Test Result of 8*56G PAM4 Transmission

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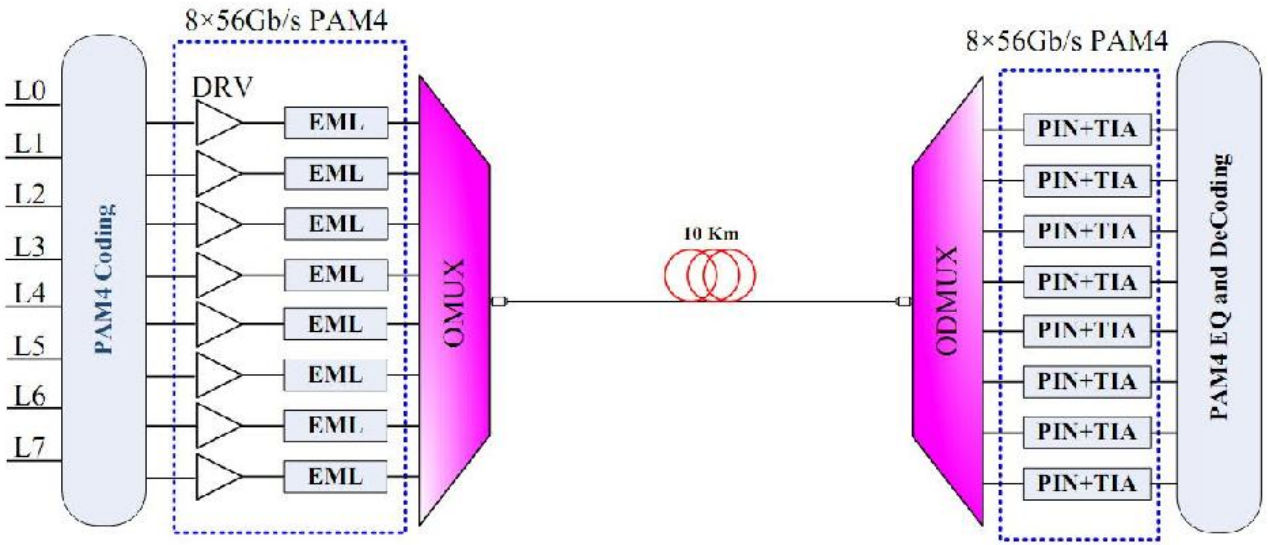
Background

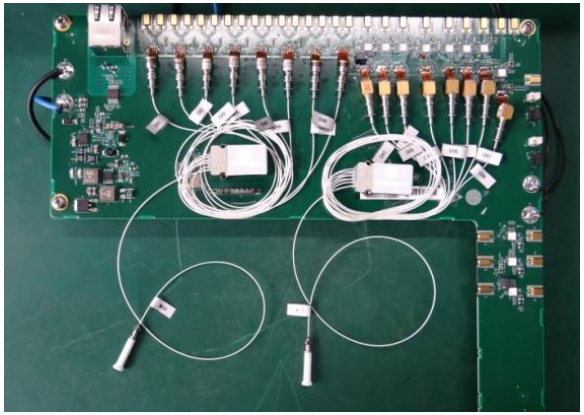
- At the Jan 2014 meeting we presented test results of 56G PAM4 over 10km SMF.
- At that meeting, we got a lot of quite helpful suggestions, based on which we carried out additional testing.
- This presentation shows our recent test results of an eight wavelength 56G PAM4 configuration, transmitted on 10km G.652 fiber.

Information

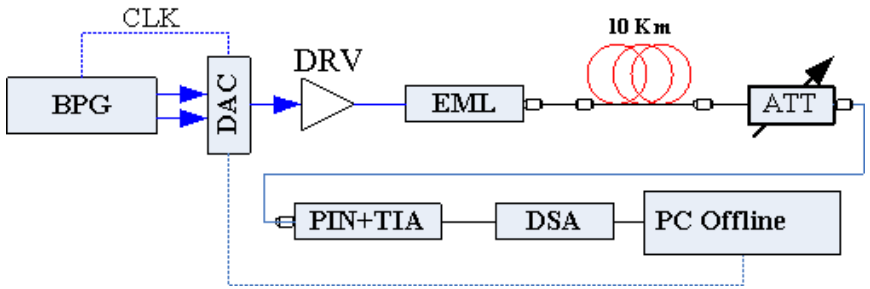
- The tests cover the following parameters to evaluate their effect on total system performance.
  - Electrical SNR of Transmitter vs. Receiver
  - Linearity of the EML
  - Channel link parameters, like chromatic dispersion, MPI, connecter loss and so on.
  - Sensitivity of the Receiver.
  - etc.

System Configuration



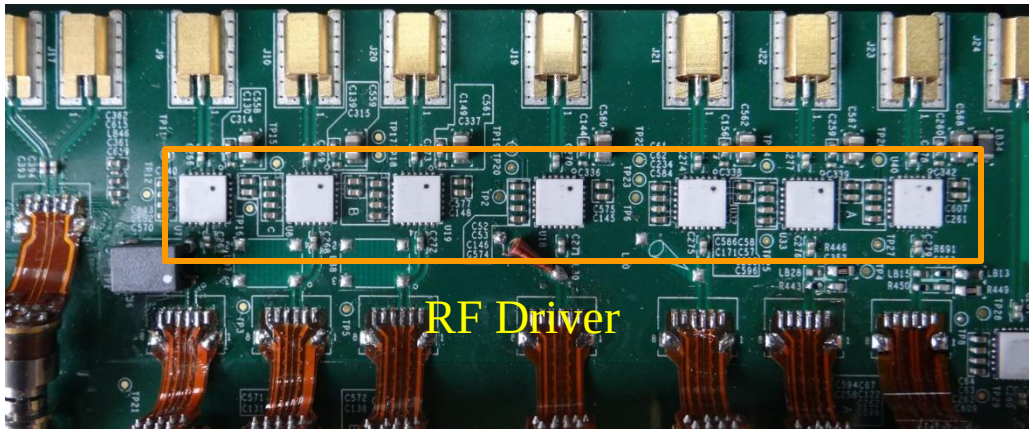


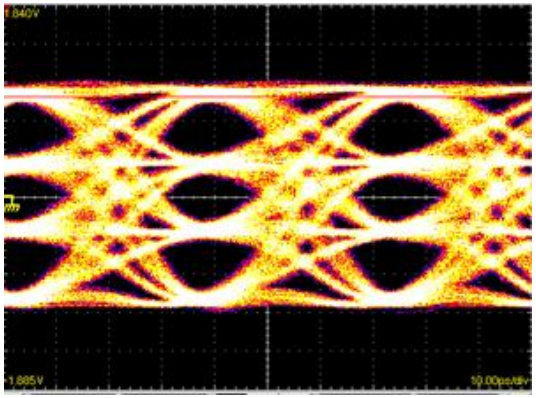
Test Board



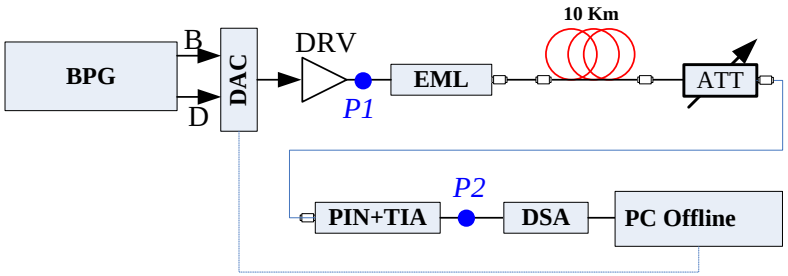
Experimental Setup

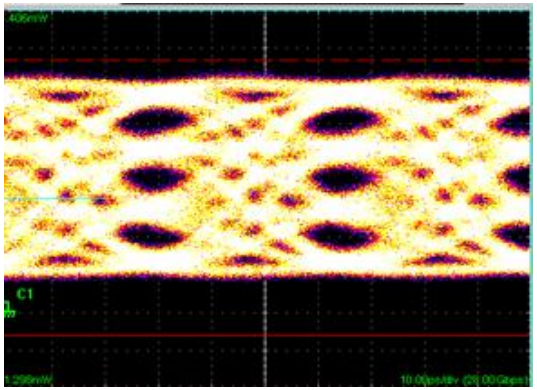
Key Component – RF Driver





Eye diagram after driver





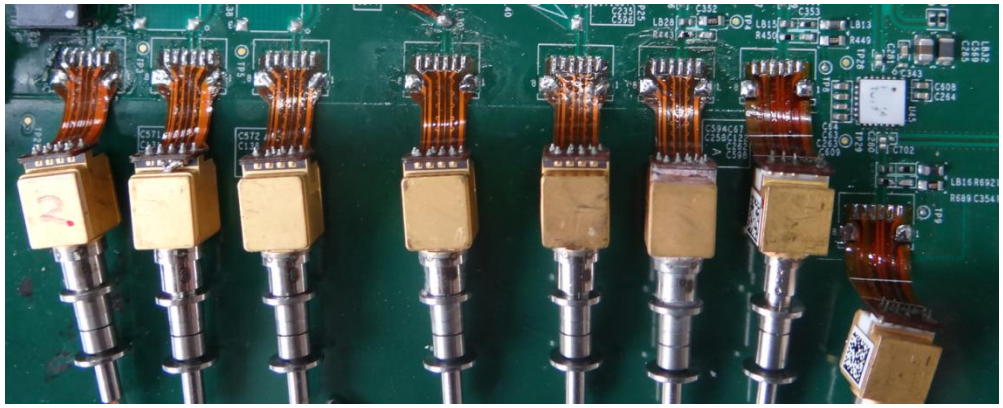
Eye diagram after EML

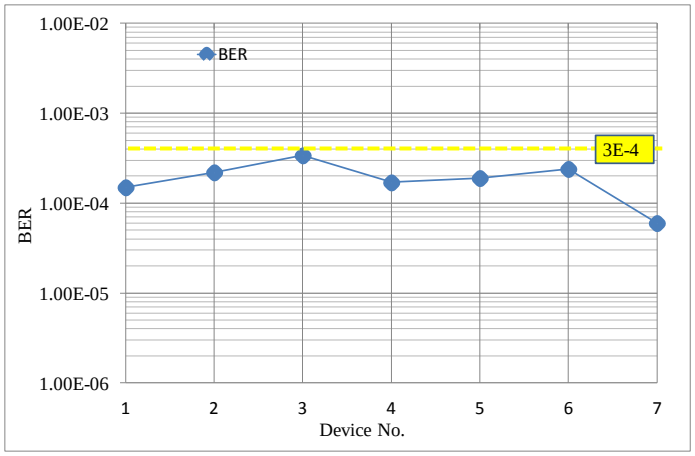
Device	BER(P1)	SNR(P1)/dB	BER(P2)	SNR(P2)/dB
DRV(Vendor1)	3.91E-06	21.63	1.8E-4@-11dBm	17.96
DRV(Vendor2)	0	27.51	1.0E-4@-11dBm	18.25

RF Driver test result conclusion

- 6dB (SNR) improvement of driver output at Transmitter only gives 0.3dB (sensitivity) improvement at Receiver.
- High SNR in RF devices (such as driver) is NOT a critical parameter in the system performance.

EML linearity test result



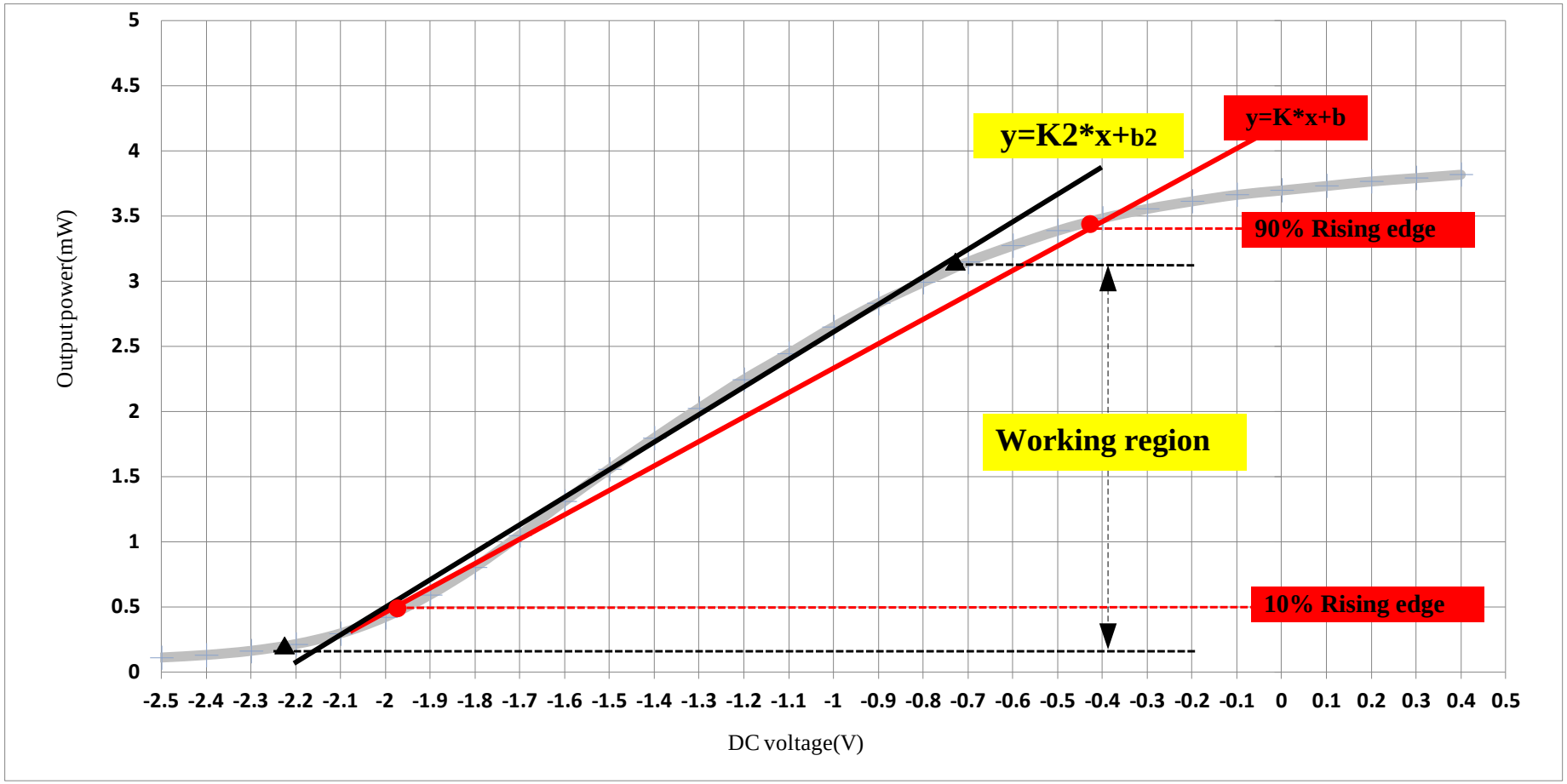


System BER out of different test samples with different linearity

Device No.	1#	2#	3#	4#	5#	6#	7#
TOSA Characteristics	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)	ER/dB DC(10%~90%)
	9.2	8.3	8.57	7.45	9.72	9.2	7.77
	K(mW/V)	K(mW/V)	K(mW/V)	K(mW/V)	K(mW/V)	K(mW/V)	K(mW/V)
	1.5361	1.388	1.2739	1.9621	3.5544	2.0574	2.336
	K Error(R.M.S)	K Error(R.M.S)	K Error(R.M.S)	K Error(R.M.S)	K Error(R.M.S)	K Error(R.M.S)	K Error(R.M.S)
	0.1093	0.1151	0.1201	0.0955	0.0312	0.0909	0.057
	ER/dB	ER/dB	ER/dB	ER/dB	ER/dB	ER/dB	ER/dB
	15.1716	15.5892	15.1703	15.4463	16.5641	15.272	14.7886
	K2(mW/V)	K2(mW/V)	K2(mW/V)	K2(mW/V)	K2(mW/V)	K2(mW/V)	K2(mW/V)
	1.5134	1.4221	1.3611	1.9577	3.0691	1.8836	2.2492
	K2 Error(R.M.S)	K2 Error(R.M.S)	K2 Error(R.M.S)	K2 Error(R.M.S)	K2 Error(R.M.S)	K2 Error(R.M.S)	K2 Error(R.M.S)
	0.112	0.1026	0.0988	0.1042	0.178	0.1571	0.0881
	3dB BW/GHz	3dB BW/GHz	3dB BW/GHz	3dB BW/GHz	3dB BW/GHz	3dB BW/GHz	3dB BW/GHz
	20.67	20.87	20.59	21.23	20.89	20.56	21.89

- System performance varies with different linearity of the EML samples while all the other parameters remain approximately the same

K and K2


y=K2*x+b2
y=K*x+b
90% Rising edge
Working region
10% Rising edge
Output power(mW)
DC voltage(V)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-2.5 -2.4 -2.3 -2.2 -2.1 -2 -1.9 -1.8 -1.7 -1.6 -1.5 -1.4 -1.3 -1.2 -1.1 -1 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

Options for EML wavelength set

Option 1

Lane	Center Wavelength /nm	Dispersion (λ0=1300) ps/nm/Km	Dispersion (λ0=1310) ps/nm/Km	Dispersion (λ0=1324) ps/nm/Km
L0	1286.49	0.04	-0.88	-2.16
L1	1291.02	0.46	-0.46	-1.74
L2	**1295.56**	0.89	-0.03	-1.32
L3	**1300.05**	1.30	0.38	-0.90
L4	**1304.58**	1.73	0.81	-0.48
L5	**1309.14**	2.15	1.23	-0.06
L6	1313.65	2.57	1.65	0.36
L7	1318.18	2.99	2.07	0.78

Option 2

Lane	Center Wavelength /nm	Dispersion (λ0=1300) ps/nm/Km	Dispersion (λ0=1310) ps/nm/Km	Dispersion (λ0=1324) ps/nm/Km
L0	**1295.56**	0.89	-0.03	-1.32
L1	**1300.05**	1.30	0.38	-0.90
L2	**1304.58**	1.73	0.81	-0.48
L3	**1309.14**	2.15	1.23	-0.06
L4	1313.65	2.57	1.65	0.36
L5	1318.18	2.99	2.07	0.78
L6	1322.70	3.41	2.49	1.20
L7	1327.23	3.83	2.91	1.62

Option 3

Lane	Center Wavelength /nm	Dispersion (λ0=1300) ps/nm/Km	Dispersion (λ0=1310) ps/nm/Km	Dispersion (λ0=1324) ps/nm/Km
L0	1277.43	-0.80	-1.72	-3.01
L1	1281.96	-0.38	-1.30	-2.59
L2	1286.49	0.04	-0.88	-2.16
L3	1291.02	0.46	-0.46	-1.74
L4	**1295.56**	0.89	-0.03	-1.32
L5	**1300.05**	1.30	0.38	-0.90
L6	**1304.58**	1.73	0.81	-0.48
L7	**1309.14**	2.15	1.23	-0.06

Option 4

Lane	Center Wavelength /nm	Dispersion (λ0=1300) ps/nm/Km	Dispersion (λ0=1310) ps/nm/Km	Dispersion (λ0=1324) ps/nm/Km
L0	**1295.53**	0.88	-0.04	-1.32
L1	1297.79	1.09	0.17	-1.11
L2	**1300.05**	1.31	0.39	-0.90
L3	1302.32	1.52	0.60	-0.69
L4	**1304.58**	1.73	0.81	-0.48
L5	1306.84	1.94	1.02	-0.27
L6	**1309.11**	2.15	1.23	-0.06
L7	1311.37	2.36	1.44	0.15

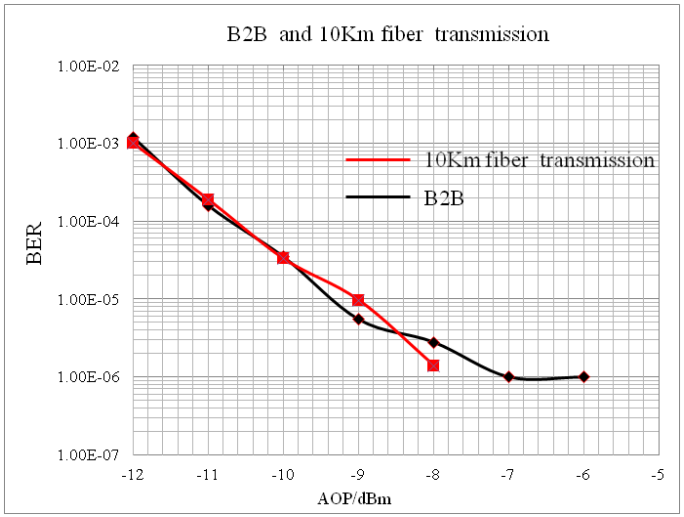
G.652

Zero dispersion wavelength: 1300 nm<λ0<1324 nm ; Dispersion slope(max) S0: 0.092 ps/nm^2 ł km

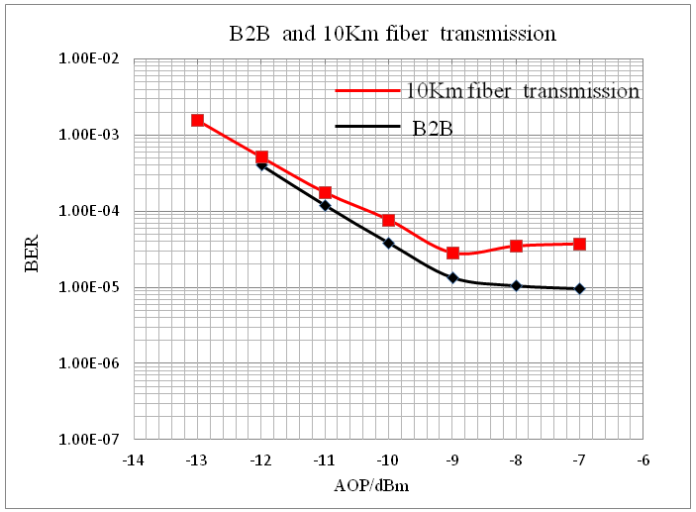
- Option 1 : Dispersion parameter for L0 : -2.16 ps/nm/km (Max); for L7 : 2.99 ps/nm/km (Max)
- Option 2: Dispersion parameter for L0 : -1.32 ps/nm/km (Max); for L7 : 3.83 ps/nm/km (Max)
- Option 3: Dispersion parameter for L0 : -3.01 ps/nm/km (Max); for L7 : 2.15ps/nm/km (Max)
- Option 4: Dispersion parameter for L0 : -1.32 ps/nm/km (Max); for L7 : 2.36 ps/nm/km (Max)

The existing 100G-LR4 wavelengths, the max negative dispersion value is higher than the max positive dispersion value, which is because one can expect that negative dispersion can be easier dealt with than positive dispersion. For 8*56G, we might also consider the oMUX/oDEMUX wavelength allocation.

Fiber Dispersion test result (Experiment)



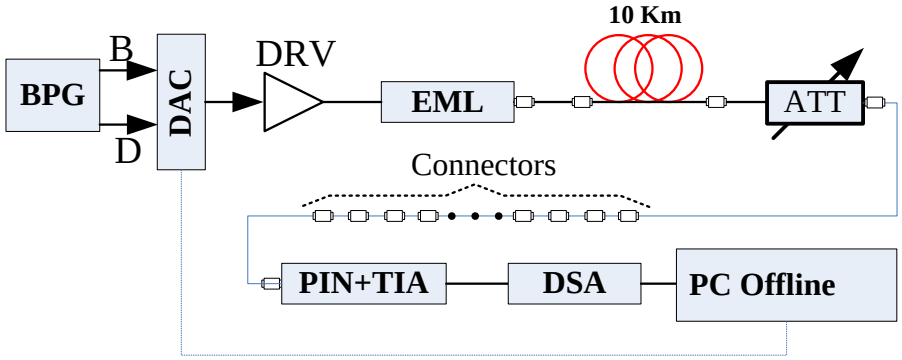
TOSA1(D0=+0.8 ps/nm/km@ λ=1320nm)



TOSA2(D0=-2.2 ps/nm/km@λ=1285nm)

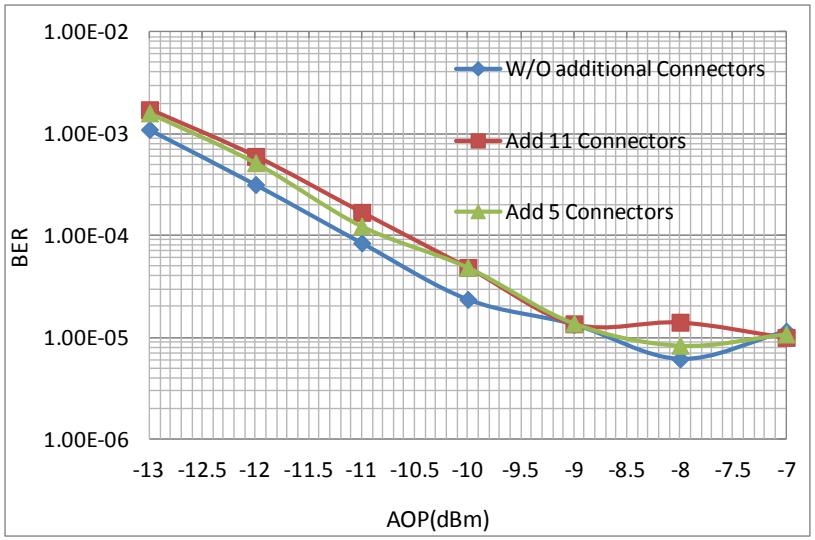
- Fiber loss is 0.39dB/Km （Experimental measurement）
- Penalty is 0.2 dB (CD=8 ps/nm/Km) due to fiber dispersion theoretically
- The measured penalty is 0.05 dB @3E-4 at 1320 nm and 0.2 dB @3E-4 at 1285 nm (including MPI penalty)
- The zero dispersion point of the fiber we used in this test is 1310 nm. We are aware that this test is not done under worst case dispersion values and therefore we plan to do additional testing.

Connector test result (MPI)



Experimental setup for optical connector

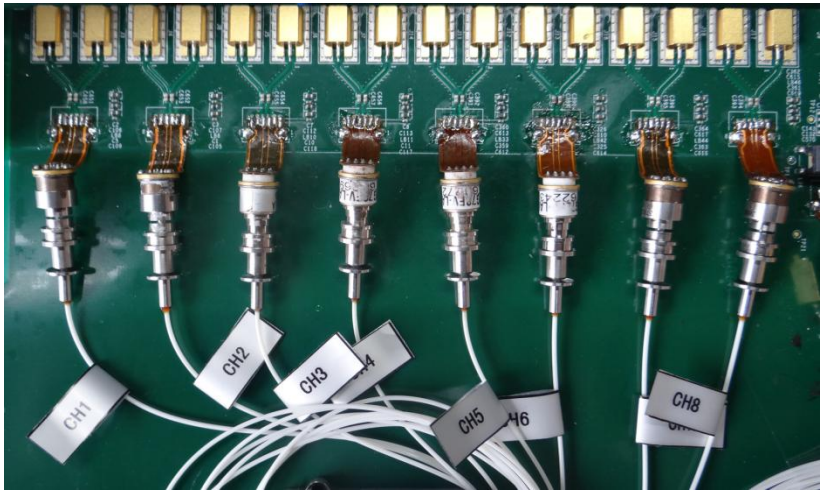
No. of Connectors	Reflected power(dBm)
1	-35.00
2	-32.04
3	-30.33
4	-29.13
5	-28.21
6	-27.47
7	-26.84
8	-26.31
9	-25.85
10	-25.44
11	-25.07



BER performance in the case of adding connectors

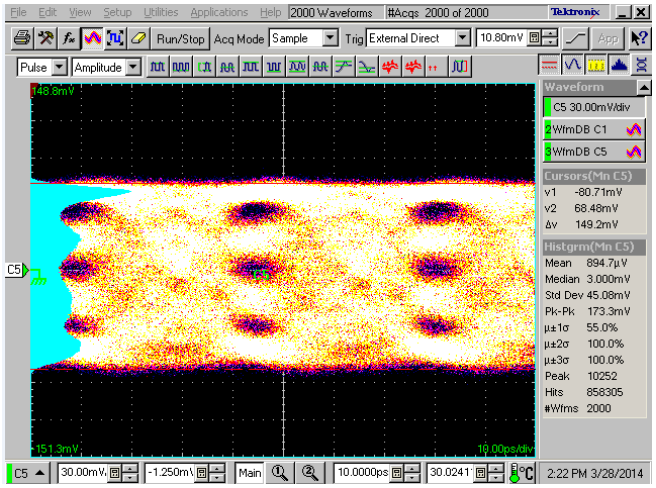
- The additional usage of optical connectors (MPI effect) will cause power penalty (0.3dB with 5 connectors and 0.5 dB with 11 connectors @3E-4)

Receiver test results Receiver test results

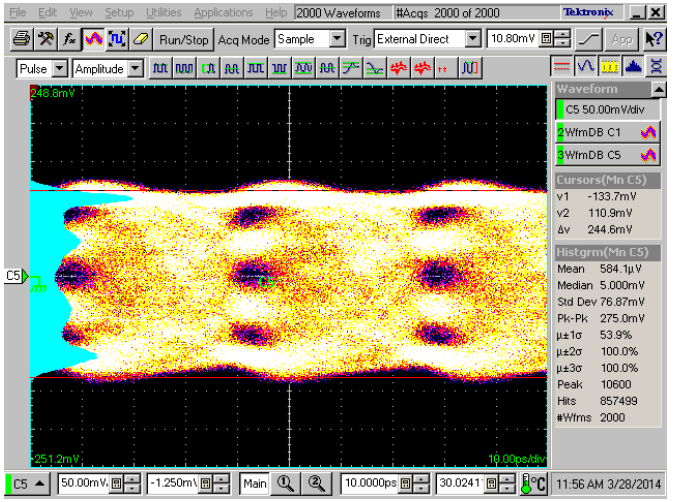


Parameter	ROSA1	ROSA2	Unit
VPD	3.3	3.3	V
VTIA	3.3	3.3	V
Vpp	98.69	168.6	mv@-11dBm
Noise amplitude	10	15	mV
Bandwidth	36	35	GHz
Power spectral density (Noise)	3.27E-11	2.54E-11	A/sqrt(Hz)
Responsivity	0.55	0.74	A/W
Gain	900	2300	V/W
Resistance	1636.36	3108.11	Ω

	ROSA 1		ROSA 2	
ROP/dBm	BER	SNR/dB	BER	SNR/dB
-7	1.02E-05	19.32	1.12E-06	19.74
-8	**3.16E-06**	**19.58**	**2.23E-06**	**19.68**
-9	5.77E-06	19.46	5.40E-06	19.43
-10	2.29E-05	19.05	1.86E-05	18.98
-11	5.99E-05	18.62	8.21E-05	18.37
-12	1.91E-04	17.97	2.76E-04	17.67
-13	6.36E-04	17.16	1.14E-03	16.62



Eye diagram of signal after ROSA1 (AOP=-8dBm)



Eye diagram of signal after ROSA2 (AOP=-8dBm)

Summary

- The system performance is not quite sensitive to eSNR of transmitter.
- According to our test results, the linearity of the transmitter is a key parameter for 8*56G PAM4 transmission performance.
- The MPI effect of connectors of optical link is acceptable.
- Future works:
  - Character studies for Receiver, sensitivity, linearity and so on.
  - Worst case of fiber dispersion penalty.
  - Further test on wavelength allocation.
  - Evaluation of performance degradation due to worst case connector RL (lower than 35dB).
  - System performance comparison between PIN and APD.
  - Receiver bandwidth relationship with system performance.
  - Study of alternative modulation formats.

Thank You