LUXTERA

400G-PSM4: Design and Specification Exercises

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FIBER TO THE CHIP

Supporters

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- Will Bliss – Broadcom
- Vasu Parthasarathy – Broadcom
- Tom Palkert – Luxtera
- Tom Issenhuth – Microsoft
- Brad Booth - Microsoft

Caveats and Disclaimers

- ***This presentation is*** an investigation into design and spec development for a 400G-PSM4 solution.

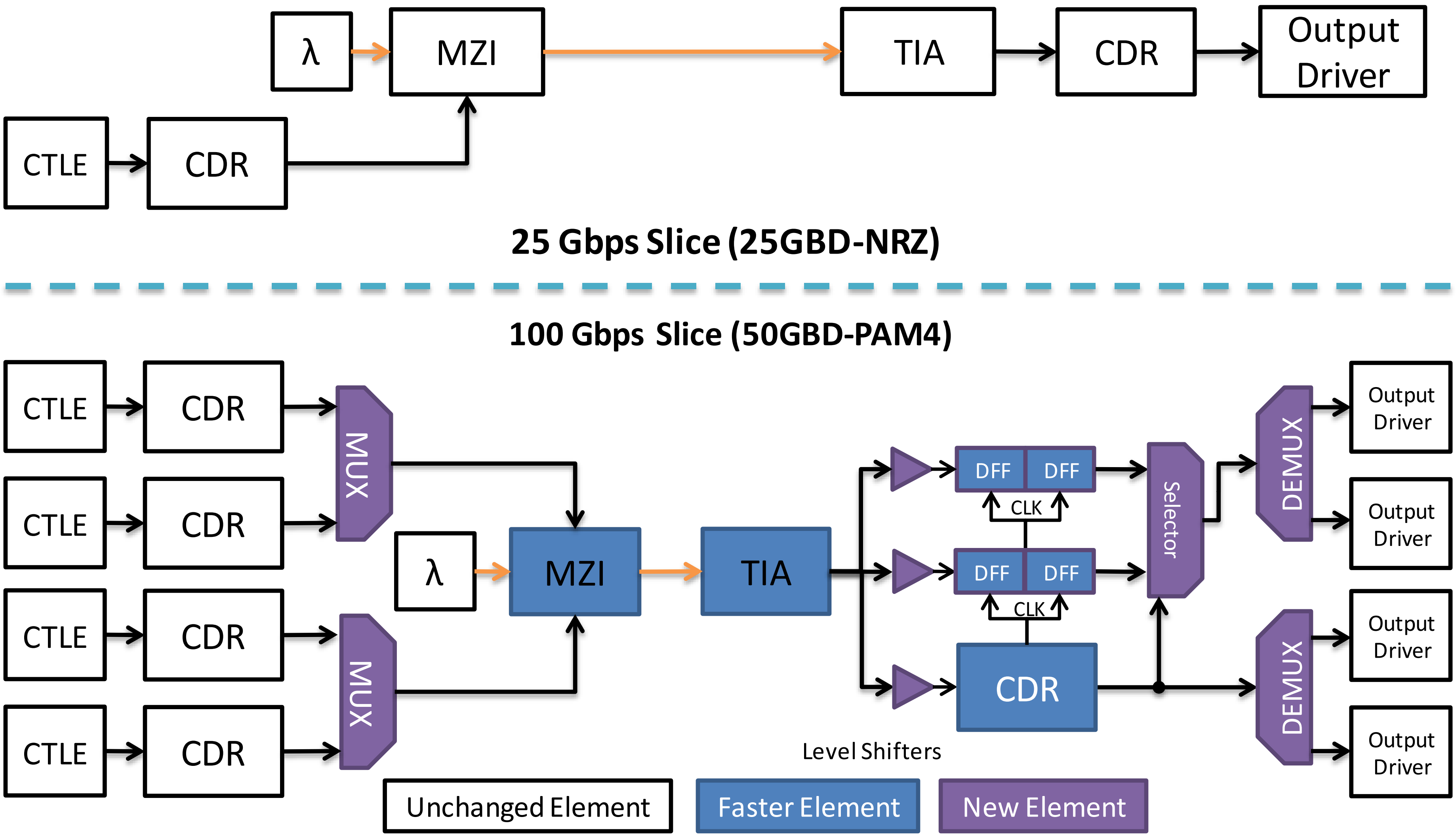
- ***This presentation represents*** work in progress, not finished designs nor specifications.

- ***This presentation is not*** a specification proposal.

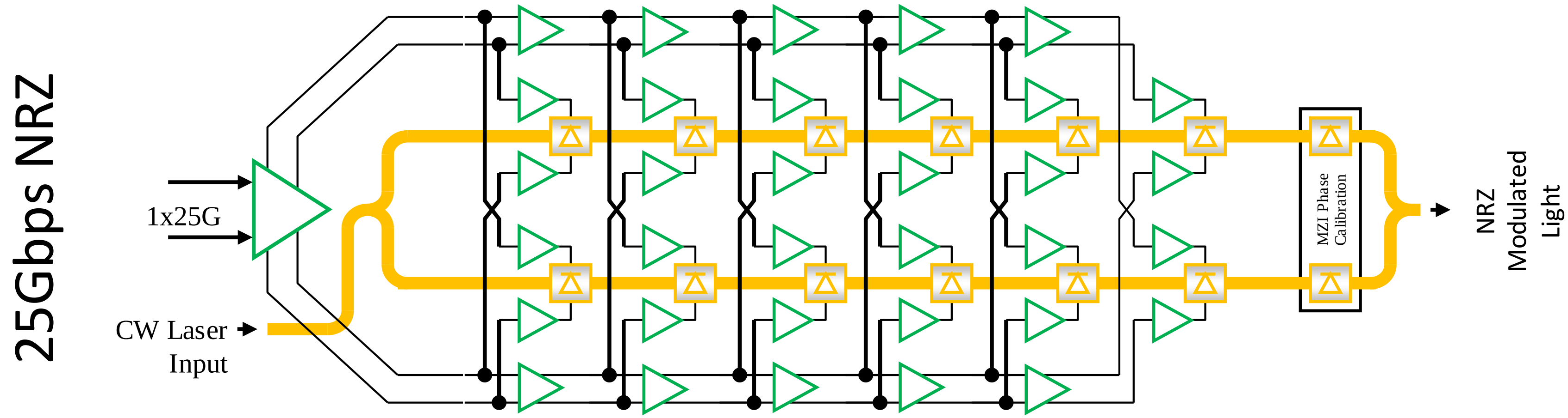
Overview

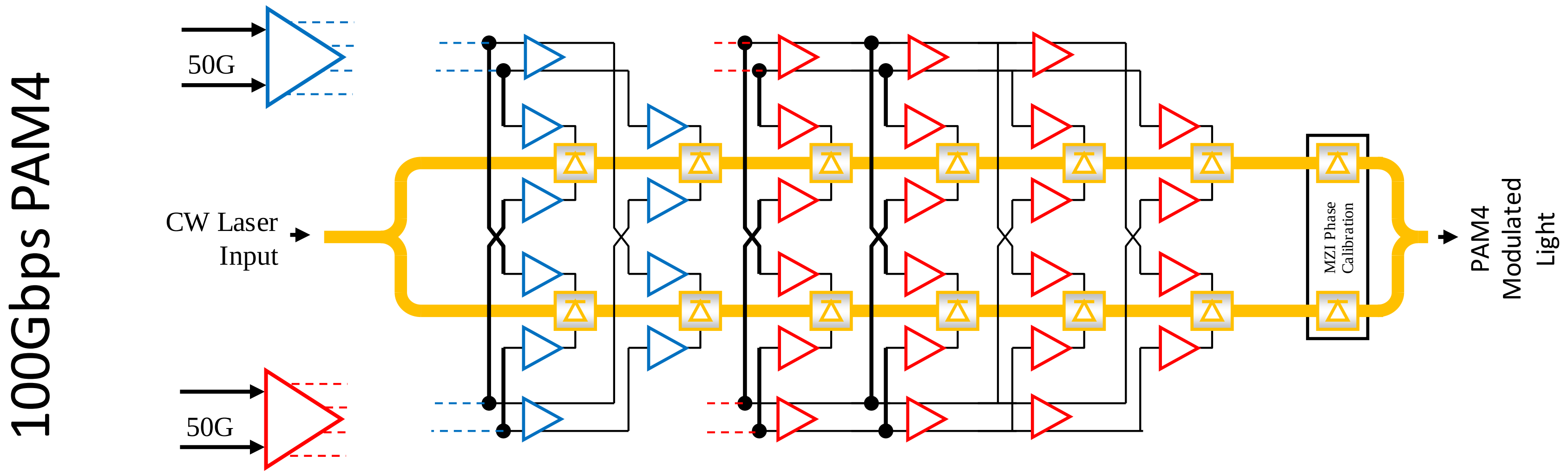
- Design Evolution
  - Design changes moving from 25GBD-NRZ lanes to 50GBD-PAM4 Lanes
    - Transmitter Encoder
    - TIA linearity
    - Receiver Decoder
  - Investigating simple solutions
- Spec evolution
  - Spec changes moving from 100G-PSM4 to 400G-PSM4
    - Receiver impairments due to bandwidth and linearity requirements
    - Transmitter impairments due to PAM4 encoding

Design Evolution – 25Gbps to 100 Gbps



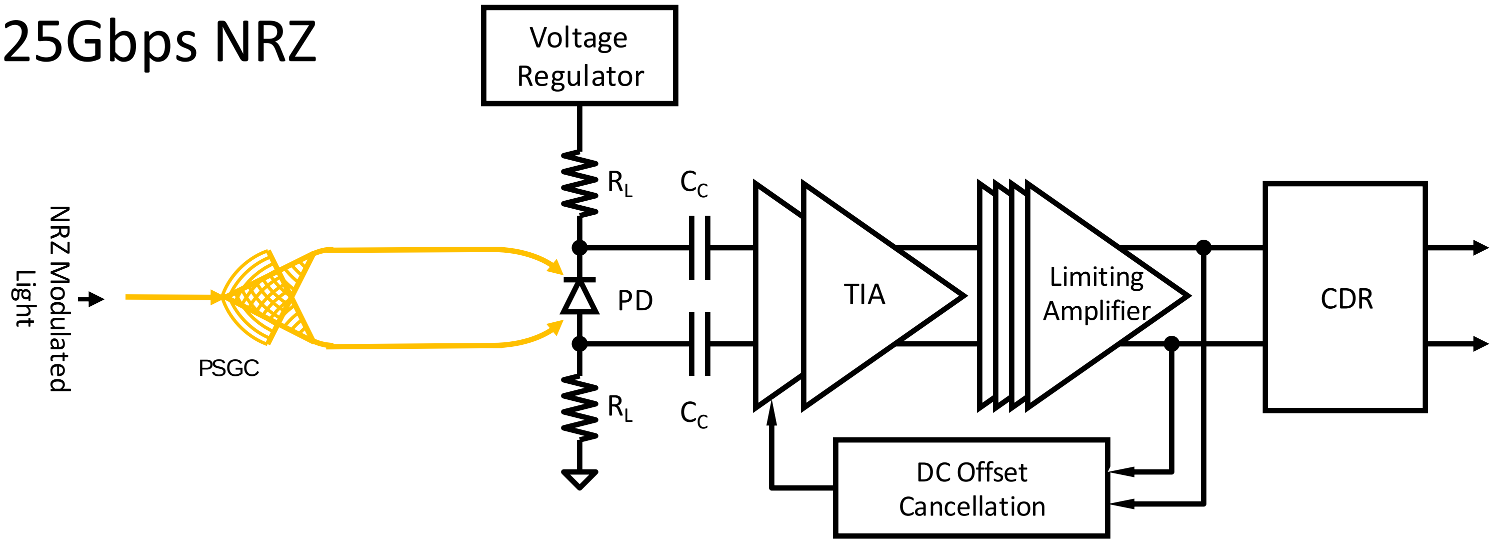
Design Evolution – Optical Transmitter/Encoder



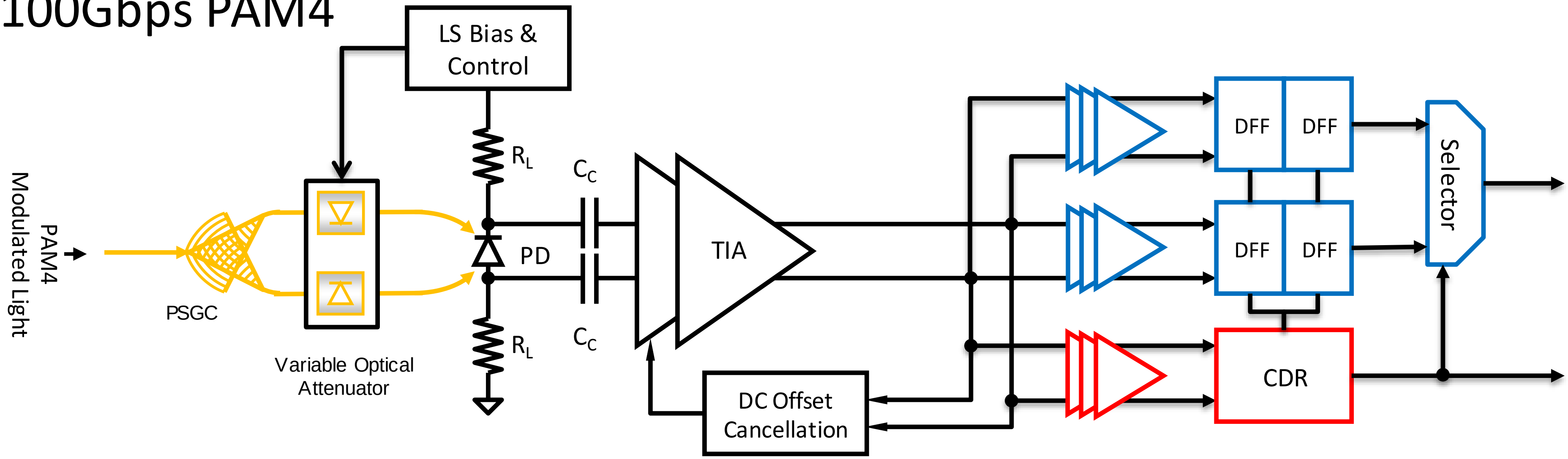


Design Evolution – Optical Receiver/Decoder

25Gbps NRZ



100Gbps PAM4



Design Evolution

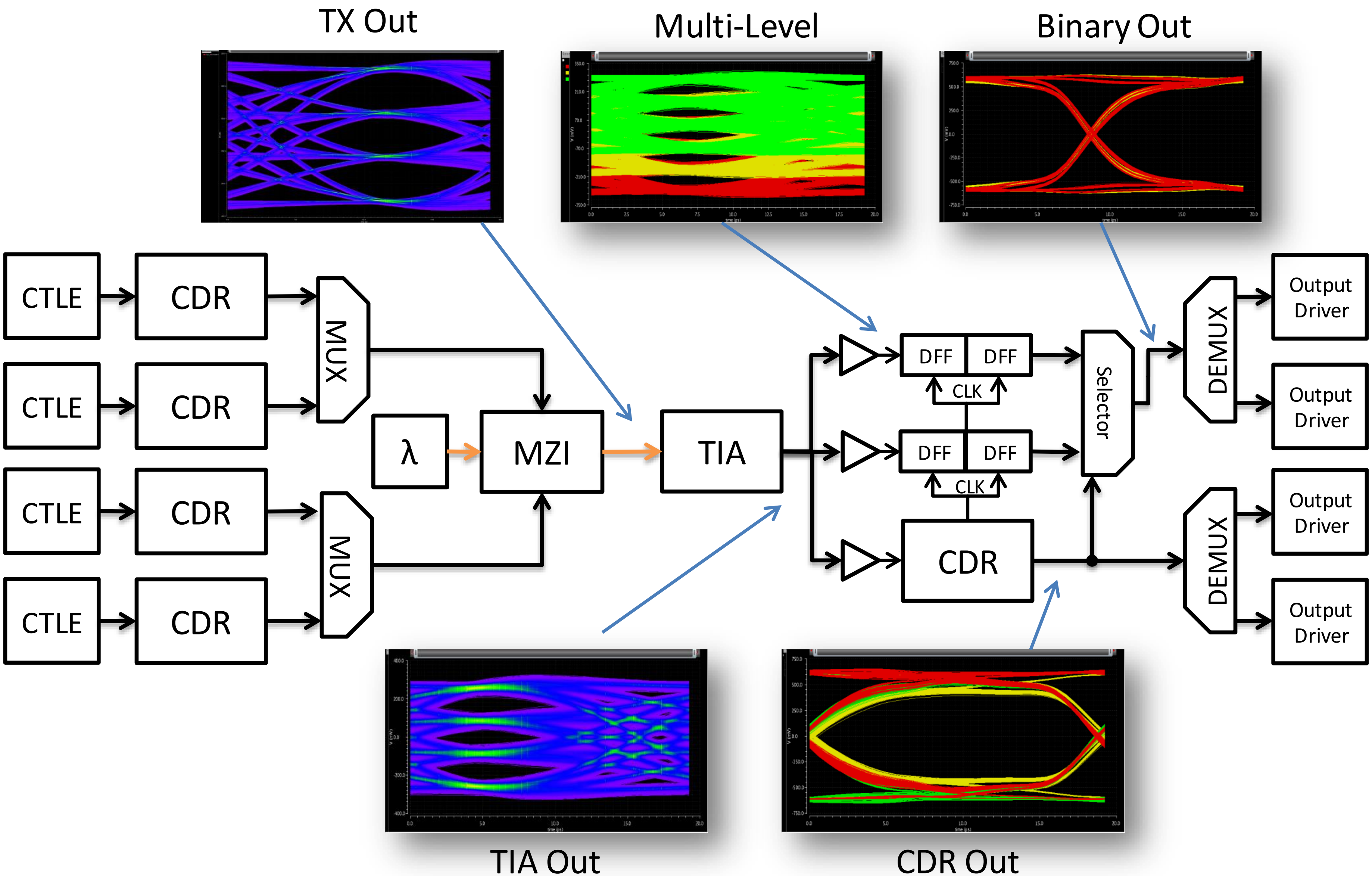
Optical Transmitter

- Break multi-segment MZI into two input device
  - Does PAM4 encoding optically from dual NRZ inputs
  - Does not require linear drivers or DAC
- Increase MZI baud rate
  - Higher bandwidth CMOS and/or reduced CMOS fanout required.

Optical Receiver

- Increase TIA bandwidth
  - Design and technology scaling
- Move to linear TIA with AGC
  - Here accomplished optically
- High baud rate CDR
  - CMOS scaling
- Analog PAM4 decoder
  - Level shifters create offset copies on PAM4 signal
  - Redundant signal paths from CDR, sharing common clock signal
  - Selector for conversion back to binary sinaling

Design Simulation – 100 Gbps PAM4 link



Specification Evolution

100G-PSM4 to 400G-PSM4

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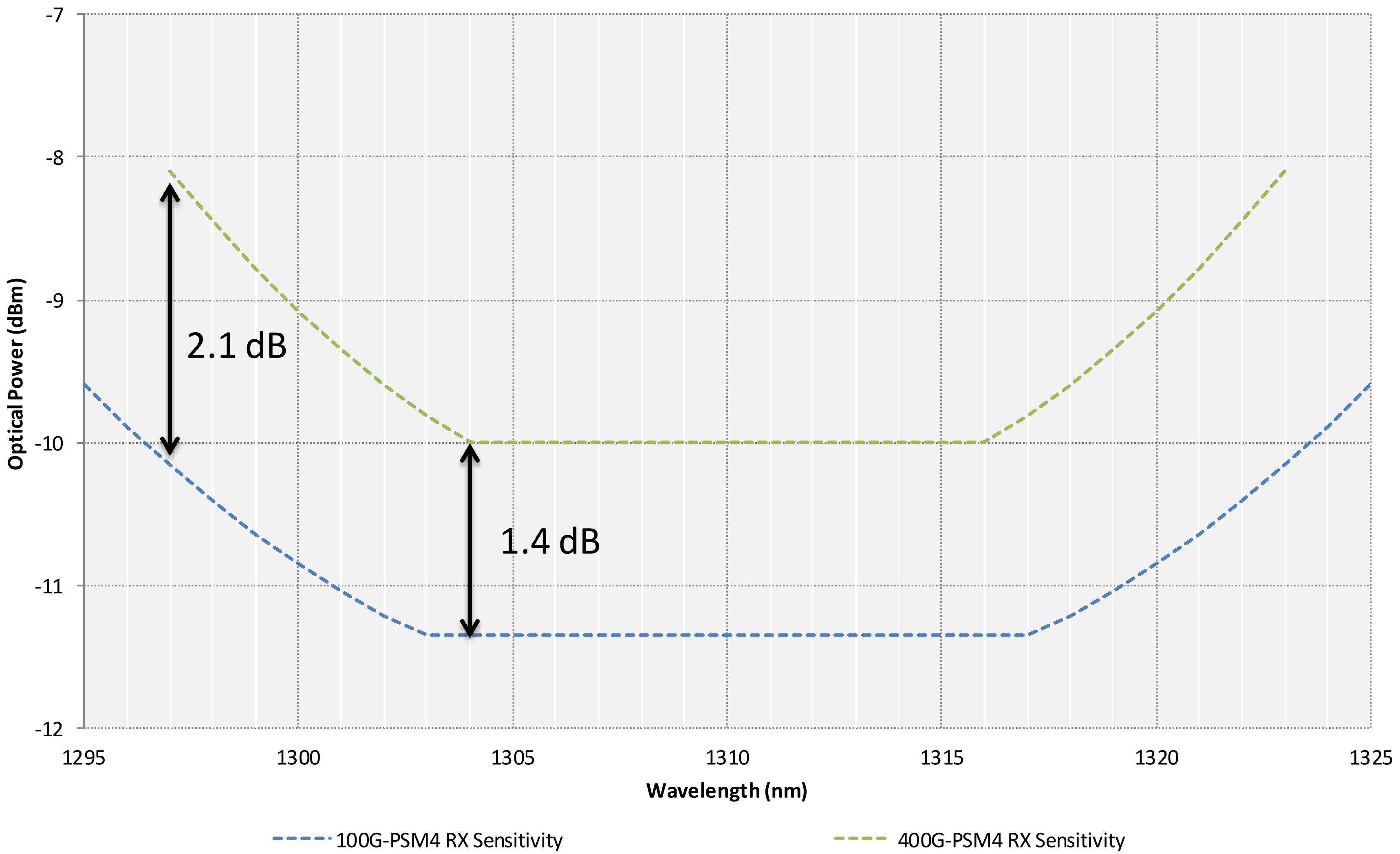
400G-PSM4 Spec Evolution - Receiver

- Use 100G-PSM4 as a baseline
  - Assume same uncorrected BER of 5e-5
    - *For ease of comparison to 100G*
    - *Actually may be lower to account for 1e-13 corrected BER requirements*
- Begin with receiver sensitivity relaxations
  - Approximately 1.5 dB of TIA noise penalty due to increase TIA bandwidth
  - Approximately 0.5 dB of TIA penalty due to linearity/AGC requirements
- 400G-PSM4 vs. 100G-PSM4
  - Slightly narrower total optical bandwidth (26nm vs. 30nm)
  - 2.1 dB of relaxation at bandwidth extremes
    - Most challenging portion of curves for 100G PSM4
  - 1.4 dB of relaxation at center bandwidth

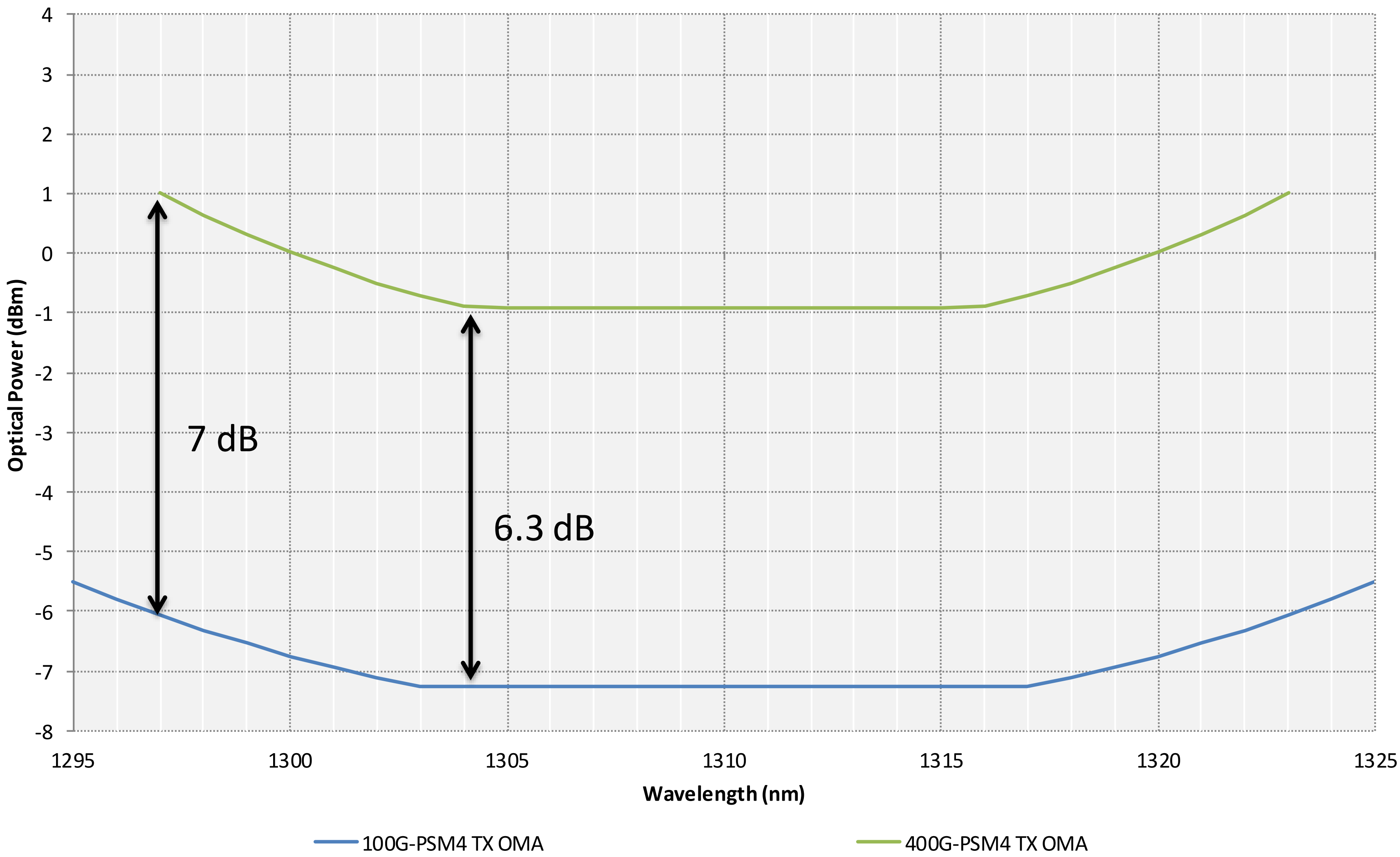
400G-PSM4 and 100G-PSM4 : Receiver Sensitivity



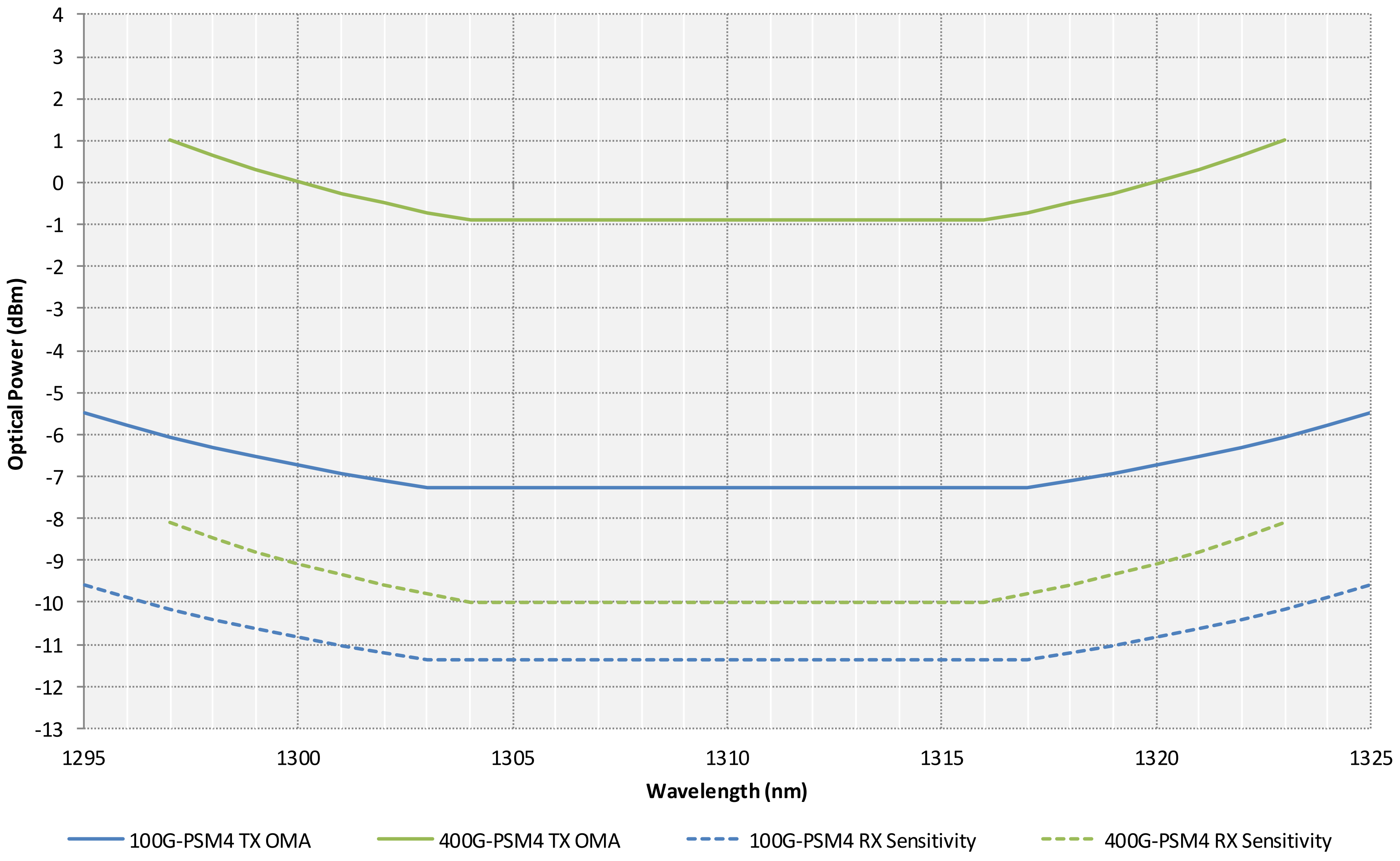
400G Spec Evolution - Transmitter

- Working back from receiver sensitivity specs
- 400G-PSM4 vs. 100G-PSM4
  - 4.77 dB link penalty due to PAM4 encoding
  - 0.7 dB of excess penalty due to MPI, Rin, and Level Accuracy
    - Assuming -35 dB connector reflectance, Rin ~ -142 dB/Hz
  - Jitter Anti-Penalty ~ 0.5 dB
    - Non Dual Dirac Jitter
    - *Value subject to further investigation*
- 400G-PSM4 vs. 100G-PSM4
  - 5 dB greater link margin (measured to $OMA_{11\text{-}00}$)
  - 6.3 dB OMA increase in center band
    - 5 dB increase average power increase, with min ER increasing from 3.5 dB to 5 dB
    - Roughly consistent optical power per unit throughput as 100G

400G-PSM4 and 100G-PSM4 : Transmitter OMA



400G-PSM4 and 100G-PSM4



Summary

- Design evolution from 100G-PSM4 to 400G-PSM4 can be relatively simple
  - Baud rate scaling from 25G to 50G
  - Moderate revisions to transmitter architecture
  - Moderate revisions to TIA
  - Multi-path slicers in CDR and selector for PAM4 decoding to 2xNRZ signaling

- Spec evolution from 100G-PSM4 to 400G-PSM4 allows for
  - Reasonable relaxation of optical receiver sensitivity
  - Moderate scaling of transmitter OMA requirements
    - Optical power scales linearly vs. net throughput from 100G
  - No optical Mux/Demux elements required

Next Steps

- Build out link simulation to:
  - Refine noise models
  - Refine jitter 'Anti-Penalties'
  - Refine transmitter OMA requirements

- Investigate duplex solutions
  - Apply four wavelength WDM to 400G-PSM4 slice design
  - CWDM? (2km reaches?)
  - LWDM? (10km reaches?)

Thank You