Demonstration of Optical 56Gbps NRZ for 400GbE PMD Using 56Gbps SerDes

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IEEE802.3bs 400GbE Task Force
San Antonio Plenary Meeting
November, 2014

HUAWEI

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Supporters

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Introduction

- 56Gb/s NRZ considered a promising candidate for 400GbE PMD due to its simplicity, high sensitivity, and high tolerance to MPI:

  cole_01_0914_smf.pdf; qian_3bs_01_0714.pdf; zhu_3bs_01a_0514.pdf; zhu_3bs_01_0714.pdf; shirao_3bs_01a_0714.pdf; stassar_01_1014_smf.pdf

- In September Interim Meeting, we demonstrated optical 56Gbps NRZ operation using commercially available 43G optical transmitter and receiver for 400GbE PMD (wen_3bs_01_0914.pdf).

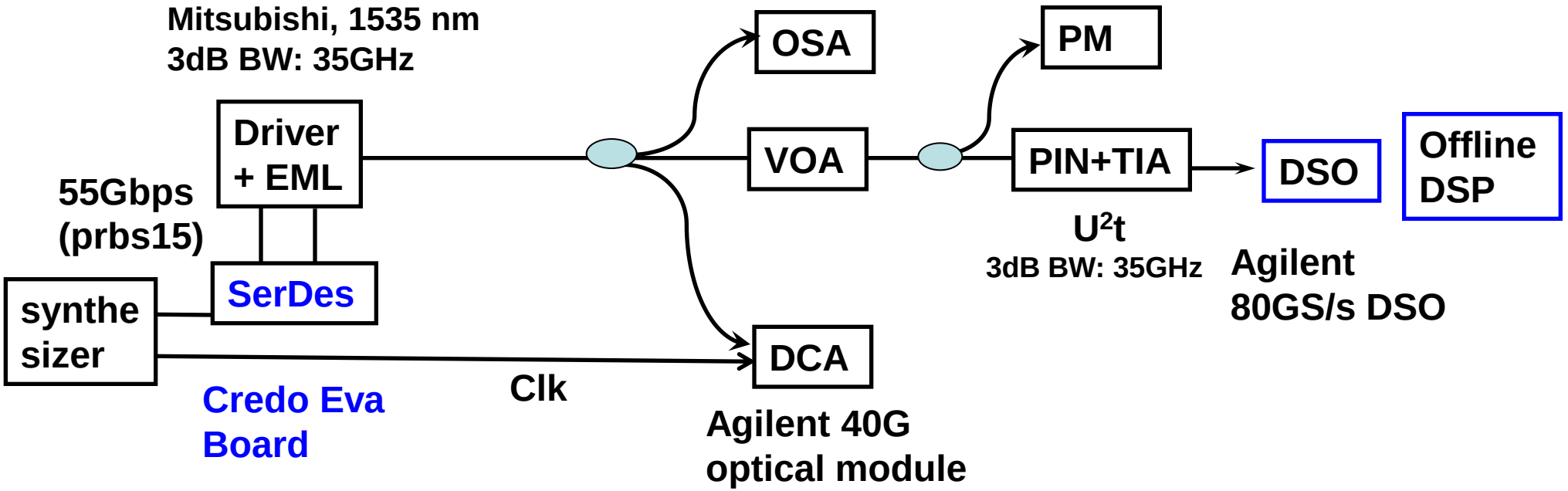
- The electrical signal in wen_3bs_01_0914.pdf was generated by using 56Gbps bit pattern generator, which is an instrument. There has been concern regarding the availability of 50GHz electrical I/O.

- It is desirable to demonstrate 56Gbps electrical signaling generation using SerDes, which is important for practical implementation.

Work in this Presentation

- In this presentation, we
  - Demonstrate 56Gbps NRZ for 400GbE PMD using 56Gbps SerDes electrical signaling with commercial 43Gbps optical components
  - Evaluate receiver sensitivity for both BtB and with chromatic dispersion
  - Analyze optical link budget for 400GbE 2km and 10km PMD

Experimental Setup



- **Operation conditions of driver and EML:**
  - **Laser bias current = 80mA**
  - **Operating temperature: 40 deg C**
  - **V_{OS} =-2.0V; V_{EE}=-5.2V; V_G=-2.2V; V_X =-1.5V**

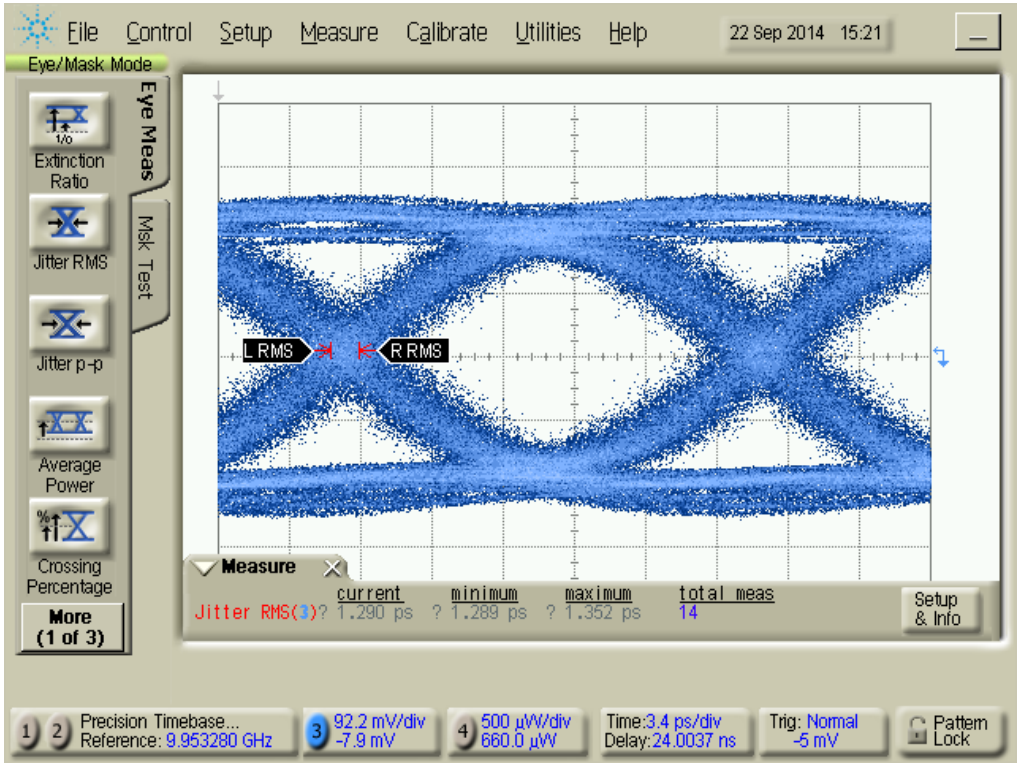
- **Tx analog equalizer: 3-tap FFE**
- **Rx equalizer: 5-tap FFE**
- **Equalization algorithm:**
  - **LMS with no training**

S21 responses of Mitsubishi driver+EML and U2t receiver can be found in wen_3bs_01_0914.pdf

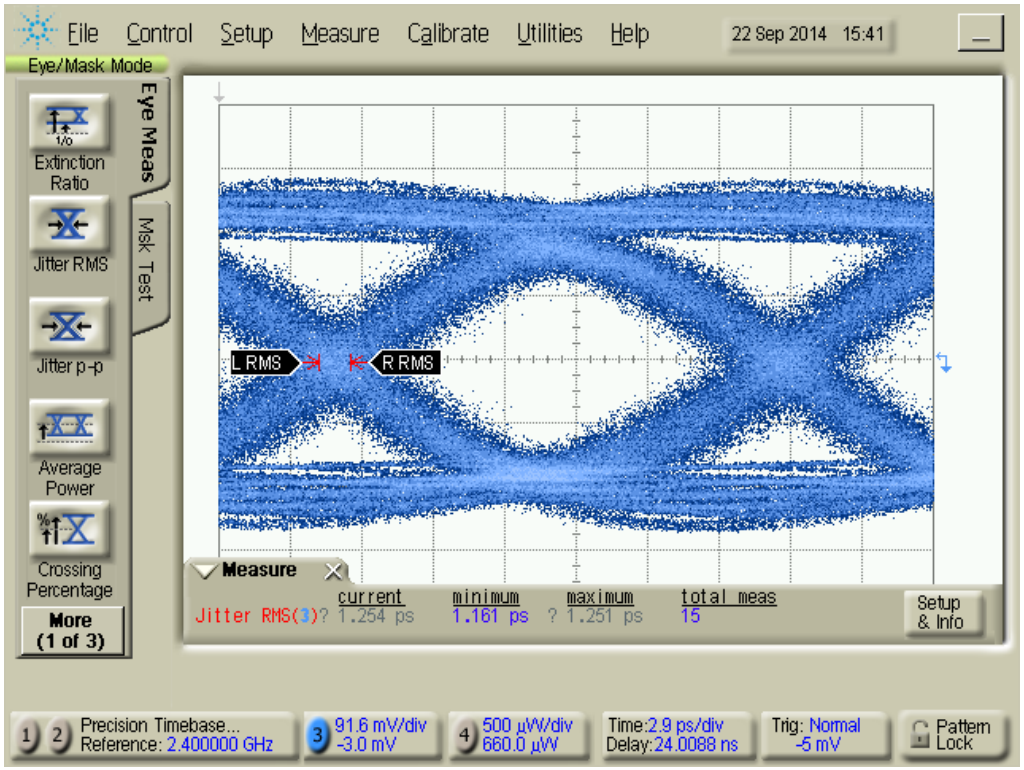
Credo 56G SerDes

- **Based on commercially available 40nm CMOS technologies**
- **Using analog equalization in TX**

Eye Diagrams of SerDes Output



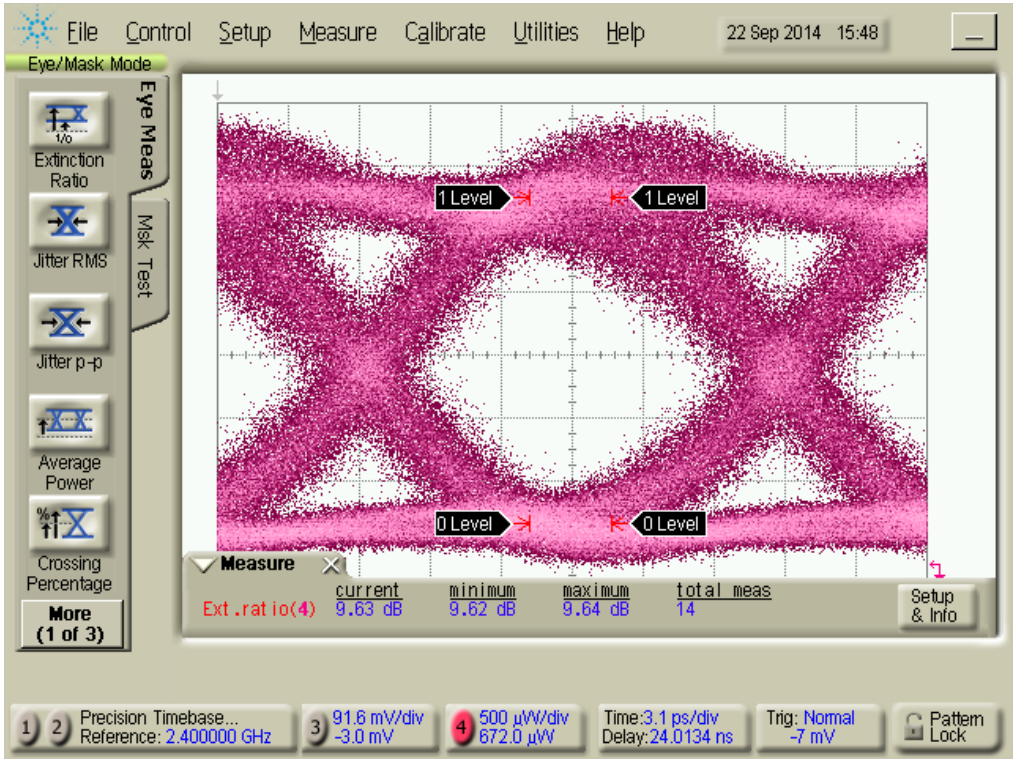
50Gbps



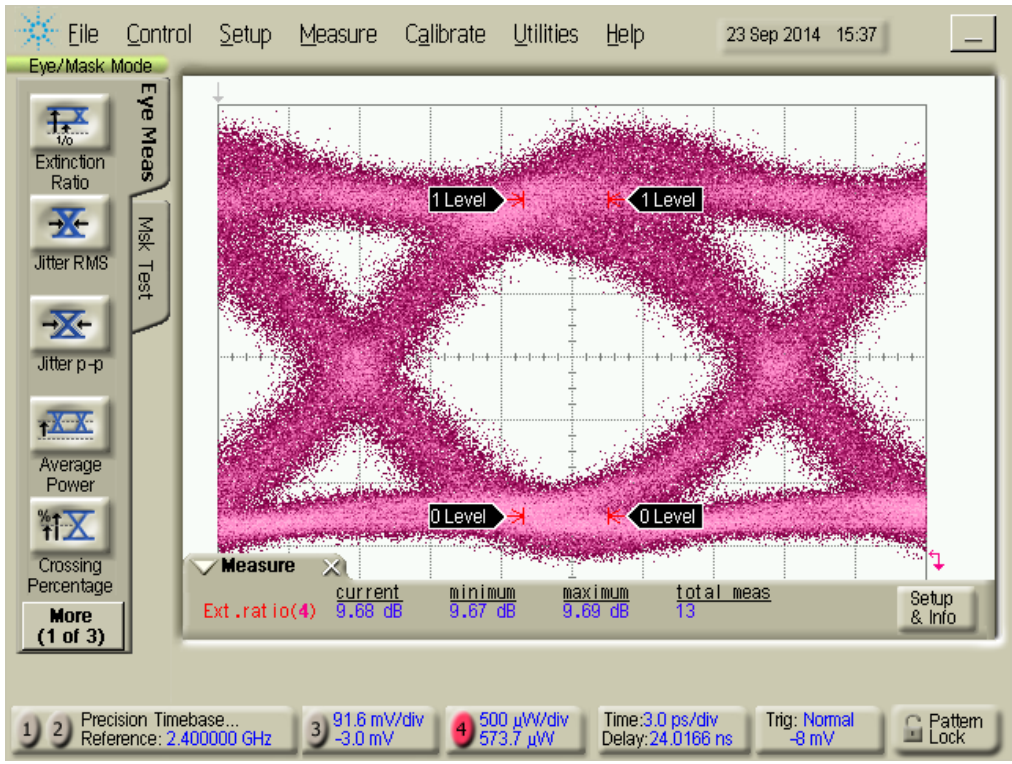
55Gbps

Optical Eye Diagrams

With Credo SerDes, 55Gbps

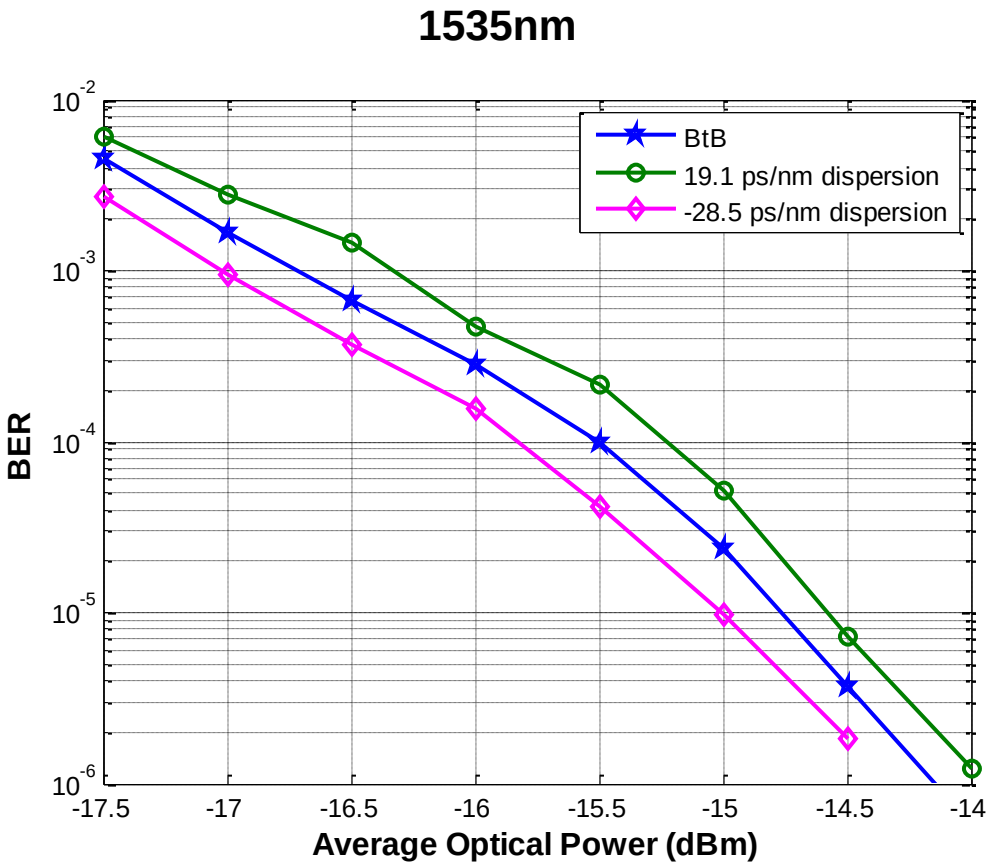


With SHF BPG, 56Gbps



- **ER = 9.6dB**
- **The optical eye diagram using Credo SerDes has similar eye quality to that of using a bit pattern generator (instrument)**

BER vs Average Optical Power



➢**Dispersion used in test covers the worst cases for both wavebands of:**

1286.66~ 1318.35 nm

And

1295.56~ 1327.69 nm

➢**The BtB sensitivity is around -16.7dBm at BER@1e-3 and -15.8dBm at BER@2e-4**

➢**Negative dispersion experiences negative penalty due to positive chirping**

➢**Observed dispersion penalty due to positive dispersion is less than 0.5dB**

Dispersion Effect for Different Wavelengths

Dispersion effect applied on optical signal via $\beta_2 L$

$$\beta_2 L = -\frac{\lambda^2}{2\pi c} DL$$

β_2 – 2nd order derivative of propagation constant over frequency

L – fiber length

D – fiber dispersion coefficient

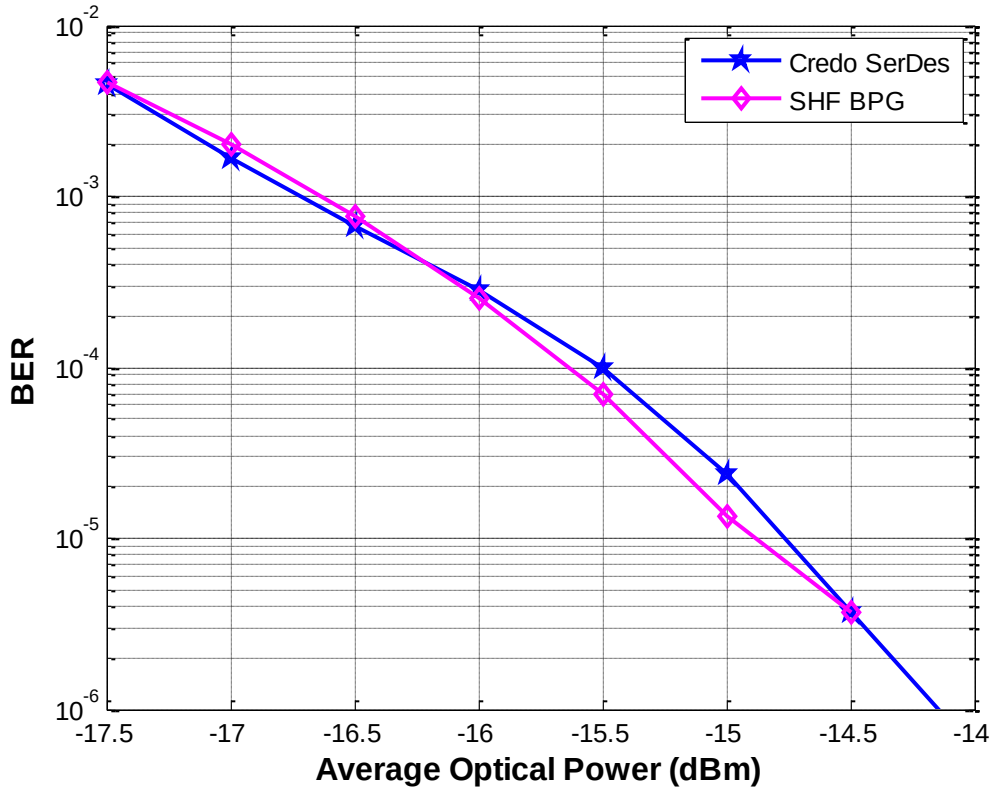
λ – wavelength

c – speed of light

The same dispersion amount has different dispersion effect at different wavelengths

Dispersion (DL) at 1535 nm	Operating wavelength at 1310nm window	For the same dispersion effect, Equivalent dispersion at operating wavelength
19.1 ps/nm	1328.78 nm	25.5 ps/nm
19.1 ps/nm	1319.42 nm	25.9 ps/nm
-28.5 ps/nm	1285.65 nm	-40.6 ps/nm

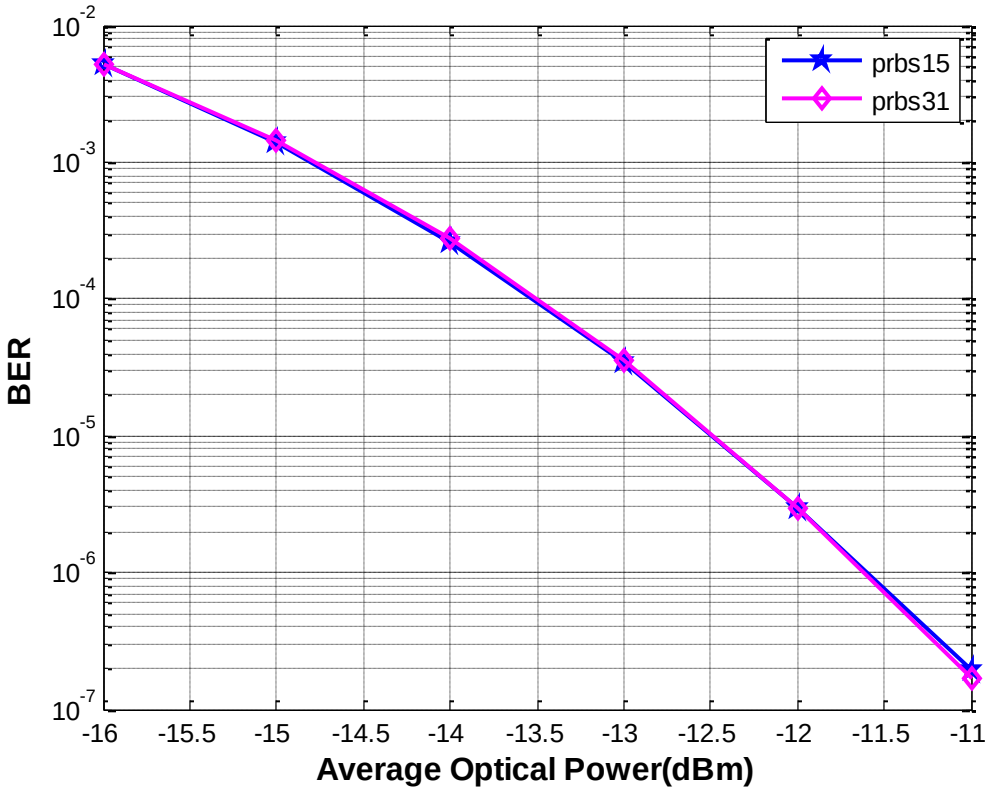
Comparison Between Credo SerDes and SFH BPG



- **1535nm**
- **Back-to-back**

- **Credo SerDes and SHF BPG have similar BtB performance**
- **This offline result using BPG has about 1.8dB sensitivity improvement at BER@1e-3 compared with that in wen_3bs_01_0914.pdf (also see next page), which may be due to:**
  - **The offline result has an FFE equalizer**
  - **The result in wen_3bs_01_0914.pdf had no CDR and may have suffered more jitter**

Comparison Between prbs31 and prbs15



- **Offline processing difficult to go to high order prbs**
- **Concern being addressed that prbs15 is too short for PAM4**
- **We compare prbs31 and prbs15 for NRZ using:**
  - **SHF BPG: for bit pattern generation**
  - **SHF BER analyzer: for real time BER test**
  - **Mitsubishi EML: transmitter**
  - **U2t Receiver**
  - **No CDR used**

No difference observed in BER performance between prbs31 and prbs15 for NRZ

Link Budget in OMA

Applications	Duplex 2km	Duplex 10km
Number of wavelength	8	
Baud rate	53.2 GBaud/s	56 GBaud/s
Operating BER	2e-4	1e-3
ER	≥6dB	
Transmitter output OMA (1)	2.0dBm	3.3dBm
Mux IL(2)	3dB	3dB
Fiber/connector loss(3)	5dB	6.4dB
MPI penalty (4)	0.2dB	0.2dB
Dispersion penalty (1)	1.0dB	1.5dB
DeMux IL(2)	3dB	3dB
Post-DeMux Rx input OMA	-10.2dBm	-10.8dBm
Rx sensitivity (OMA)(5)	-12.6dBm	-13.3dBm
Margin	2.4dB	2.5dB

(1) shirao_3bs_01_0914.pdf, preliminary specifications
(2) cole_01_0914_smf.pdf ; (3) kolesar_3bs_01_0514.pdf; (4) wen_3bs_01_0914.pdf
(5) The receiver sensitivity was measured in average power at 55Gbps with ER=9.6dB, and has been converted to OMA with ER=6dB for 56Gpbs and 53.2Gbps respectively

Summary

- **Demonstrated the feasibility of 8x56G NRZ for 400GbE 2km and 10km PMD using 56G SerDes electrical signaling**
- **There is sufficient link budget for both 2km and 10km (with 2.5dB margin) applications**