Experimental Verification of 56Gbps NRZ Performance for 400GbE 2km and 10km PMD

Yangjing Wen, Fei Zhu, and Yusheng Bai
Huawei US R&D Center
Santa Clara, CA 95050

and

Mizuki Shirao and Keisuke Kojima
Mitsubishi Electric Corporation

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HUAWEI

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Supporters

- **Yoshikazu Tanaka, Mitsubishi Electric Corporation**
- **Atsushi Sugitatsu, Mitsubishi Electric Corporation**
- **Atsushi Takai, Oclaro**
- **Ichiro Ogura, PETRA**
- **Bill Brennan, Credo Semiconductor**
- **Haoli Qian, Credo Semiconductor**
- **Jeff Twombly, Credo Semiconductor**

Introduction

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

  cole_02_0814_smf.pdf; qian_3bs_01_0714.pdf;

  zhu_3bs_01a_0514.pdf; zhu_3bs_01_0714.pdf

- Using commercially available 43G optical transmitter and receiver for 56Gbps NRZ operation is desirable considering the technical maturity and tight time frame for 400GbE standards

- In the July plenary meeting, Mitsubishi demonstrated 56Gb/s NRZ with clear eye from a production EML(shirao_3bs_01a_0714.pdf).

Work in this Presentation

- In this presentation, we
  - Investigate 56Gb/s NRZ performance using Mitsubishi 43Gbps EML and commercial 43Gbps optical receiver
  - Evaluate receiver sensitivity for both BtB and with chromatic dispersion
  - Analyze optical link budget for 400GbE 2km and 10km PDM

Assignment of 8 Wavelength LAN-WDM – Symmetric Extension

Current 4-ch LAN-WDM

Lane	Central Wavelength (nm)	Longest wavelength (nm)	Shortest wavelength (nm)	Max positive dispersion (ps/nm/km)	Max negative dispersion (ps/nm/km)
L0	1286.66		1285.65		-3.70
L1	1291.10				
L2	1295.56				
L3	1300.05				
L4	1304.58				
L5	1309.14				
L6	1313.73				
L7	1318.35	1319.42		1.75	

For 10km SMF, the total dispersion is in the range of

-37ps/nm ~ +17.5ps/nm

Assignment of 8 Wavelength LAN-WDM – Red Band Extension

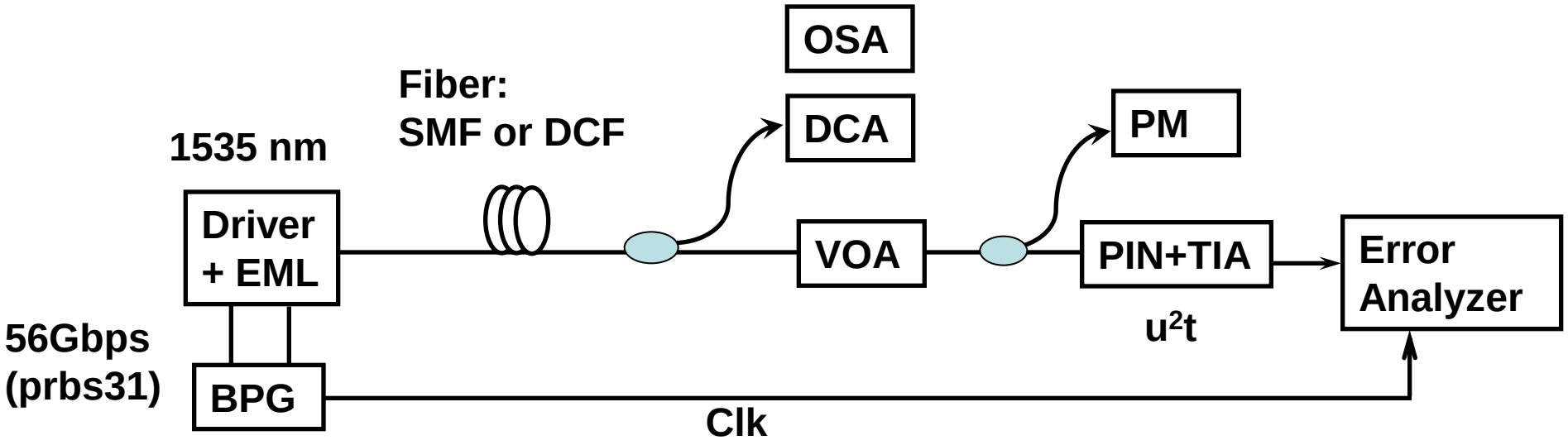
Current 4-ch LAN-WDM

Lane	Central Wavelength (nm)	Longest wavelength (nm)	Shortest wavelength (nm)	Max positive dispersion (ps/nm/km)	Max negative dispersion (ps/nm/km)
L0	1295.56		1294.53		-2.81
L1	1300.05				
L2	1304.58				
L3	1309.14				
L4	1313.73				
L5	1318.35				
L6	1323.01				
L7	1327.69	1328.78		2.56	

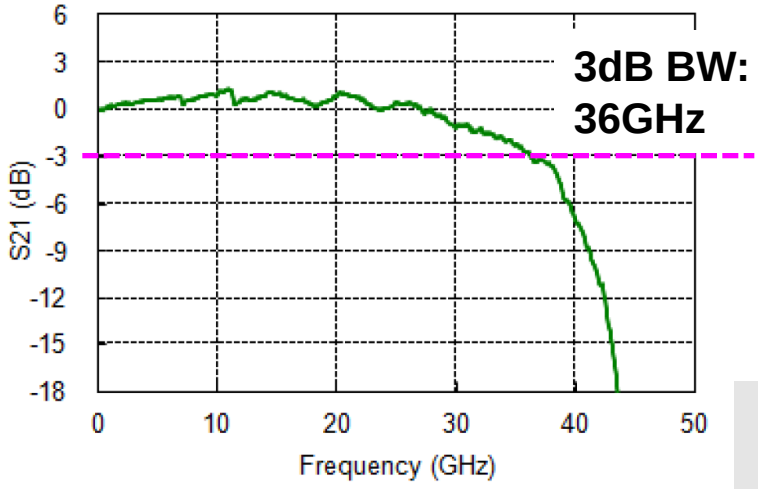
For 10km SMF, the total dispersion is in the range of

-28.1ps/nm ~ +25.6ps/nm

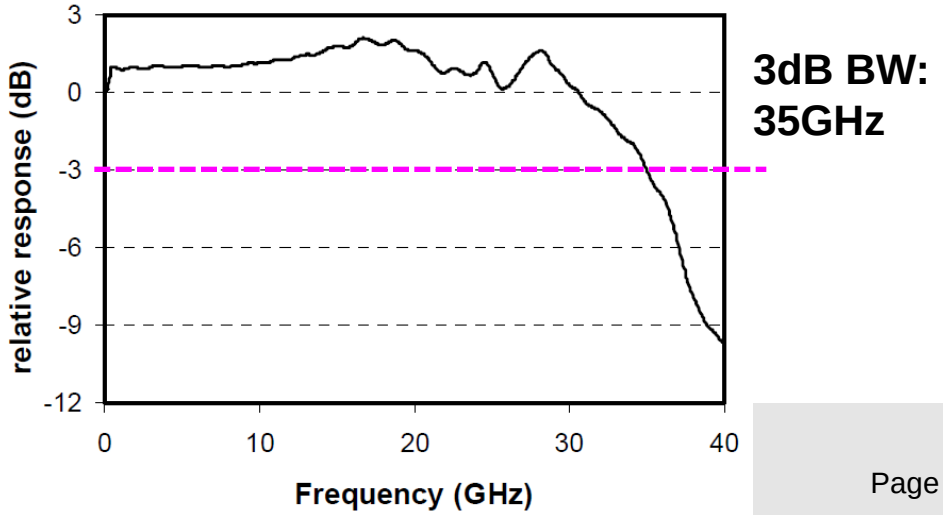
Experimental Setup



S21 of Driver + EML (Mitsubishi FU-697SEA-T3M2)



u²t 43Gbps photoreceiver - XPRV2022

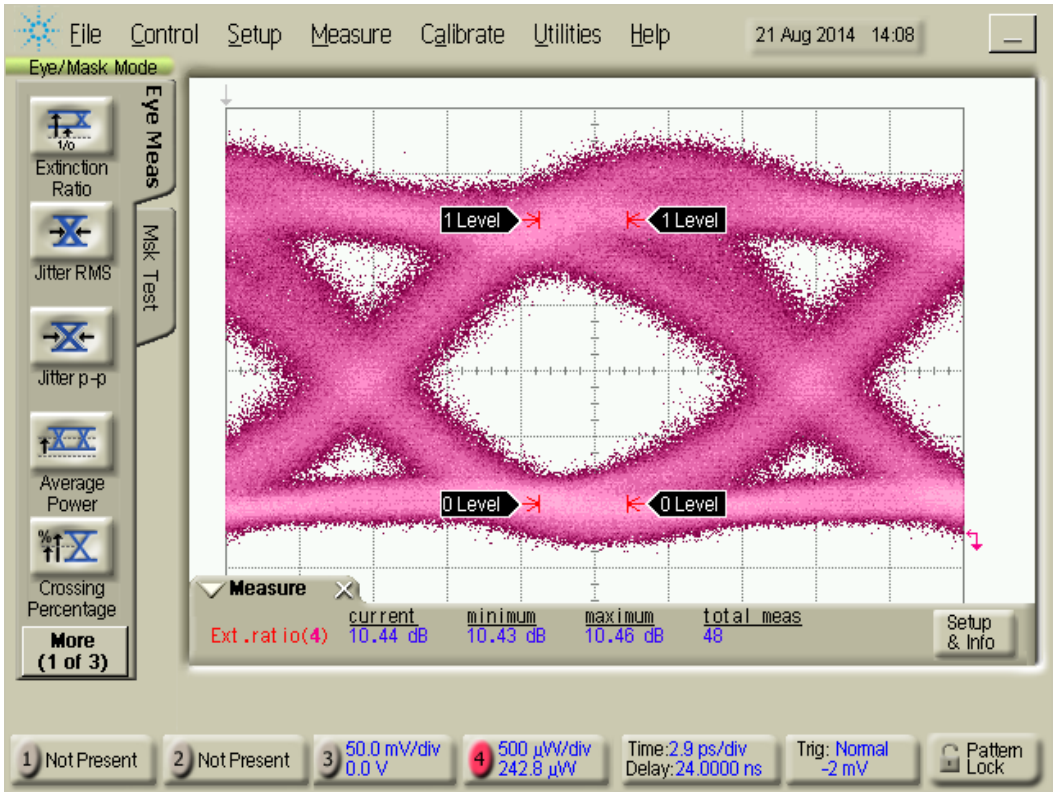


Eye Diagram and Optical Spectrum

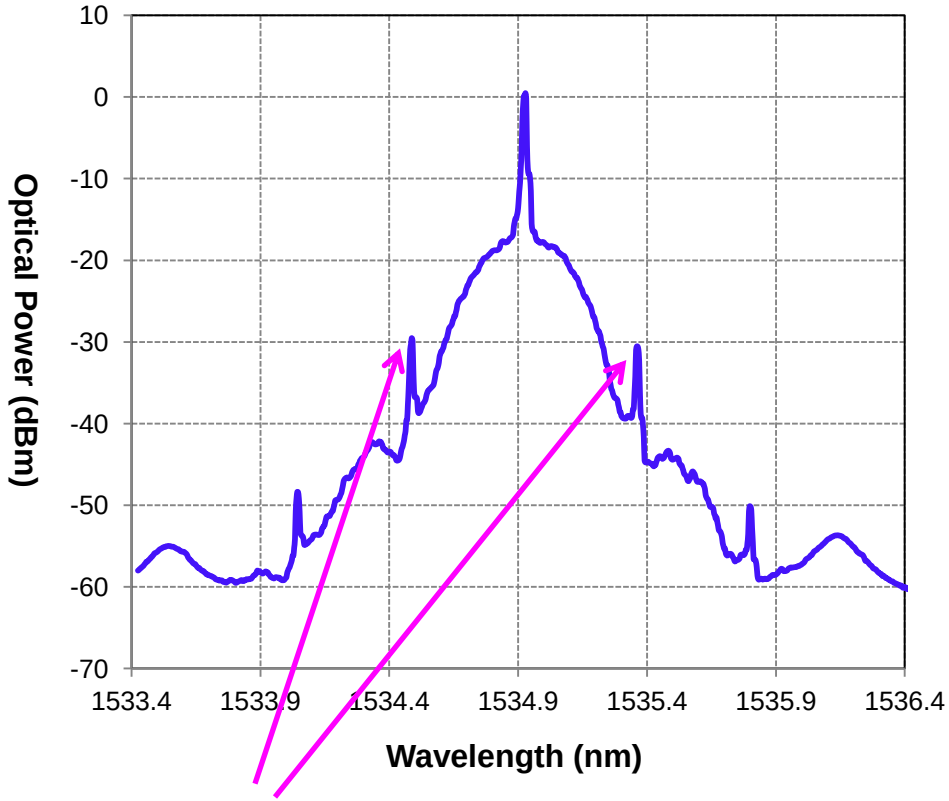
Laser bias current =80mA, and operating temperature: 40 deg C

V_{OS} =-2.0V; V_{EE}=-5.2V; V_G=-2.2V; V_X =-1.5V

BtB

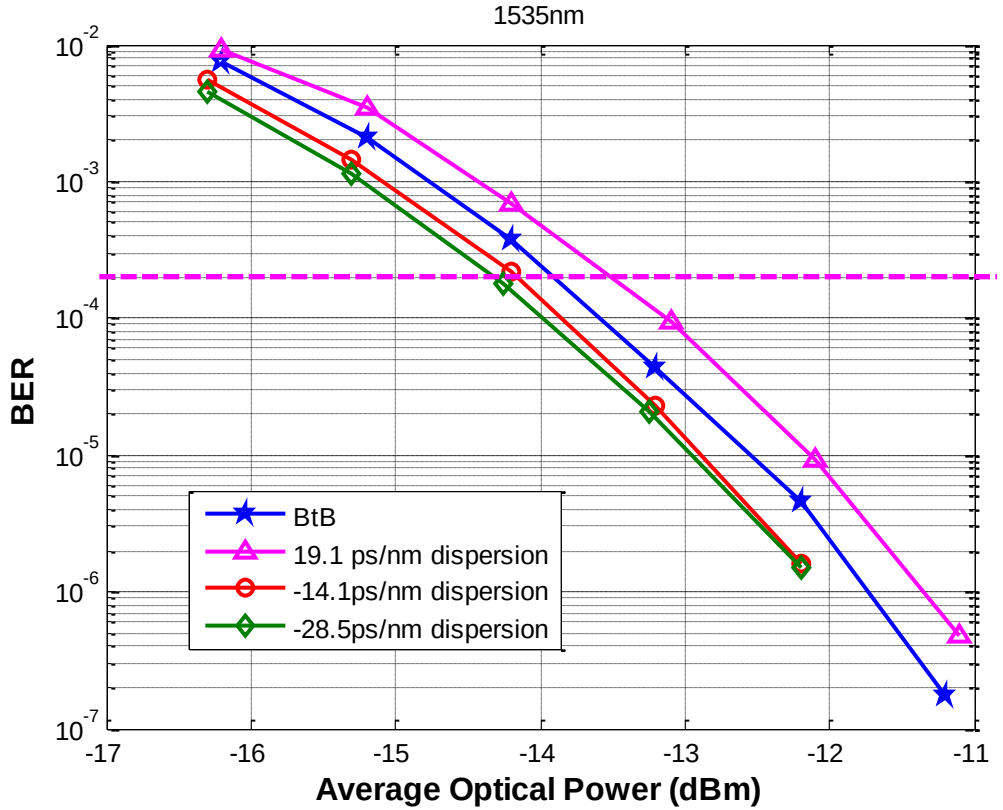


Measured with an Agilent 40G optical module (86116C Opt. 025)



Asymmetry in optical spectrum, enhanced at blue sideband, indicating positive chirp

BER vs Average Optical Power – EML #1



- **KP4 FEC considered**
- **Dispersion used in test covers the worst cases for both wavebands of:**

1286.66~ 1318.35 nm

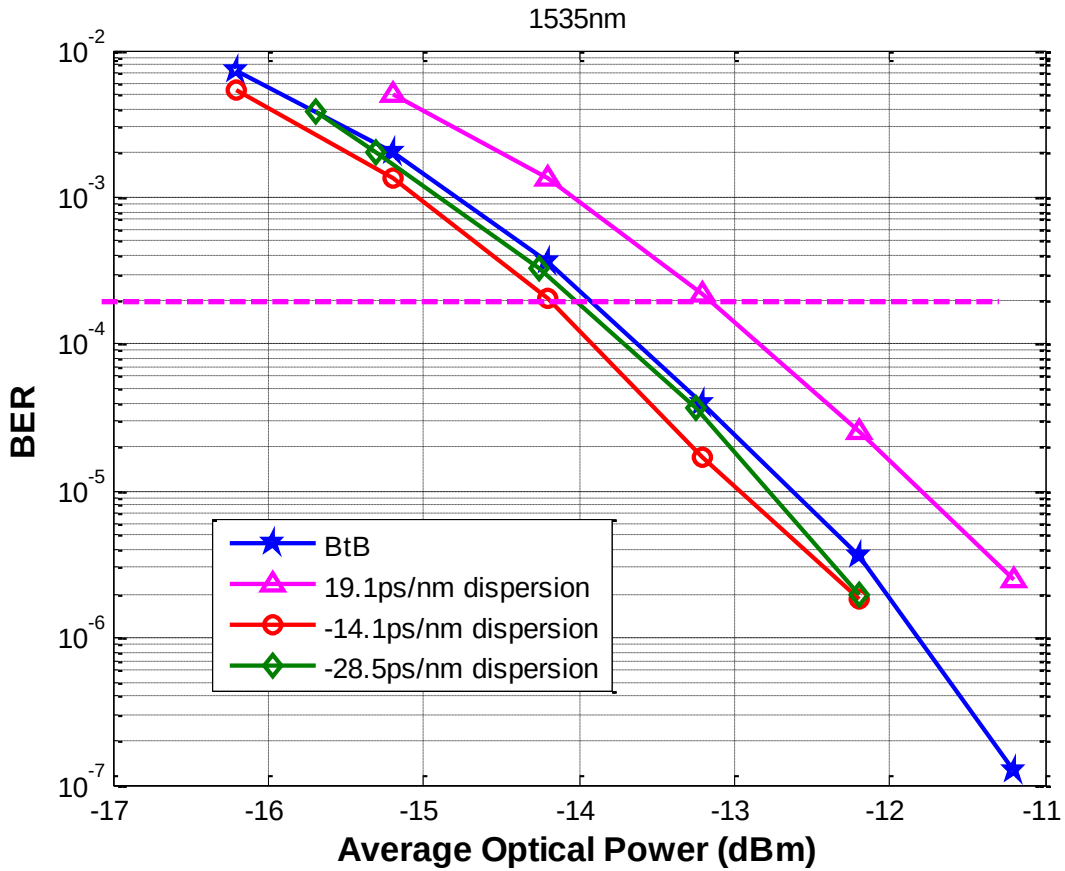
And

1295.56~ 1327.69 nm

Dispersion at 1535 nm	Operating wavelength at 1310nm window	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
-14.1 ps/nm	1285.65 nm	-20.1 ps/nm
-28.5 ps/nm	1285.65 nm	-40.6 ps/nm

$$D_1\lambda_1^2 = D_2\lambda_2^2$$

BER vs Average Optical Power – EML#2



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

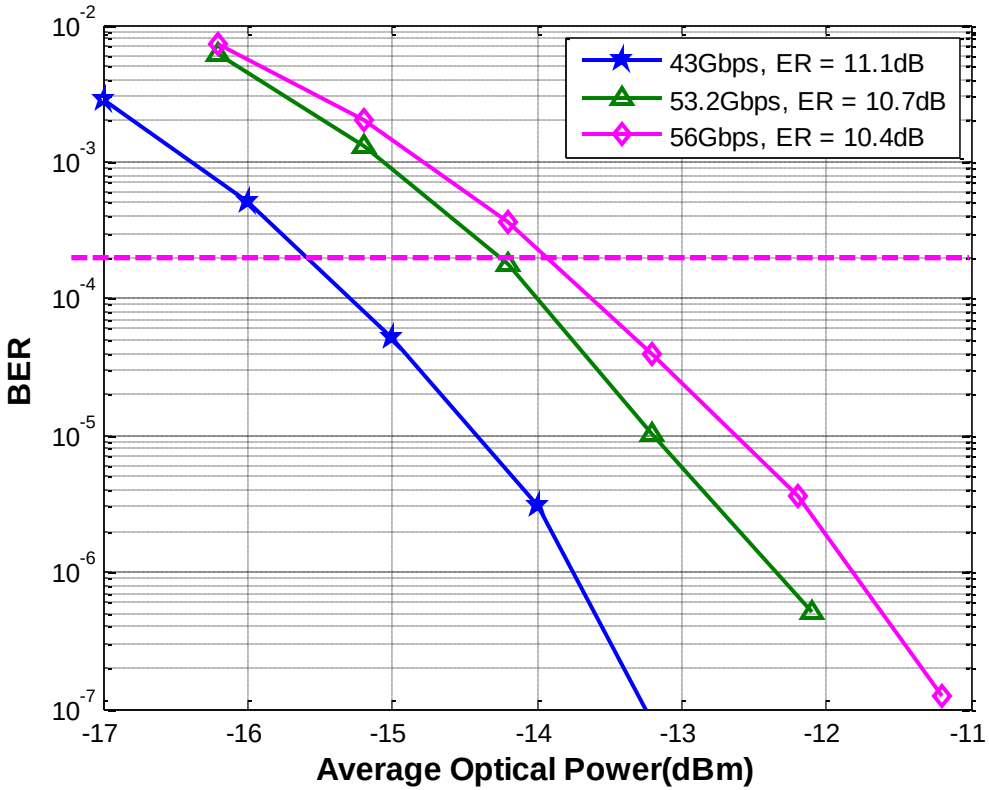
1286.66~ 1318.35 nm

And

1295.56~ 1327.69 nm

- **EML#1 and EML#2 show similar BtB BER performance**
- **Maximum dispersion penalty less than 1dB**

Dependence on Data Rate – EML#2

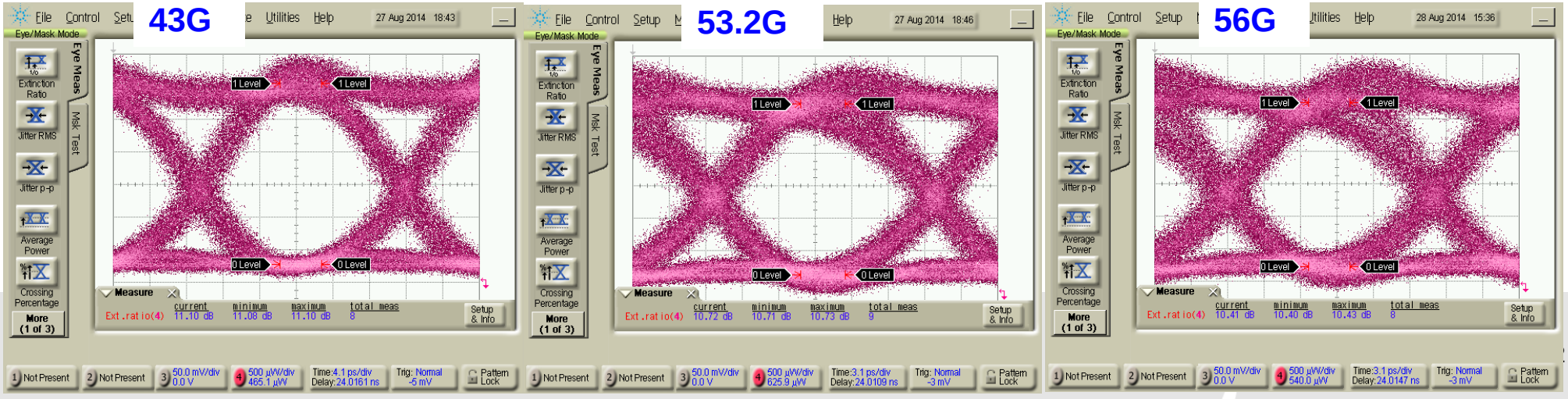


All data rates have the same operation conditions:

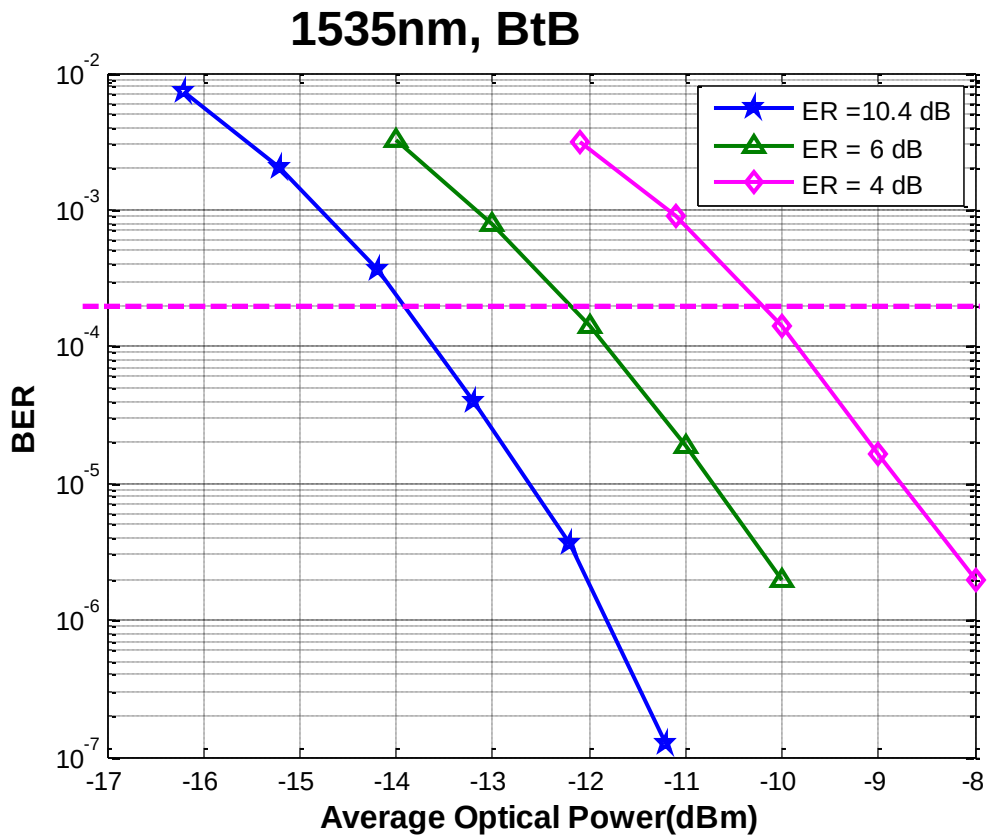
Laser bias current =80mA

Operating temperature: 40 deg C

V_{OS} =-2.0V; V_{EE}=-5.2V; V_G=-2.2V; V_X =-1.5V



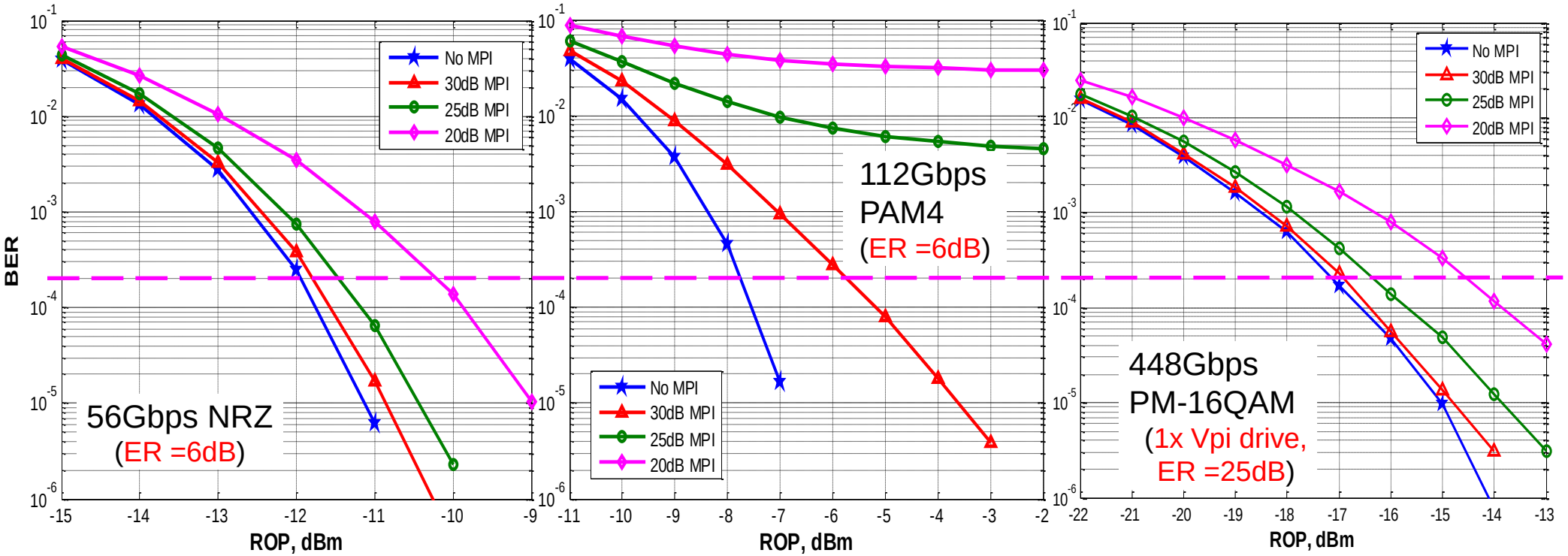
Impact of Extinction Ratio – EML#2



- **Data Rate:56Gbps**
- **The relatively poor sensitivity for ER=4dB may be due to its:**
  - **Lower OMA**
  - **Lower tolerance to RIN & jitter**
- **ER higher than 6dB offers incremental improvement**

ER	10.4dB	6dB	4dB
Rx Sensitivity (Ave Power)	-13.9dBm	-12.2dBm	-10.2dBm
Rx Sensitivity (OMA)	-11.7dBm	-11.4dBm	-10.8dBm

*N*x 56Gbaud Alternatives: Tolerance to MPI



	Rx Sensitivity (@ BER of 2e-4, Tx/Rx 3dB BW=0.75x BaudRate, 5th order Bessel)		
	56Gbps NRZ	**112Gbps PAM4**	**448Gbps PM-16QAM**
Penalty at 30dB MPI	0.2dB	2dB	0.2dB

Recaptured from *zhu_3bs_01_0714.pdf*

Link Budget in Average Optical Power

Applications	**Duplex 2km**	**Duplex 10km**
Number of wavelength	8	
Baud rate	53.2 GBaud/s	
Operating BER (KP4 FEC)	2e-4	
ER (1)	≥6dB	
Transmitter output power (1)	1.2dBm	2.5dBm
Mux IL(2)	2.5dB	2.5dB
Fiber/connector loss	5.0dB	6.4dB
TDP	1.0dB	1.5dB
MPI penalty	0.2dB	0.2dB
DeMux IL(2)	2.5dB	2.5dB
Post-DeMux Rx input power	-10.0dBm	-10.6dBm
Rx sensitivity (Ave Power)(3)	-12.4dBm	-12.4dBm
Margin	2.4dB	1.8dB

(1) shirao_3bs_01_0914.pdf, preliminary specifications
(2) Specifications from a number of vendors use 2.5dB insertion loss
(3) The receiver sensitivity was measured at 56Gbps and is -12.2dBm, 0.2dB gain is introduced when converting from 56Gpbs to 53.2Gbps

Link Budget in OMA

Applications	**Duplex 2km**	**Duplex 10km**
Number of wavelength	8	
Baud rate	53.2 GBaud/s	
Operating BER (KP4 FEC)	2e-4	
ER (1)	≥6dB	
Transmitter output OMA (1)	2.0dBm	3.3dBm
Mux IL(2)	2.5dB	2.5dB
Fiber/connector loss	5.0dB	6.4dB
TDP	1.0dB	1.5dB
MPI penalty	0.2dB	0.2dB
DeMux IL(2)	2.5dB	2.5dB
Post-DeMux Rx input OMA	-9.2dBm	-9.8dBm
Rx sensitivity (OMA)(3)	-11.6dBm	-11.6dBm
Margin	2.4dB	1.8dB

(1) shirao_3bs_01_0914.pdf, preliminary specifications
(2) Specifications from a number of vendors use 2.5dB insertion loss
(3) The receiver sensitivity in OMA was measured at 56Gbps and is -11.4dBm, 0.2dB gain is introduced when converting from 56Gpbs to 53.2Gbps

Summary

- **Demonstrated the feasibility of 8x53.2G NRZ for 400GbE 2km and 10km PDM**
- **There is sufficient link budget for both 2km and 10km (with 1.8dB margin) applications using KP4 FEC**
- **1286.66nm -1318.35nm waveband (symmetric extension) is preferred due to extra margin in dispersion penalty**