

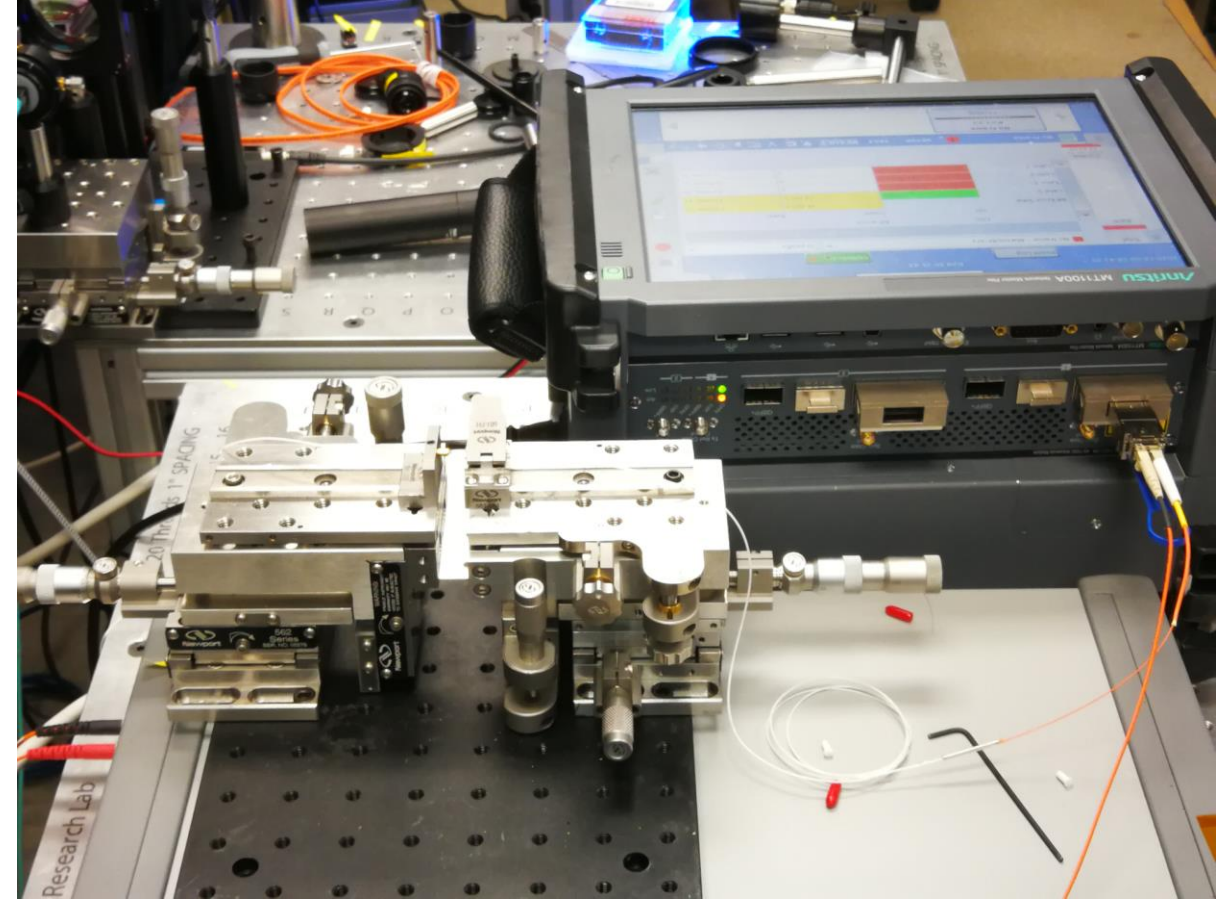
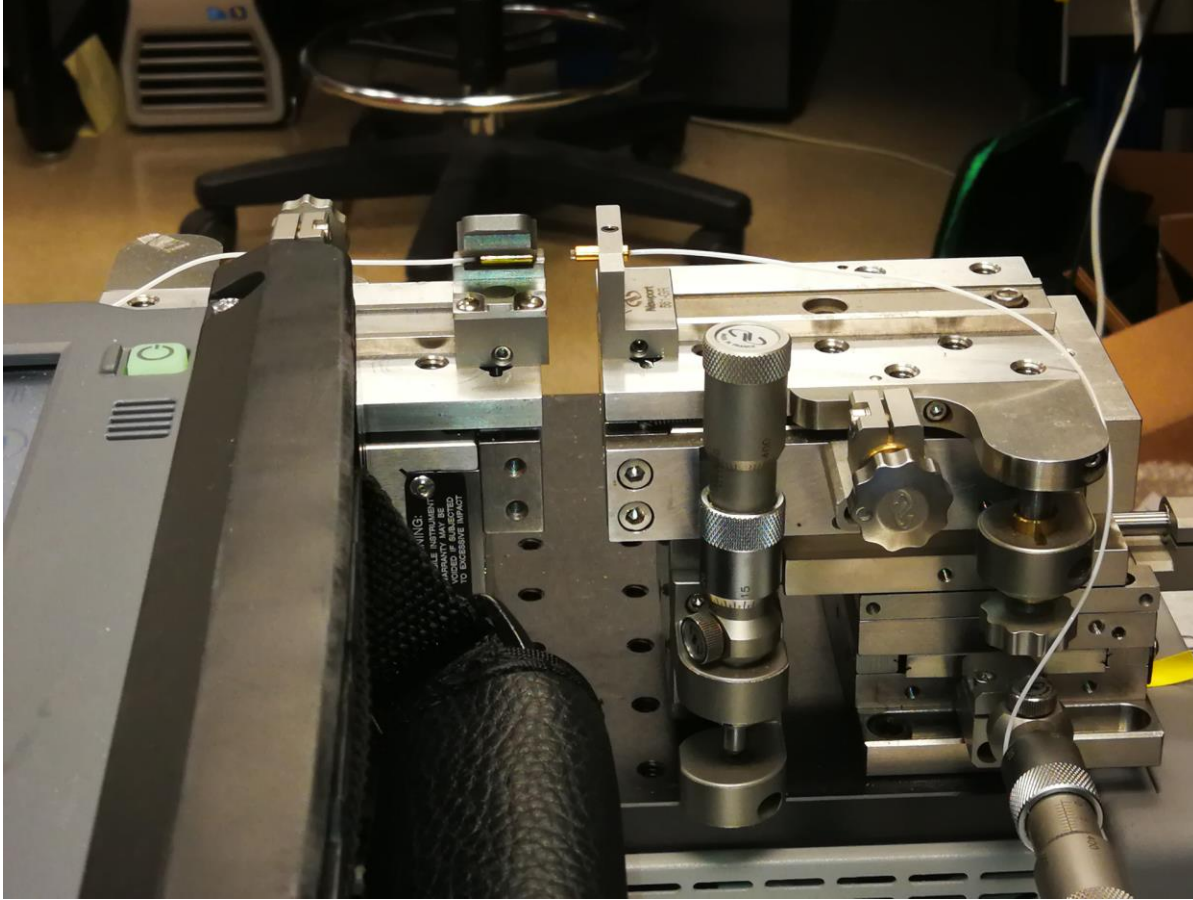
# Model Noise Measurement for an Expanded Beam Connector

Rick Pimpinella, Yu Hwang, and Jose Castro  
Panduit Labs, Panduit Corp.

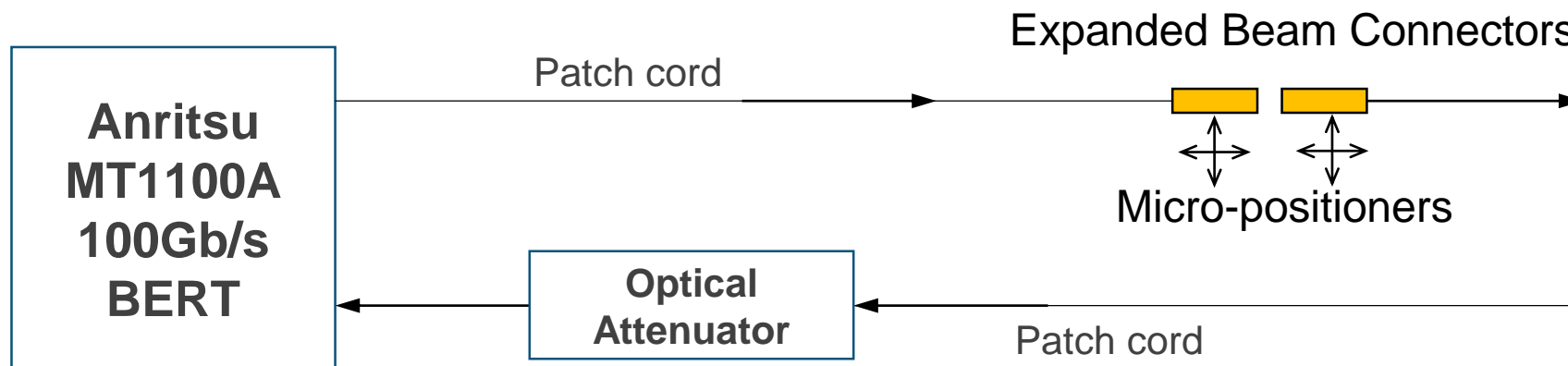
*Multi-Gigabit Automotive Optical PHY Study Group  
Ad hoc Telecon, November 27, 2020*

# Bit Error Rate vs. Connector Insertion Loss

## *25 Gb/s NRZ Signaling*

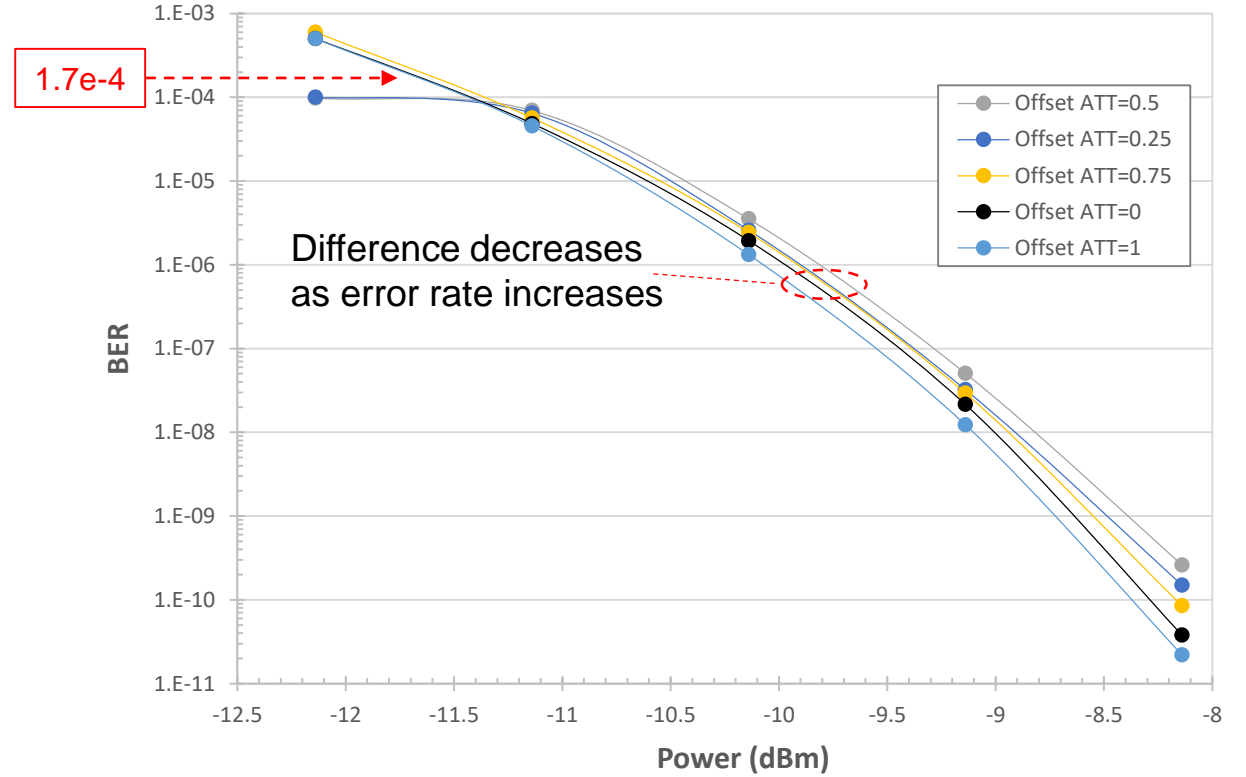
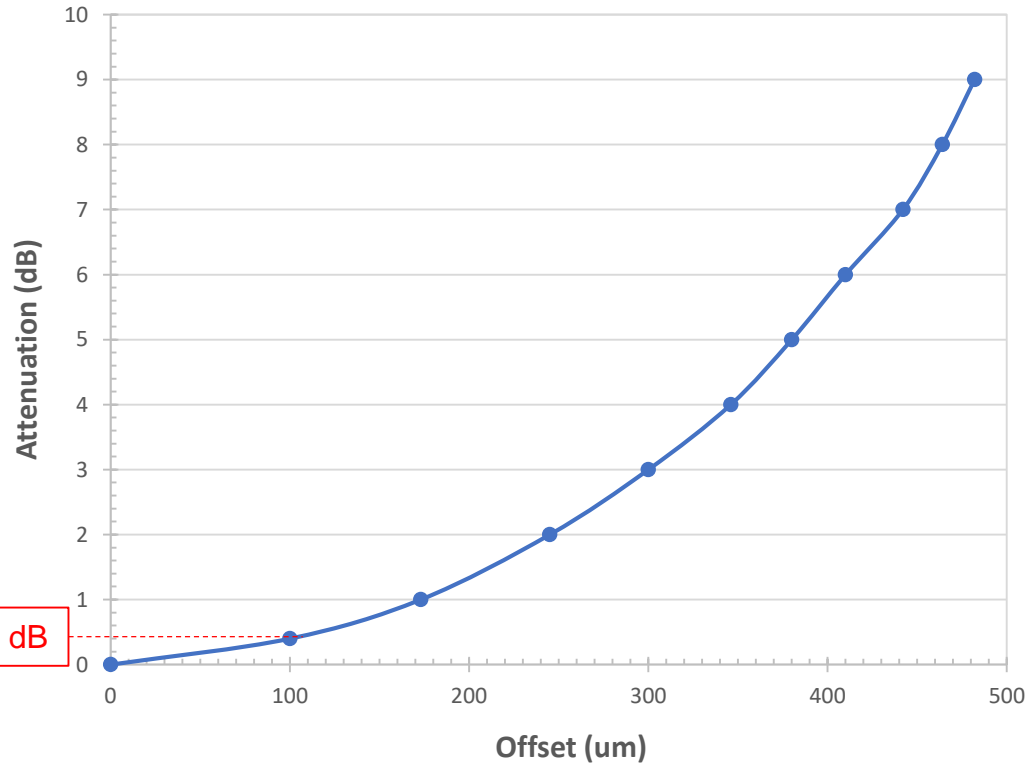


# Error Rate (BER) Channel Test Setup

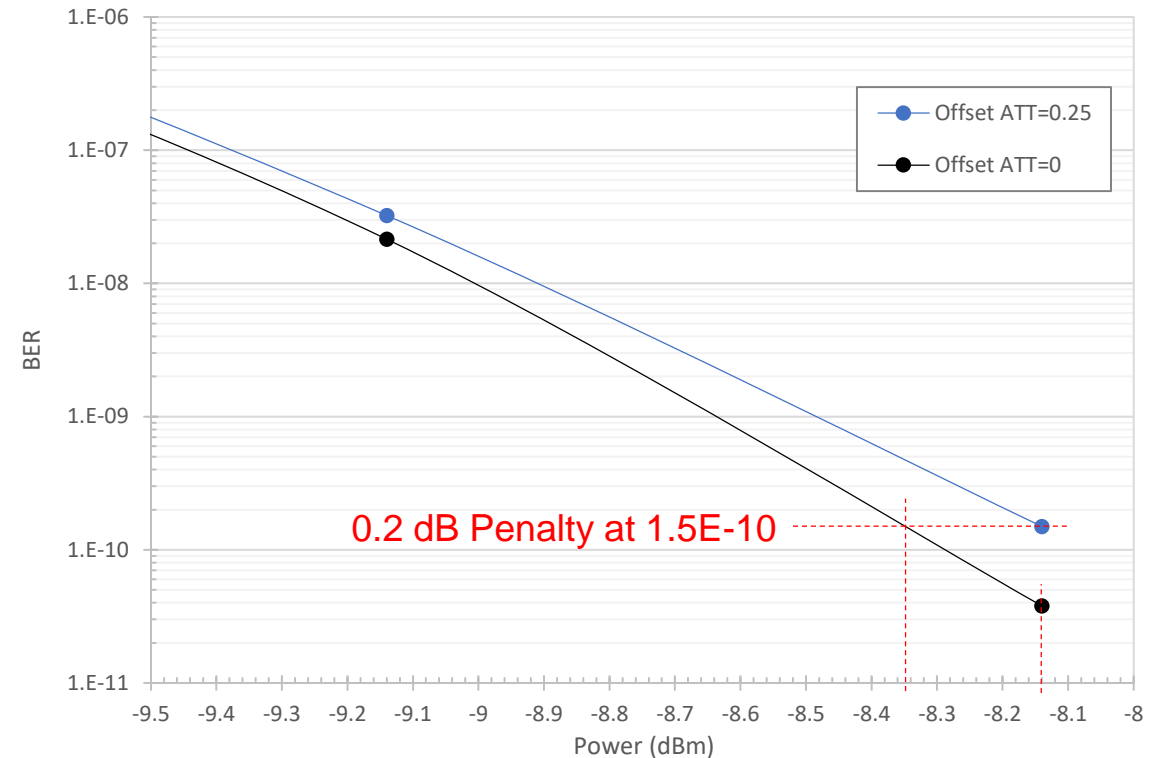
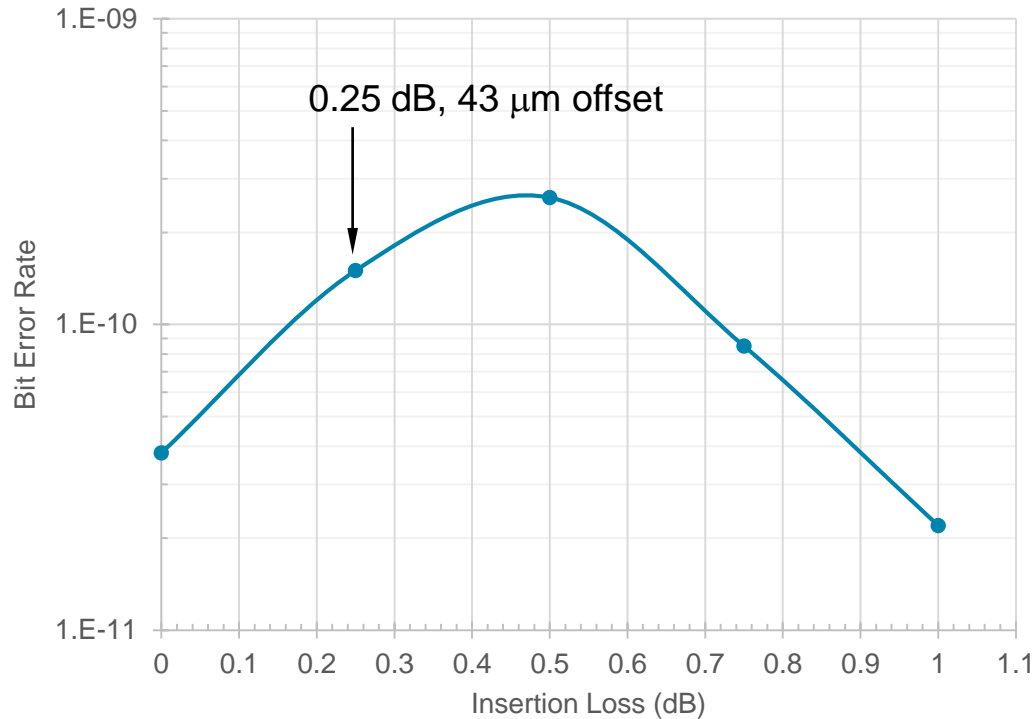


# BER Results

Attenuation vs offset



# Test Results & Estimated MN power penalty



Optical penalty = 0.2 dB at  $1.5 \times 10^{-10}$

For offset of: 43  $\mu$ m, MN penalty = 0.25 dB

**+/- 10  $\mu$ m = 0.05 dB penalty**

**Negligible for  $1.8 \times 10^{-4}$  BER**

# IEEE Link Model – 10 Gb/s

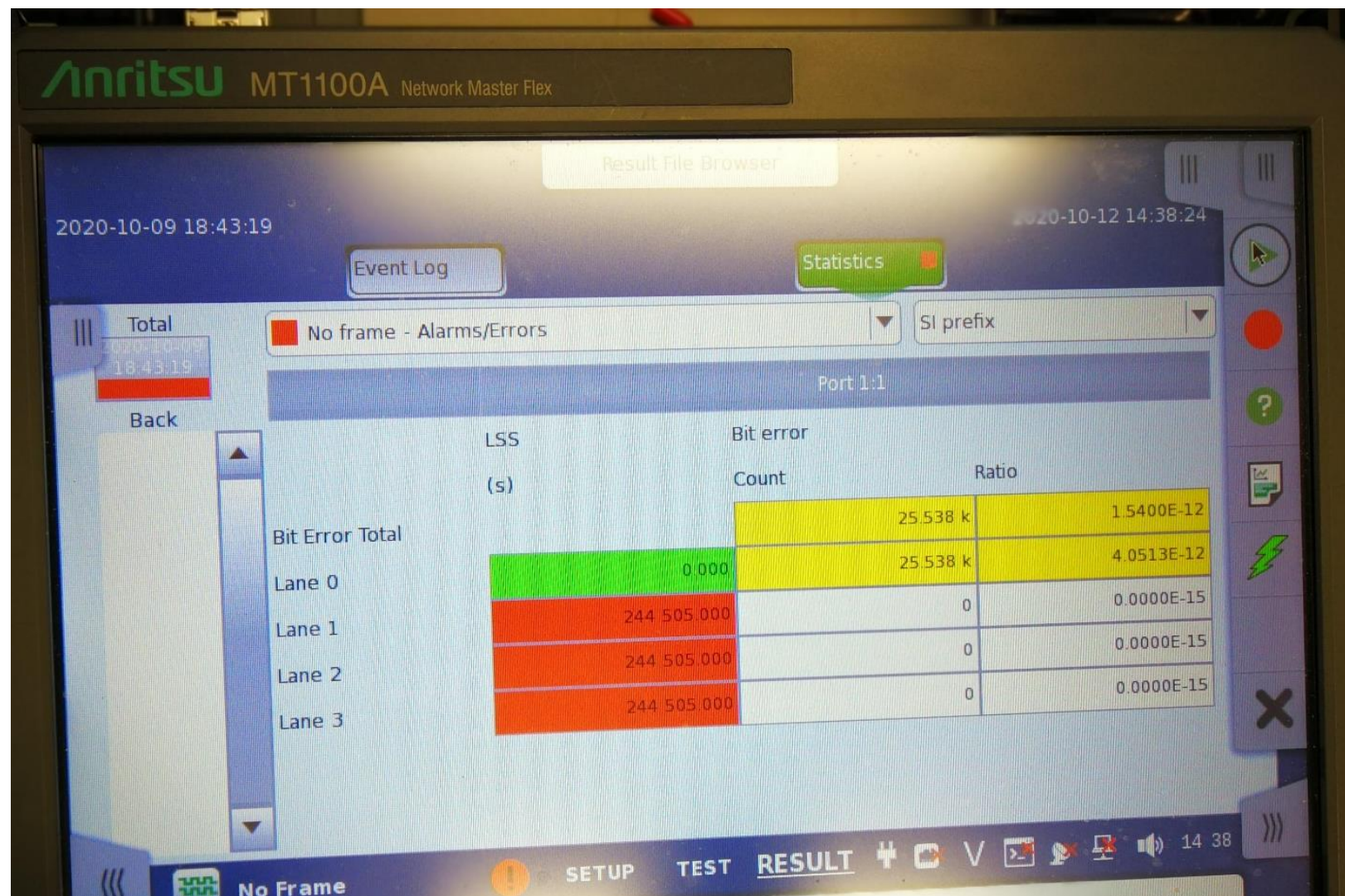
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	Spreadsheet by Del Hanson, David Cunningham, Piers Dawe, David Dolfi Agilent Technologies													Rev.	3.2/3	This file	10GEPBud3_1_16a.xls	of	17-Oct-01					
2	Basics	Input=	Bold			Ts(20-80)	35 ps		Case: 850nm serial	newMMF				Attenuation=	3.5 dB/km		Model/format rev 3.1.16a	of	31-Oct-01					
3		Q=	7.04			Ts(10-90)	53 ps		Target reach	0.30 km				Fiber at	850 nm		NomSens OMA	-11.10 dBm	Margin	0.02 dB at				
4		Base Rate=	10313 MBd			RIN(OMA)	-130 dB/Hz		and L_start=	0.2 km				C_att=	1.00		Receive Refl Rx	-12 dB	Answer!	0.3 km				
5	Transmitter					RIN at MinER	-139.6 dB/Hz		graph L_inc=	0.01 km				Attenuation=	3.62 dB/km		Rec_BW=	8,250 MHz	est Rx BW	7500 MHz				
6	Wavelength Uc	840 nm				RIN_Coef=	0.70		Power Budget P=	7.30 dB				at	840 nm		c_rx	329 ns.MHz						
7	Uw (see notes)	0.29 nm				Det.Jitter	6.0 ps inc.		DCD Connections C	1.5 dB				Disp. min. Uo=	1320 nm		T_rx(10-90)	39.9 ps	Test Source ER=					
8	Tx pwr OMA=	-3.80 dBm				DCD_DJ=	6 ps TP3		Pwr.Bud.-Conn.Loss	5.8 dB				Disp. So=	0.11 ps/nm^2*km		TP4 Eye	19 ps	Test Tx	6.5 dB				
9	Min. Ext Ratio=	3.00 dB				Effect. DJ=	0.00 (UI)		ex DCD C1=	480 ns.MHz				Disp. D1=	-117.76 ps/(nm.km)		Opening	(=Tx ey	TestERpen	1.98 dB				
10	Worst ave.TxPwr	-2.03 dBm				MPN k(OMA)	0.3		Reflection Noise factor	0 no units							RMS Baseline wander SD	0.025	fraction of 1/2 eye					
11	Ext. ratio penalty	4.78 dB				Tx eye height	70.7%		Effective Rate	10993 MBd				(not in use)	10		P_BLW(no ISI)	0.07 dB						
12	Tx masl X1=	0.3 UI				Refl Tx	-12 dB		Tb_eff=	91 ps				BWm=	1769.9 MHz*km		P_BLW	0.07 dB						
13	X2=					ModalNoisePen	0.3 dB		Effective Rec Eye	0.21 UI				Eff. BWm=	1769.9 MHz*km									
14	Y1=	0.25				Tx mask top	-0.2 UI		Pisi	P Eye	P_DJ	P_DJ		Preflection			Pcross							
15	L	Patt	Ch IL	D1.L	D2.L	BWcd	effBWm	Te	Tc	J=0, dB	central	corners	central	Beta	SDmpn	Pmpn	Prin	Ptotal	<Ptotal	LP Pen	Margin	OMA		
16	(km)	(dB)	(dB)	ps/nmps/nm	(MHz)	(MHz)	(ps)	(ps)	(ps)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dB)	(dBm)	
17	0.002	0.01	1.51	-0.24	0.00	3E+06	#####	53	66	0.75	0.22	0.00	0.00	-2E-03	0.00	0.00	0.13	0.17	1.11	1.33	1.1	4.7	-5.7	
18	0.20	0.72	2.22	-23.6	0.00	27,379	8,850	78	88	1.98	0.25	0.00	0.00	0	-0.24	0.01	0.01	0.13	0.17	3.3	3.6	2.6	2.5	-6.6
19	0.21	0.76	2.26	-24.7	0.00	26,075	8,428	80	89	2.11	0.25	0.00	0.00	0	-0.25	0.01	0.02	0.14	0.19	3.5	3.8	2.7	2.3	-6.6
20	0.22	0.80	2.30	-25.9	0.00	24,890	8,045	82	91	2.25	0.25	0.00	0.00	0	-0.26	0.01	0.02	0.14	0.21	3.7	4.0	2.9	2.1	-6.7
21	0.23	0.83	2.33	-27.1	0.01	23,808	7,695	84	93	2.39	0.25	0.00	0.00	0	-0.27	0.02	0.02	0.15	0.23	3.9	4.2	3.1	1.9	-6.7
22	0.24	0.87	2.37	-28.3	0.01	22,816	7,375	87	95	2.54	0.25	0.00	0.00	0	-0.28	0.02	0.03	0.15	0.25	4.1	4.4	3.3	1.7	-6.8
23	0.25	0.91	2.41	-29.4	0.01	21,903	7,080	89	97	2.70	0.25	0.00	0.00	0	-0.29	0.02	0.03	0.16	0.28	4.4	4.6	3.5	1.4	-6.9
24	0.26	0.94	2.44	-30.6	0.01	21,061	6,807	91	100	2.86	0.25	0.00	0.00	0	-0.31	0.02	0.04	0.17	0.31	4.6	4.9	3.7	1.2	-6.9
25	0.27	0.98	2.48	-31.8	0.01	20,280	6,555	94	102	3.04	0.25	0.00	0.00	0	-0.32	0.02	0.05	0.18	0.35	4.9	5.1	3.9	0.9	-7.0
26	0.28	1.01	2.51	-33.0	0.01	19,556	6,321	96	104	3.22	0.25	0.00	0.00	0	-0.33	0.02	0.05	0.19	0.40	5.2	5.4	4.2	0.6	-7.1
27	0.29	1.05	2.55	-34.2	0.01	18,882	6,103	98	106	3.40	0.26	0.00	0.00	0	-0.34	0.02	0.06	0.20	0.45	5.5	5.7	4.4	0.3	-7.2
28	0.30	1.09	2.59	-35.3	0.01	18,252	5,900	101	108	3.60	0.26	0.00	0.00	0	-0.35	0.02	0.07	0.21	0.51	5.8	6.0	4.7	0.0	-7.2
29	0.31	1.12	2.62	-36.5	0.01	17,664	5,709	103	111	3.80	0.26	0.00	0.00	0	-0.37	0.03	0.08	0.23	0.59	6.1	6.4	5.0	-0.3	-7.3
30	0.32	1.16	2.66	-37.7	0.01	17,112	5,531	106	113	4.01	0.26	0.00	0.00	0	-0.38	0.03	0.09	0.24	0.68	6.5	6.7	5.3	-0.7	-7.5
31	0.33	1.20	2.70	-38.9	0.01	16,593	5,363	108	115	4.23	0.27	0.00	0.00	0	-0.39	0.03	0.10	0.26	0.79	6.9	7.1	5.7	-1.1	-7.6
32	0.34	1.23	2.73	-40.0	0.01	16,105	5,206	111	117	4.46	0.27	0.00	0.00	0	-0.40	0.03	0.11	0.29	0.94	7.3	7.6	6.1	-1.5	-7.7
33	0.35	1.27	2.77	-41.2	0.01	15,645	5,057	113	120	4.70	0.27	0.00	0.00	0	-0.41	0.03	0.12	0.31	1.12	7.8	8.1	6.6	-2.0	-7.9
34	0.36	1.30	2.80	-42.4	0.01	15,210	4,916	116	122	4.95	0.28	0.00	0.00	0	-0.42	0.03	0.14	0.35	1.37	8.4	8.7	7.1	-2.6	-8.1
35	0.37	1.34	2.84	-43.6	0.01	14,799	4,784	118	125	5.22	0.28	0.00	0.00	0	-0.44	0.04	0.15	0.39	1.71	9.1	9.4	7.8	-3.3	-8.4
36	0.38	1.38	2.88	-44.7	0.01	14,410	4,658	121	127	5.49	0.29	0.00	0.00	0	-0.45	0.04	0.17	0.43	2.24	10.0	10.3	8.6	-4.2	-8.7
37	0.39	1.41	2.91	-45.9	0.01	14,040	4,538	123	129	5.78	0.30	0.00	0.00	0	-0.46	0.04	0.18	0.49	3.16	11.3	11.6	9.9	-5.5	-9.3
38	0.40	1.45	2.95	-47.1	0.01	13,689	4,425	126	132	6.09	0.31	0.00	0.00	0	-0.47	0.04	0.20	0.56	5.65	14.3	14.6	12.8	-8.5	-10.7

# Summary

- We measured the BER vs. lateral offsets of an EBO connector to quantify the impact of modal noise
- We have limited data, however no red flags were raised
- Measured MN penalty was less than 0.1 dB
- The MN penalty for our baseline proposal can be lowered from the traditional 0.3 dB for butt coupled connector channels
- A conservative penalty is 0.1 dB



# BER Tester – Ethernet Traffic Analyzer



## Transceiver

CVR-QSFP28-SFP28  
100G QSFP28 to SFP28 Converter  
S/N: G1910159072

