Modulation proposal for 200G/L solutions for 500m and 2km reaches

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Overview

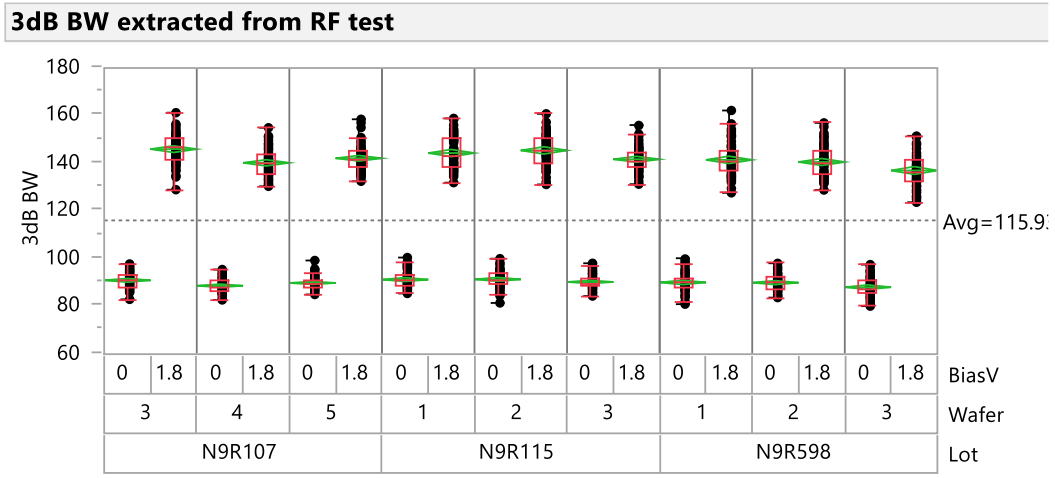
- Proposal (PAM4) and Motivations
- Optics Outlook
  - Component bandwidth
  - (Early) Simulation results
- Electronics Outlook
  - CMOS scaling
  - Measurement Results
  - Industry Results
- Summary

Proposal (PAM4) and Motivations

- **Proposal**: Use PAM4 as the modulation type for 200G/L optical solutions at 500m and 2km reaches.
- **Motivations**:
  - PAM4 (after considerable work) is well understood for both design and test
  - PAM4 link penalties (especially MPI) are well understood and reasonably contained.
    - Higher order PAM modulation may lead to considerably higher link penalties
  - PAM4 enables multi-rate (backward compatibility) to 100G/L and lower rates
    - Alternate modulations schemes, such as PAM6, would bring considerable complexity and/or penalty to support multi-rate operation. Including much higher DAC resolution for optical transmitters (up to 15-bit DAC resolution) or > 2dB OMA penalty.

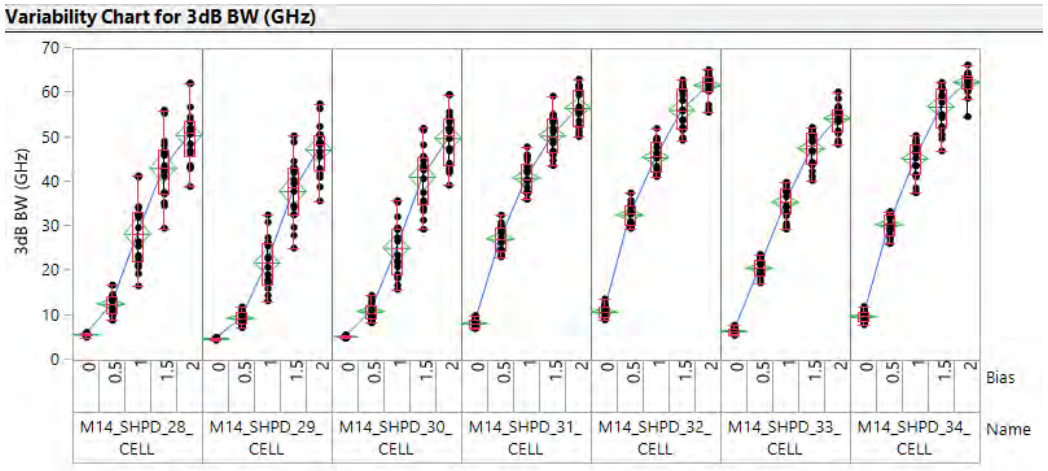
Optics Outlook: Component Bandwidth

Transmitter: MZI



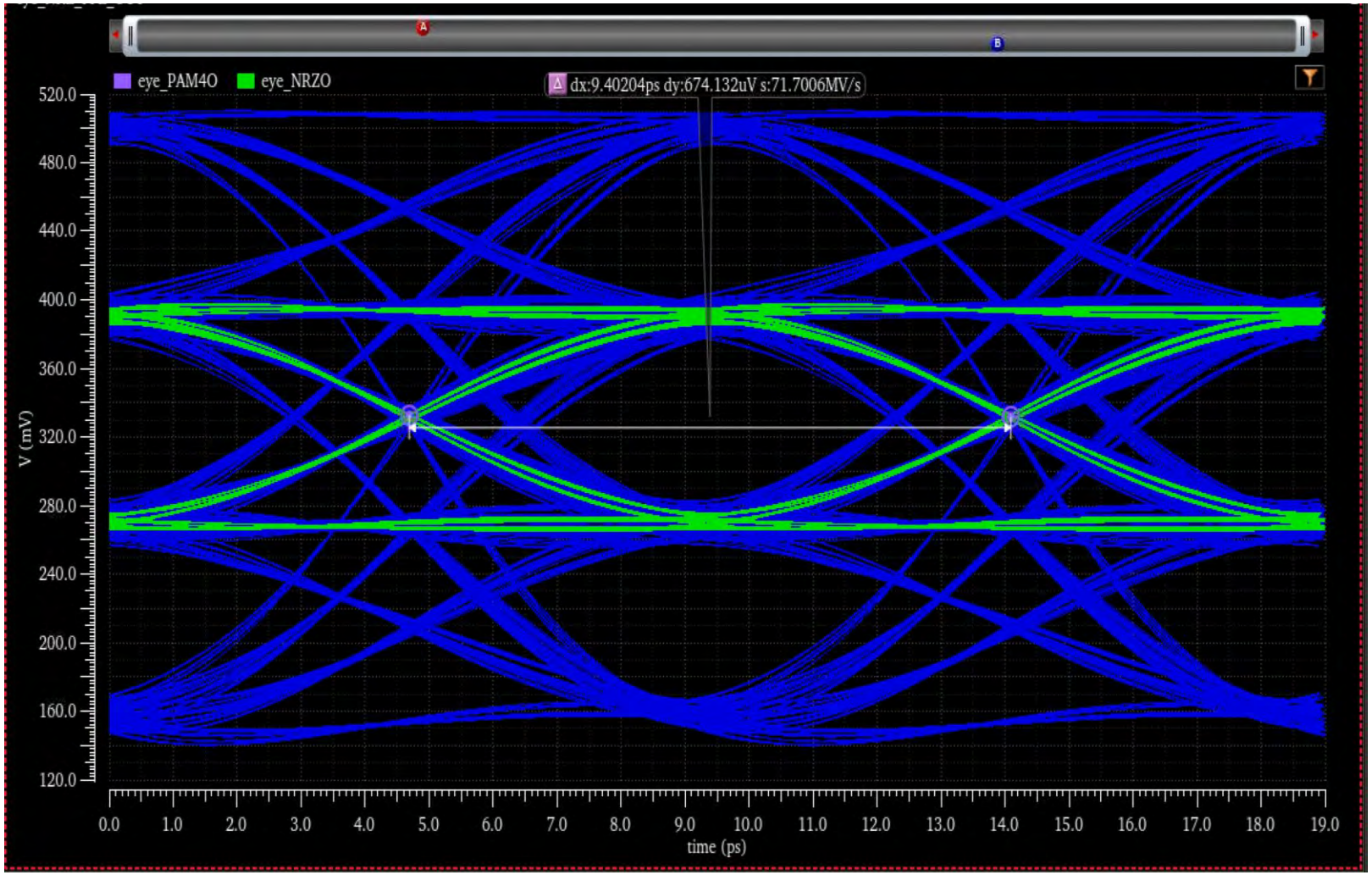
- Silicon photonics MZI component (phase shifting diodes) bandwidth demonstrated (across multiple sites/wafers) to ~ **115 GHz**

Receiver: PD



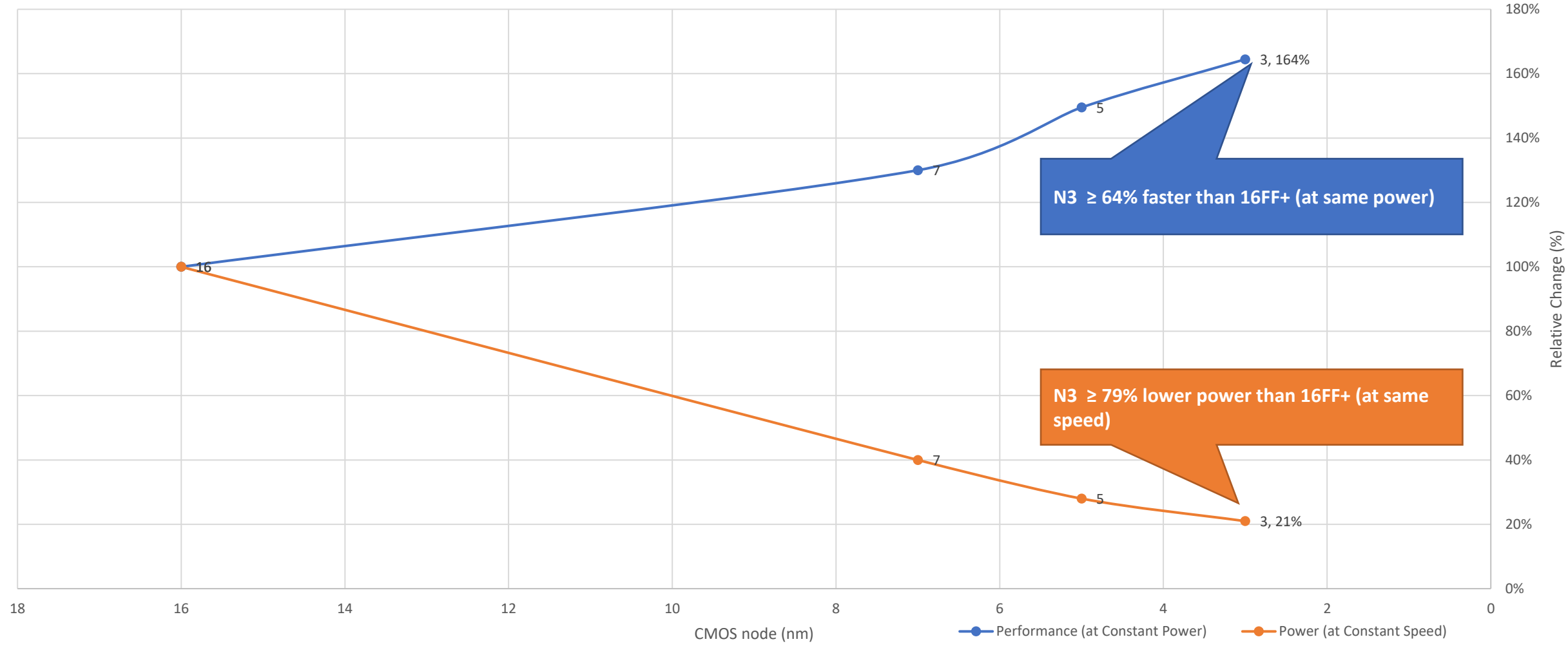
- Silicon photonics receiver component (PIN photodiode) bandwidth demonstrated (across multiple sites/wafers) up to **62 GHz**
- Practical receiver implementation for 200G/L likely to have more restricted bandwidth (~50 GHz or less) to optimize receiver sensitivity. Use RX equalization to compensate.

Optics Outlook: Simulation Results (Transmitter)



- Early simulation result of 106 GBD-PAM4 MZI
- MZI+Driver only: No input jitter applied in this simulation.
- No output filter or equalization

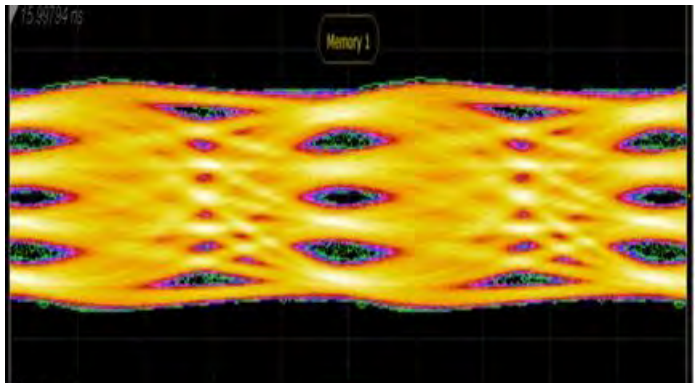
Electronics Outlook: CMOS Scaling



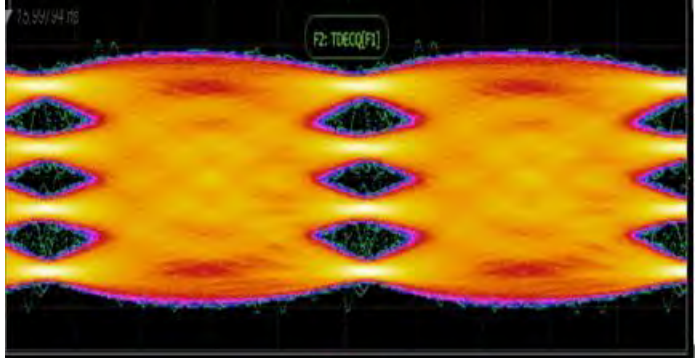
https://www.anandtech.com/show/16024/tsmc-details-3nm-process-technology-details-full-node-scaling-for-2h22

Electronics Outlook: Measurement Results

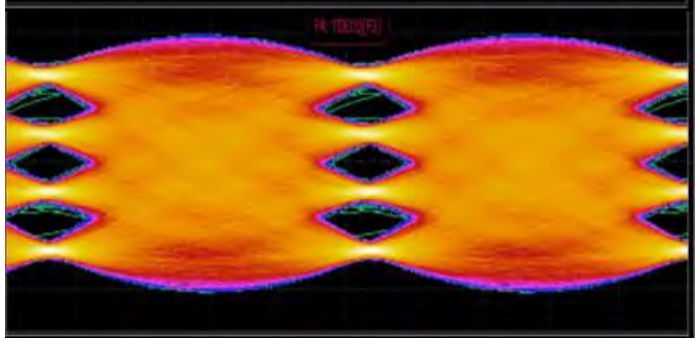
Filter BW: 85 GHz
No EQ

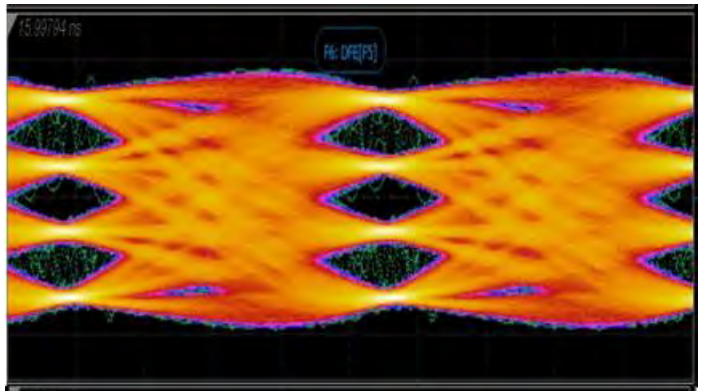


Filter BW: 56 GHz
5T FFE
TDECQ: 3.12 dB



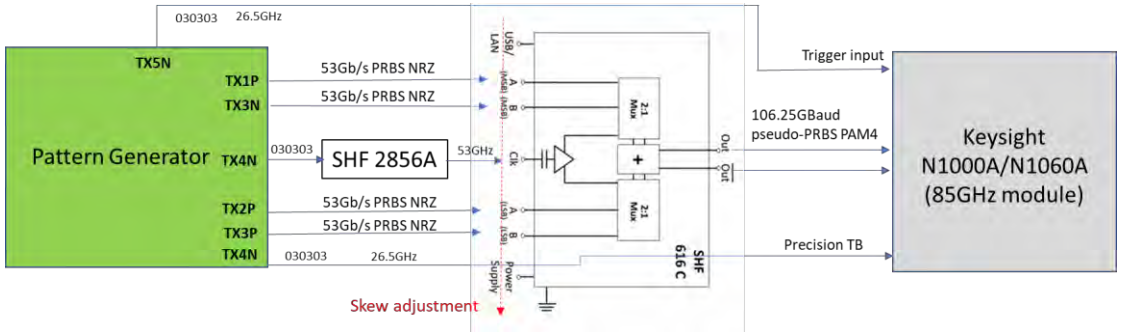
Filter BW: 40 GHz
7T FFE
TDECQ: 3.17 dB





Filter BW: 85 GHz
15T FFE + 1 DFE
TDECQ: 1.09 dB

Filter BW: 40 GHz
15T FFE + 1 DFE
TDECQ: 1.35 dB



Electronics Outlook: Industry Results

- *A 224 Gb/s DAC-Based PAM-4 Transmitter with 8-Tap FFE in 10nm CMOS,* IEEE International, Solid State Circuits Conference, Jihwan Kim, Sandipan Kunda, et. Al.

- OIF CEI-224G: https://www.oiforum.com/technical-work/current-work/#cei-xsr

Summary

- Technologies exist to support 200G/L using PAM4:
  - Optical component bandwidths ≥ 56 GHz
  - Electrical 224G-PAM4 already demonstrated in 10nm CMOS, more advanced nodes (3nm or smaller) expected in production
- PAM4 provides the best path to multi-rate operation
  - Backward compatibility (to 100G/L optics) has emerged as a strong market requirement for 800GE.
- PAM4 for 200G/L not likely to drive highest baud rate
  - Likely ≤ 112GBD for PAM4. vs ~ 120GBD for Coherent
- **Recommendation: Focus 200G/L optical PMD proposals on PAM4 modulation**

Thank You