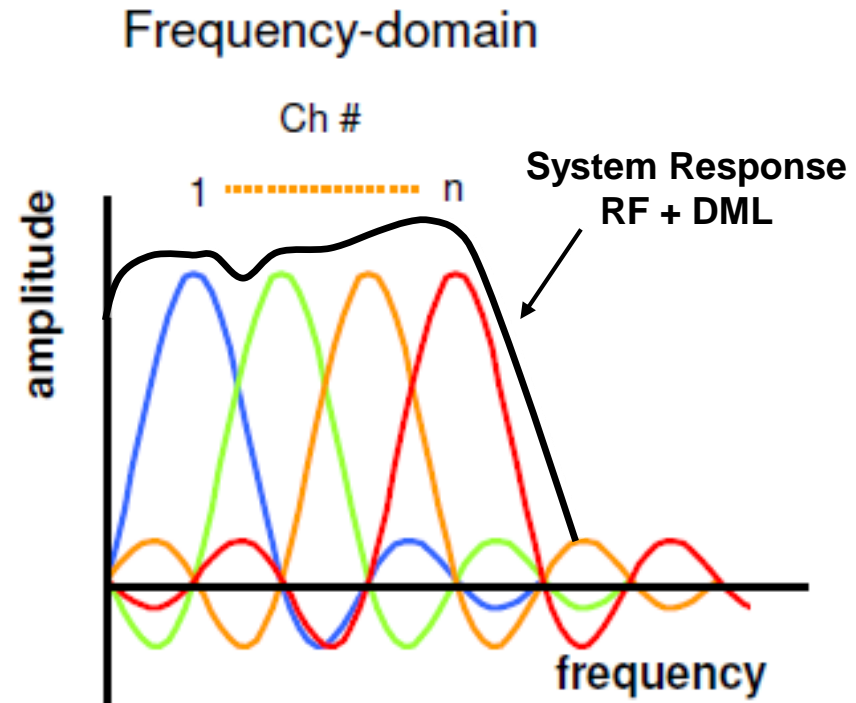
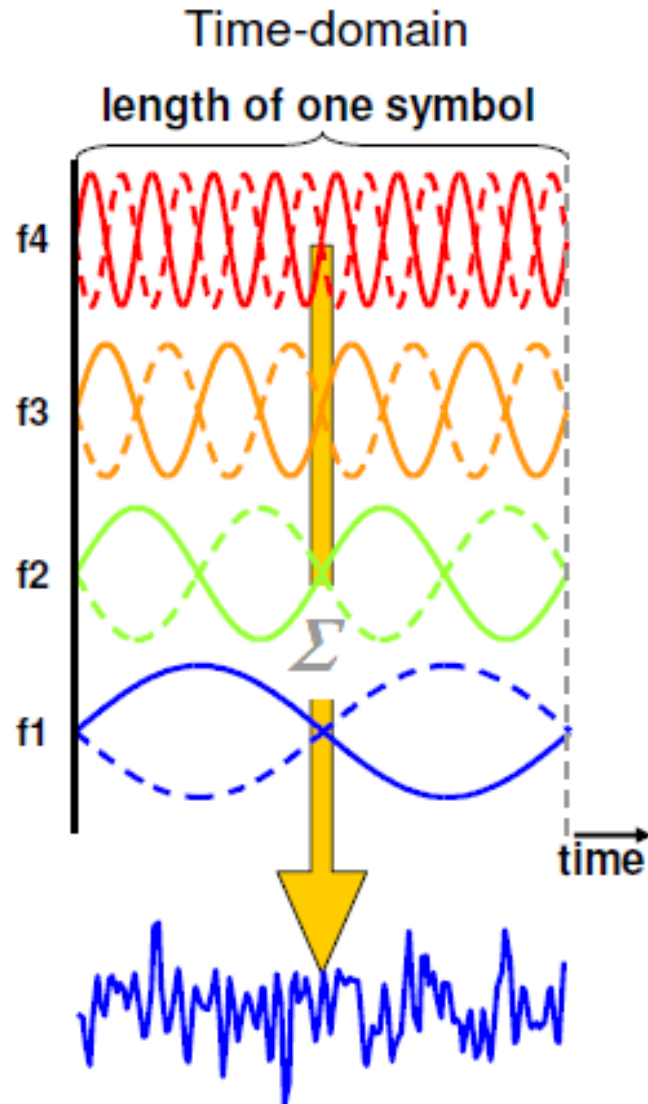
CDAUI 8x50G lanes

IEEE 802.3bs SMF

What is the Best 100G Modulation Format for DML?

- ◆ Pulse Amplitude Modulation (PAM-M)
- ◆ Discrete Multi-Tone Modulation (DMT)
- ◆ Quadrature Amplitude Modulation (QAM)
- ◆ Carrierless Amplitude Phase (CAP)

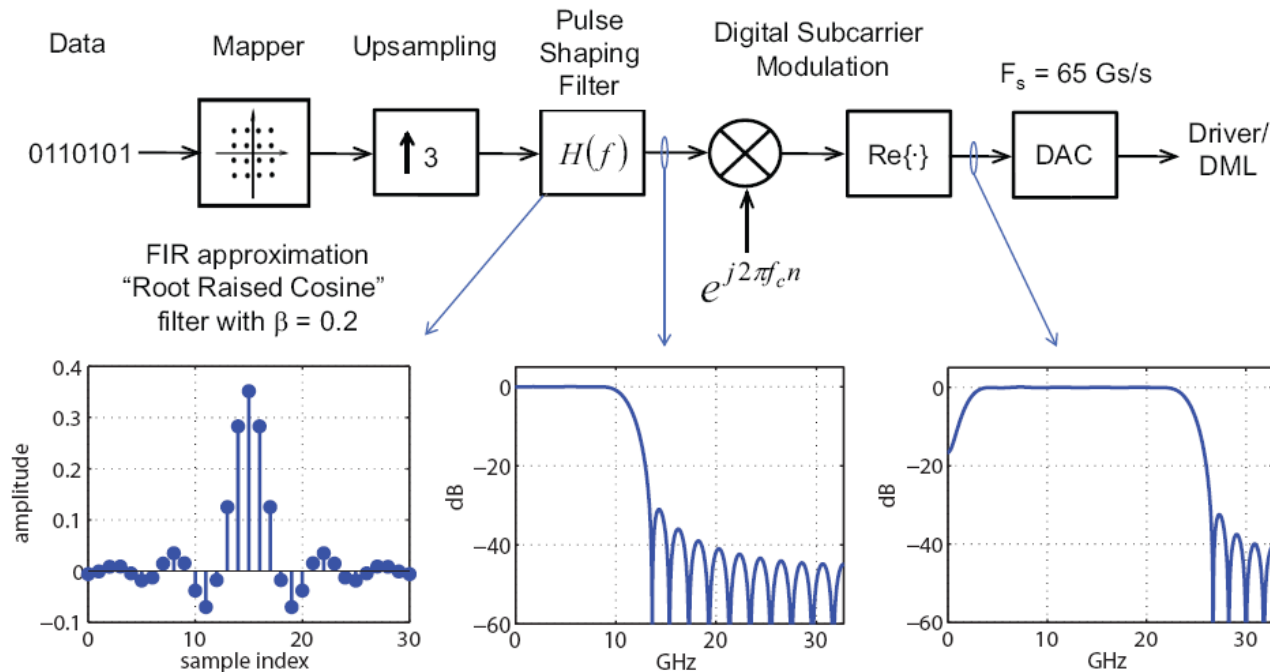
Discrete Multi-Tone (DMT) Modulation



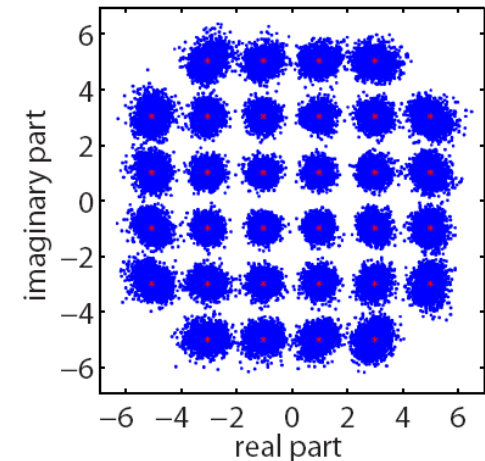
Each subcarrier samples only a small portion of system frequency response

⇒ Very resilient to amplitude and phase ripples

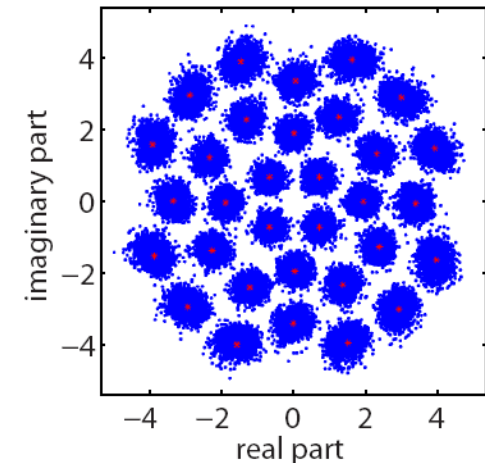
Quadrature Amplitude Modulation (QAM)



Conventional QAM32

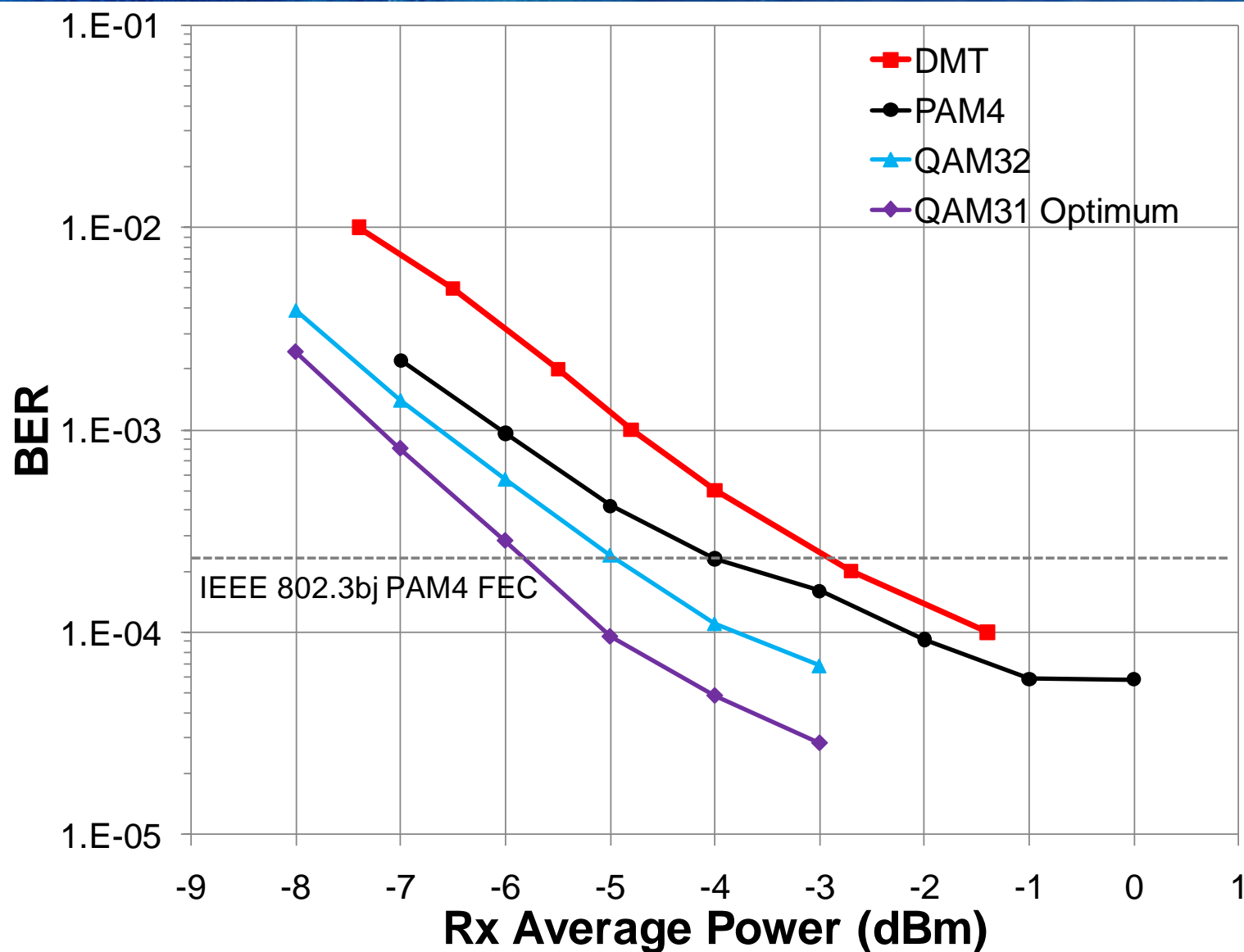


Optimized for DFB Tx

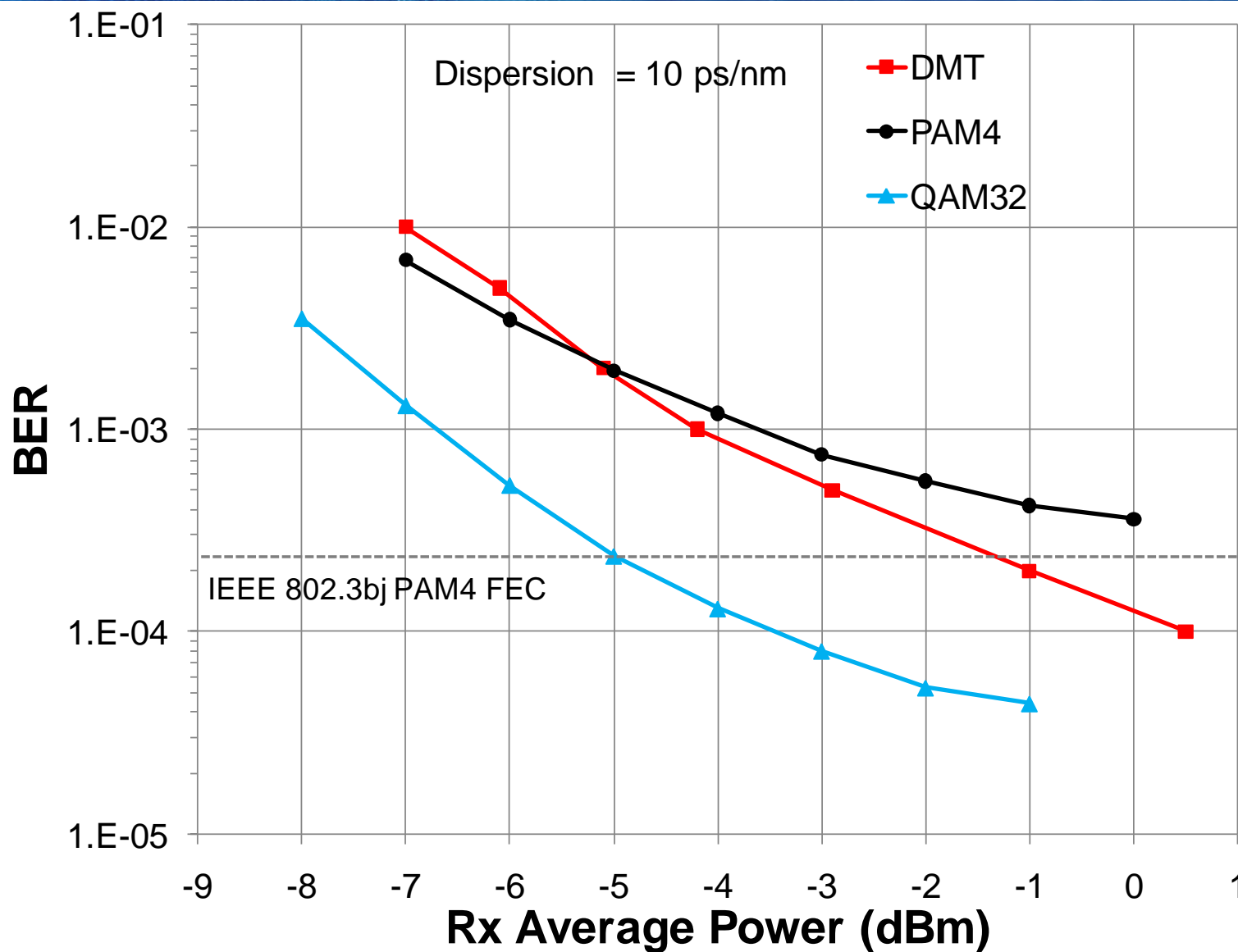


Source: W. Ling, I. Lyubomirsky, O. Solgaard, "Digital Quadrature Amplitude Modulation with Optimized Non-Rectangular Constellations for 100 Gb/s Transmission by a Directly-Modulated Laser," Optics Express, Vol. 22, Issue 9, pp. 10844-10857, 2014

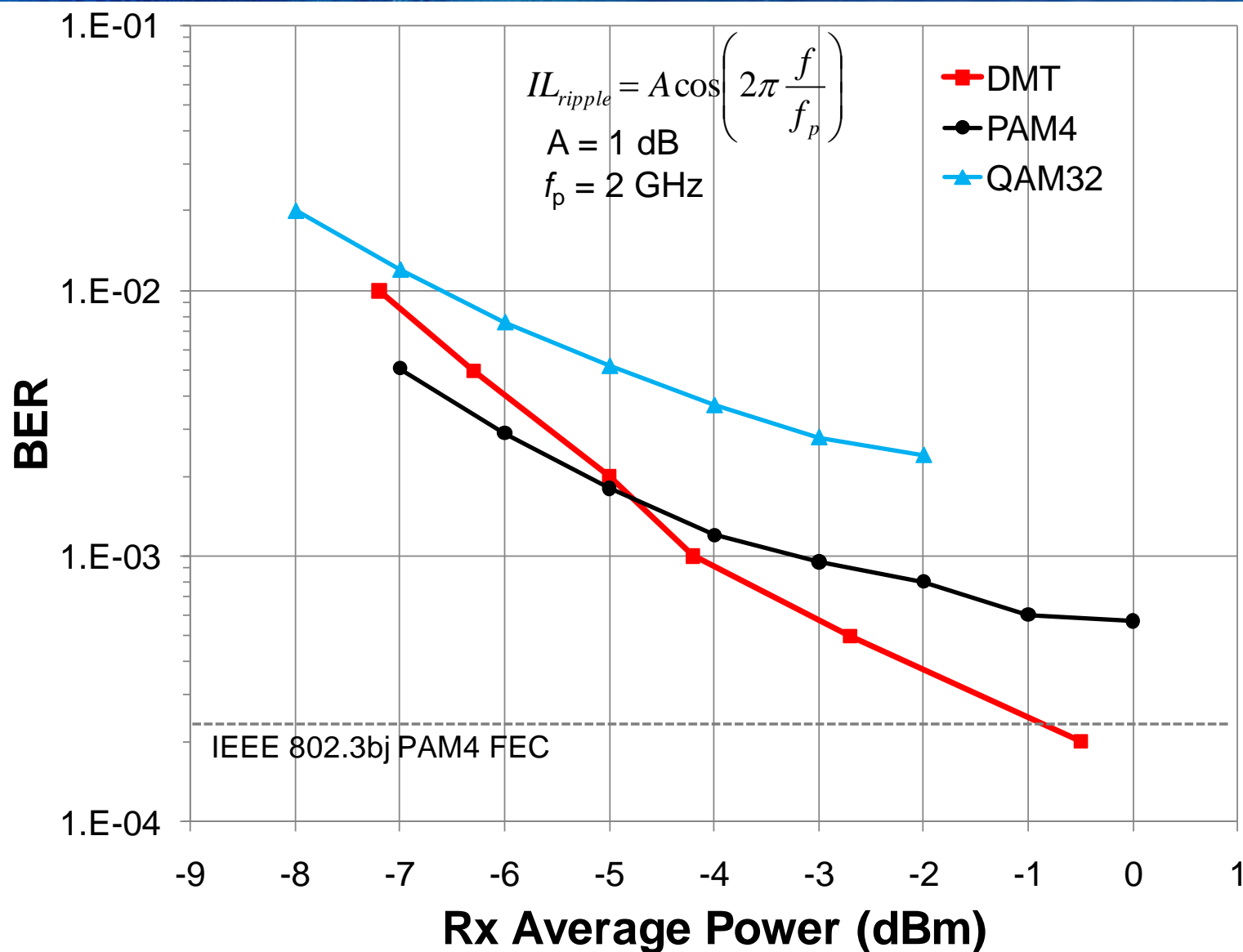
Modulation Comparison Back-to-Back (B2B)



Modulation Comparison with 10km SMF Dispersion



Modulation Comparison with RF Ripple



Modulation Comparison Summary

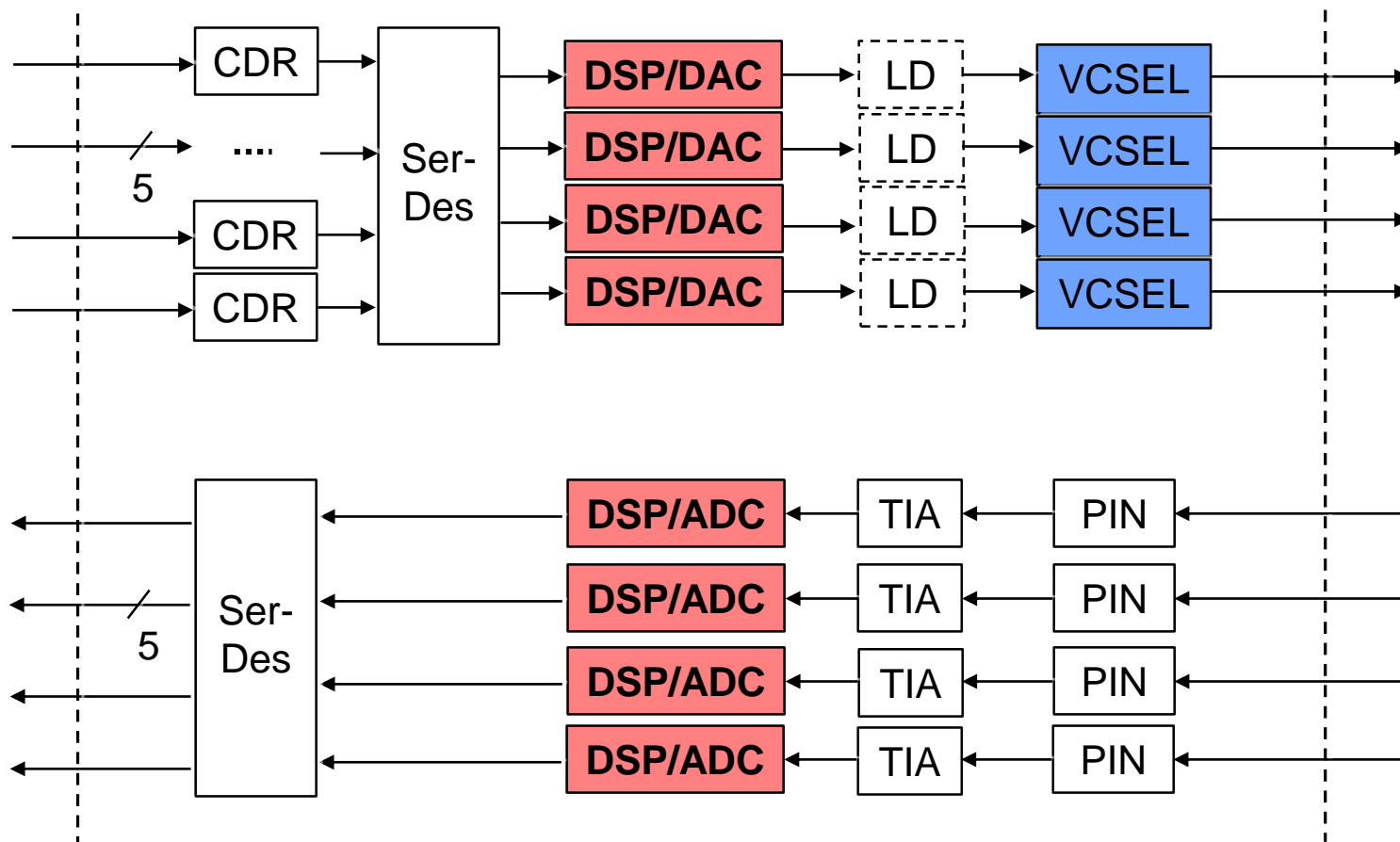
	PAM4	DMT	QAM
B2B Rx Sensitivity	Yellow	Yellow	Green
Dispersion	Red	Yellow	Green
RF Imperfections	Red	Yellow	Red
Power Dissipation	Green	Yellow	Red
Latency	Green	Yellow	Yellow

green = good

yellow = ok

red = potential trouble

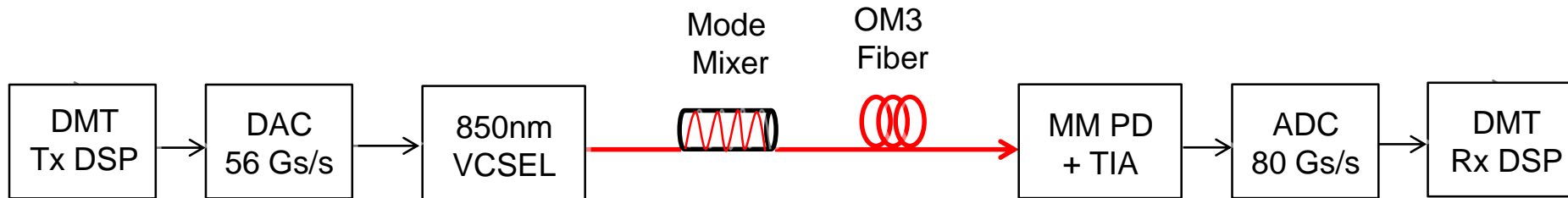
400GbE Parallel MMF Module Concept



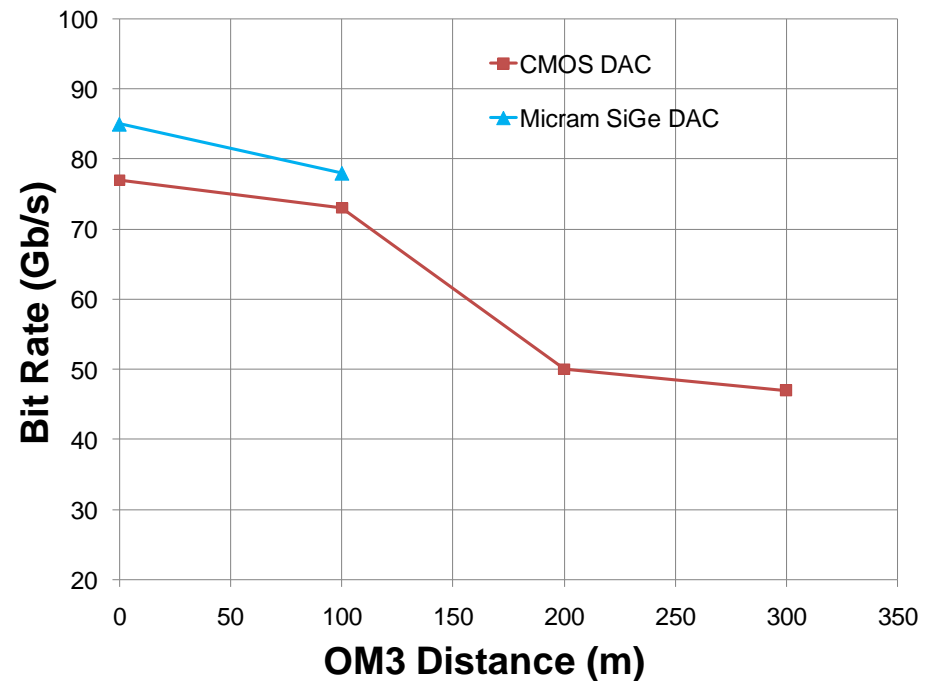
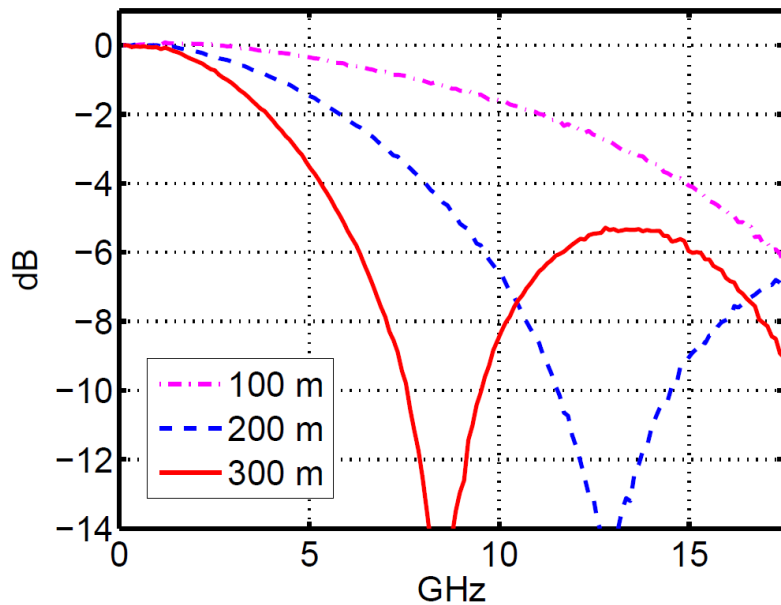
CDAUI 8x50G lanes

IEEE 802.3bs MMF

VCSEL DMT Experiment



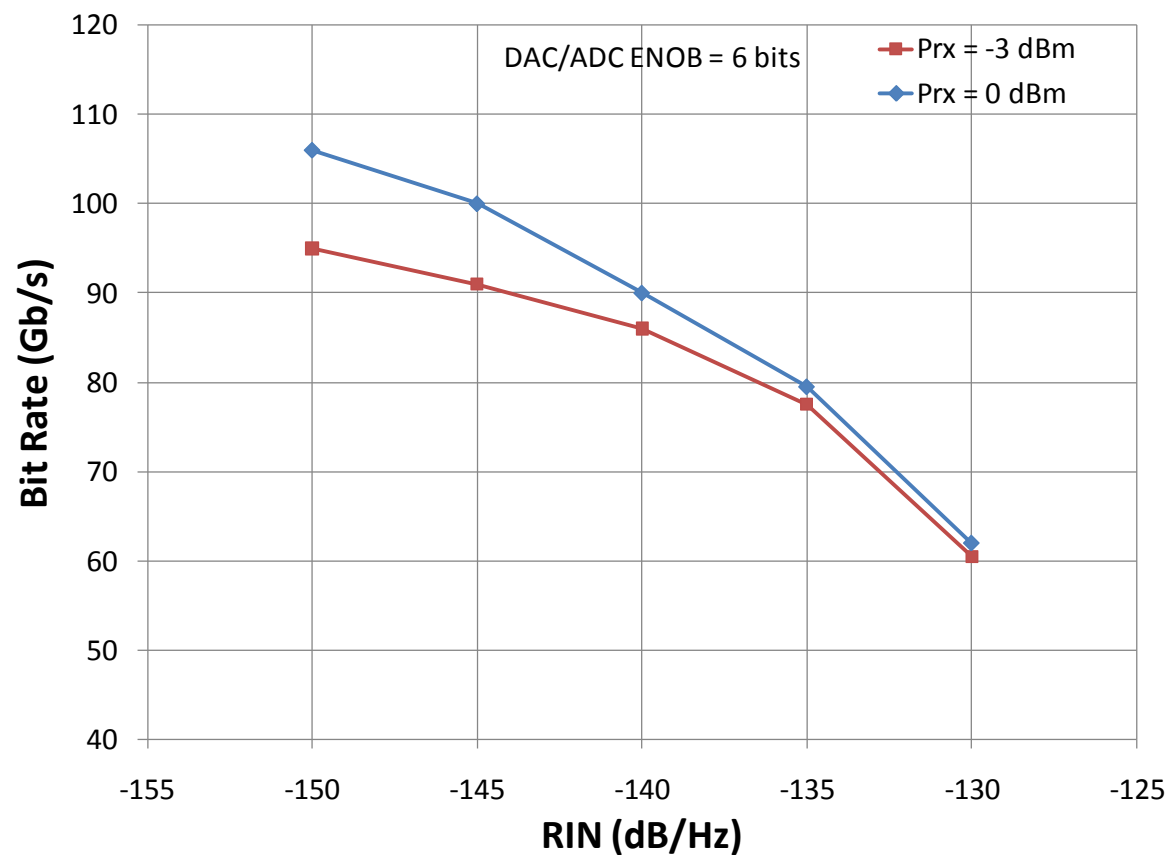
OM3 Transfer Functions



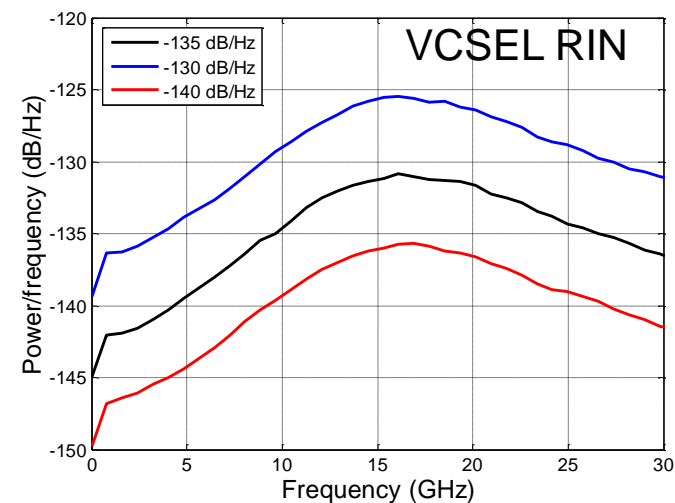
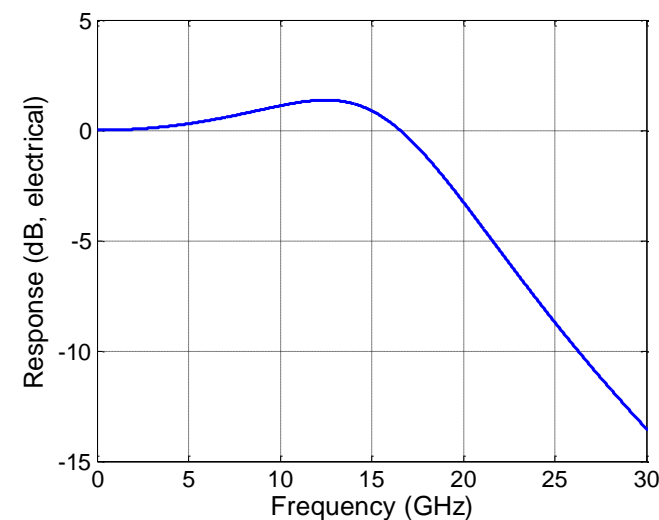
Source: I. Lyubomirsky, et. al. "56 Gb/s Transmission over 100m OM3 using 25G-class VCSEL and Discrete Multi-Tone Modulation," OIC, paper TuC2, Coronado, CA, May, 2014

Simulation Study on Feasibility of 100 GbE VCSEL

Max. Bit Rate at BER = 10^{-3} achievable with DMT



VCSEL small signal response



Next Step: Activate your 100GbE Archetype

“Are there people in legend, history, mythology or religion that truly inspire you? Study them, and then become them.”

- Deepak Chopra