

Optical Specifications of SMF PMDs Study

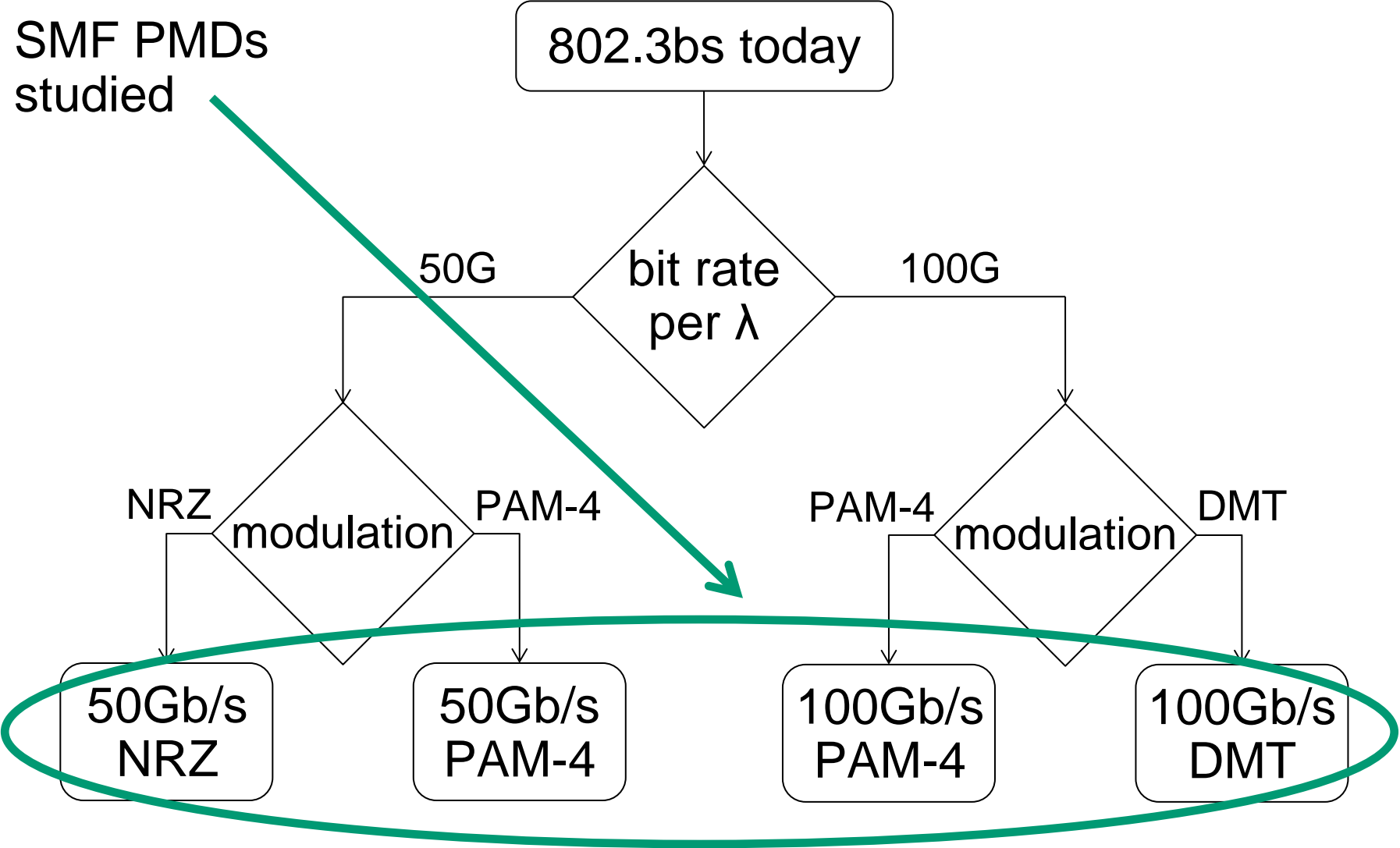
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Duplex SMF & PSM4 PMDs Decision Tree

SMF PMDs
studied



TX Limit, Mux Loss & Modulation Penalty

- Eye safety limit (1310nm) = 14.1dBm AOP
- Mux loss
 - 2:1 ratio = 1.5 dB
 - 4:1 ratio = 2.5 dB
 - 8:1 ratio = 3.5 dB
- Modulation penalty
 - NRZ = 0.0 dB
 - PAM-4 = 4.8 dB
 - DMT-k (25G DML, +/- 3 σ clipping) = 8.8 dB
- Modulation 5% accuracy penalty = 0.2 dB
- DMT-k sub-carrier I & Q channel power split factor penalty
 - $F_k = 10 * \log_{10} (2 * k)$

TDP 2km

2km	8x50G NRZ	8x50G PAM4	8x50G PAM4	4x100G PAM4	4x100G DMT-k
Source	Mod	Mod	DML	Mod	25G DML
Grid	LAN WDM	LAN WDM	LAN WDM	CWDM	LAN WDM
FEC	KP4	KP4	KP4	KP4	BCH
Operating BER	2.0e-4	2.0e-4	2.0e-4	2.0e-4	1.0E-03
RX FFE taps or FFT pts.	3	3	3	13	k
TDP dB	1.8	0.7	1.0	2.5	2.5

Methodology as per [cole_3bs_01a_0714](#), updated with jitter, and residual quantization effects for 100G PAM-4 & DMT

TDP 10km

10km	8x50G NRZ	8x50G PAM4	8x50G PAM4	4x100G PAM4	4x100G DMT-k
Source	Mod	Mod	DML	Mod	25G DML
Grid	LAN WDM	LAN WDM	LAN WDM	LAN WDM	LAN WDM
FEC	BCH	BCH	BCH	BCH	BCH
Operating BER	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
RX FFE taps or FFT pts.	3	3	3	13	k
TDP dB	2.3	0.7	1.5	2.5	3.0

Methodology as per [cole_3bs_01a_0714](#), updated with jitter, and residual quantization effects for 100G PAM-4 & DMT

RX Channel Loss & FEC Gain

- 2km Channel Insertion Loss & MPI Penalty = 5 dB
 - 4.0 dB channel base loss
 - up to 1.0 dB MPI Penalty
- 10km Channel Insertion Loss & MPI Penalty = 7 dB
 - 6.3 dB channel base loss
 - up to 0.7 dB MPI Penalty
- FEC Optical Gain (vs. $1e-12$ BER)
 - KR4 = 2.6 dB
 - KP4 = 3.2 dB
 - BCH (2858, 2570, $t=24$) = 3.8 dB

RX DeMux Loss & Bandwidth Penalty

- DeMux loss
 - 2:1 ratio = 1.5 dB
 - 4:1 ratio = 2.5 dB
 - 8:1 ratio = 3.5 dB
- Bandwidth Penalty (vs. 25G NRZ)
 - 50G NRZ = 1.5 dB
 - 50G PAM-4 = 0.0 dB
 - 100G PAM-4 = 1.0 dB
 - 100G DMT = 0.0 dB
- FEC overhead Bandwidth Penalty
 - KR4 (0%) = 0.0 dB
 - KP4 (3%) = 0.1 dB
 - BCH (8%) = 0.2 dB
 - BCH (DMT, 25G DML) = 0.0 dB

RX Design Penalty

- 50G TIA device noise penalty (vs. 25G) = 1.0 dB
- Linear TIA AGC noise penalty (vs. Limiting) = 0.5 dB
- TIA cross-talk penalty
 - 25G NRZ = 0.2 dB
 - 50G NRZ = 0.4 dB
 - 50G PAM-4 (linear) = 0.3 dB
 - 100G PAM-4 (linear) = 0.4 dB
 - 100G DMT-k (linear) = 0.3 dB
- Analog equalizer non-idealities or ADC quantization penalty
 - 50G NRZ 3-tap FFE = 0.4 dB
 - 50G PAM-4 3-tap FFE = 0.5 dB
 - 100G PAM-4 6-bit ENOB ADC = 0.4 dB
 - 100G DMT-k 6-bit ENOB ADC = 0.6 dB

400G 2km Duplex SMF PMDs TX Specs

TX Specifications	4x25G NRZ LR4 No FEC MOD / DML		8x50G NRZ KP4 FEC MOD	8x50G PAM4 KP4 FEC MOD / DML		4x100G KP4 FEC PAM4 MOD	4x100G DMT BCH FEC 25G DML
	Operating BER	1.0E-12		2.0E-04	2.0E-04		2.0E-04
ER Full Scale (min) dB	7.0	4.0	4.5	7.0	4.5	7.0	4.5
TX OMA pre-Mux (min) @TDP (max) dBm	1.2	2.4	1.5	2.2	2.5	3.5	5.0
Mux Loss dB	2.5		3.5	3.5		2.5	2.5
TX OMA (min) @TDP (max) dBm	-1.3	-0.1	-2.0	-1.3	-1.0	1.0	2.5
Modulation Penalty dB	0.0		0.0	5.0		5.0	9 + Fk
TX OMA Eye (min) @TDP (max) dBm	-1.3	-0.1	-2.0	-6.3	-6.0	-4.0	-6.5 - Fk
TDP (max) dB	1.0	2.2	1.8	0.7	1.0	2.5	2.5
TX OMA Eye - TDP each lane (min) dBm	-2.3		-3.8	-7.0		-6.5	-9 - Fk

400G 2km Duplex SMF PMDs RX Specs

RX Specifications	NRZ 4x25G LR4 No FEC MOD / DML	8x50G NRZ KP4 FEC MOD	8x50G PAM4 KP4 FEC MOD / DML	4x100G KP4 FEC PAM4 MOD	4x100G DMT BCH FEC 25G DML
Symbol (or Sample) Rate Gbaud (or GS)	25.8	53.2	26.6	53.2	55.9
Operating BER	1.0E-12	2.0E-04	2.0E-04	2.0E-04	1.0E-03
TX OMA Eye - TDP each lane (min) dBm	-2.3	-3.8	-7.0	-6.5	-9 - Fk
Channel Insertion Loss & MPI penalty dB	6.3	5.0	5.0	5.0	5.0
RX Sens. OMA pre-FEC each lane (max) dBm	-8.6	-8.8	-12.0	-11.5	-14 - Fk
FEC Optical Gain v. 1e-12 BER dB	0.0	3.2	3.2	3.2	3.8
DeMux Loss + Lane BW Penalty dB	2.5	5.1	3.6	3.6	2.5 - Fk
TIA, Xtalk, Quantization Penalties dB	0.2	1.8	1.3	1.8	1.3
RX Sens. OMA post- DeMux v. LR4 dBm	-11.3	-12.5	-13.7	-13.7	-14.0

400G 2km Duplex SMF PMDs Comparison

400G 2km specs minus LR4 specs 4x25G NRZ no FEC MOD & DML	8x50G NRZ KP4 FEC MOD	8x50G PAM-4 KP4 FEC MOD DML	4x100G PAM-4 KP4 FEC MOD	4x100G DMT-K BCH FEC 25G DML	
TX OMA delta (pre-Mux) dB	0.3	1.0	0.1	2.3	2.6
RX Sens. delta (post-DeMux) dB	-1.2	-2.4	-2.4	-2.7	

Every RX Sens. delta is idealized, incomplete, and optimistic

400G (4x100G) PSM4 PMDs TX Specs

TX Specifications CWDM Grid	4x25G NRZ CWDM4 KR4 MOD / DML		2x50G NRZ KP4 FEC MOD	2x50G PAM4 KP4 FEC MOD / DML		1x100G KP4 FEC PAM4 MOD	1x100G DMT BCH FEC 25G DML
Operating BER	5.0E-05		2.0E-04	2.0E-04		2.0E-04	1.0E-03
ER Full Scale (min) dB	6.5	3.5	4.5	7.0	4.5	7.0	4.5
TX OMA pre-Mux (min) @TDP (max) dBm	-1.5	0.5	-1.0	-0.3	0.0	0.0	1.5
Mux Loss dB	2.5		1.5	1.5		0.0	0.0
TX OMA (min) @TDP (max) dBm	-4.0	-2.0	-2.5	-1.8	-1.5	0.0	1.5
Modulation Penalty dB	0.0		0.0	5.0		5.0	9 + Fk
TX OMA Eye (min) @TDP (max) dBm	-4.0	-2.0	-2.5	-6.8	-6.5	-5.0	-7.5 - Fk
TDP (max) dB	1.0	3.0	1.8	0.7	1.0	2.5	2.5
TX OMA Eye - TDP each lane (min) dBm	-5.0		-4.3	-7.5		-7.5	-10 - Fk

400G (4x100G) PSM4 PMDs RX Specs

RX Specifications CWDM Grid	4x25G NRZ CWDM4 KR4 MOD / DML	2x50G NRZ KP4 FEC MOD	2x50G PAM4 KP4 FEC MOD / DML	1x100G KP4 FEC PAM4 MOD	1x100G DMT BCH FEC 25G DML
Symbol (or Sample) Rate GBaud (or GS)	25.8	53.2	26.6	53.2	55.9
Operating BER	5.0E-05	2.0E-04	2.0E-04	2.0E-04	1.0E-03
TX OMA Eye - TDP each lane (min) dBm	-5.0	-4.3	-7.5	-7.5	-10 - Fk
Channel Insertion Loss & MPI penalty dB	5.0	5.0	5.0	5.0	5.0
RX Sens. OMA pre-FEC each lane (max) dBm	-10.0	-9.3	-12.5	-12.5	-15 - Fk
FEC Optical Gain dB	2.6	3.2	3.2	3.2	3.8
DeMux Loss + Lane BW Penalty dB	2.5	3.1	1.6	1.1	0 - Fk
TIA, Xtalk, Quantization Penalties dB	0.2	1.8	1.3	1.8	1.3
RX Sens. OMA post- DeMux v. CWDM4 dBm	-10.1	-11.0	-12.2	-12.2	-12.5

400G (4x100G) PSM4 PMDs Comparison

4x100G 2km specs minus CWDM4 Specs 4x25G NRZ KR4 FEC MOD & DML	2x50G NRZ KP4 FEC MOD	2x50G PAM-4 KP4 FEC MOD DML	1x100G PAM-4 KP4 FEC MOD	1x100G DMT-K BCH FEC 25G DML	
TX OMA delta (pre-Mux) dB	0.5	1.2	-0.5	1.5	1.0
RX Sens. delta (post-DeMux) dB	-0.9	-2.1	-2.1	-2.4	

Every RX Sens. delta is idealized, incomplete, and optimistic

400G 10km Duplex SMF PMDs TX Specs

TX Specifications LAN WDM Grid	4x25G NRZ LR4 No FEC MOD / DML		8x50G NRZ BCH FEC MOD	8x50G PAM4 BCH FEC MOD / DML		4x100G BCH FEC PAM4 MOD	4x100G DMT BCH FEC 25G DML
	Operating BER	1.0E-12		1.0E-03	1.0E-03		1.0E-03
ER Full Scale (min) dB	7.0	4.0	4.5	7.0	4.5	7.0	4.5
TX OMA pre-Mux (min) @TDP (max) dBm	1.2	2.4	2.5	2.7	3.5	4.0	5.0
Mux Loss dB	2.5		3.5	3.5		2.5	2.5
TX OMA (min) @TDP (max) dBm	-1.3	-0.1	-1.0	-0.8	0.0	1.5	2.5
Modulation Penalty dB	0.0		0.0	5.0		5.0	9 + Fk
TX OMA Eye (min) @TDP (max) dBm	-1.3	-0.1	-1.0	-5.8	-5.0	-3.5	-6.5 - Fk
TDP (max) dB	1.0	2.2	2.3	0.7	1.5	2.5	3.0
TX OMA Eye - TDP each lane (min) dBm	-2.3		-3.3	-6.5		-6.0	-9.5 - Fk

400G 10km Duplex SMF PMDs RX Specs

RX Specifications LAN WDM Grid	NRZ 4x25G LR4 No FEC MOD / DML	8x50G NRZ BCH FEC MOD	8x50G PAM4 BCH FEC MOD / DML	4x100G BCH FEC PAM4 MOD	4x100G DMT BCH FEC 25G DML
Symbol (or Sample) Rate Gbaud (or GS)	25.8	55.9	28.0	55.9	55.9
Operating BER	1.0E-12	1.0E-03	1.0E-03	1.0E-03	1.0E-03
TX OMA Eye - TDP each lane (min) dBm	-2.3	-3.3	-6.5	-6.0	-9.5 - Fk
Channel Insertion Loss & MPI penalty dB	6.3	7.0	7.0	7.0	7.0
RX Sens. OMA pre-FEC each lane (max) dBm	-8.6	-10.3	-13.5	-13.0	-16.5 -Fk
FEC Optical Gain v. 1e-12 BER dB	0.0	3.8	3.8	3.8	3.8
DeMux Loss + Lane BW Penalty dB	2.5	5.2	3.7	3.7	2.5 - Fk
TIA, Xtalk, Quantization Penalties dB	0.2	1.8	1.3	1.8	1.4
RX Sens. OMA post- DeMux v. LR4 dBm	-11.3	-13.5	-14.7	-14.7	-16.6

400G 10km Duplex SMF PMDs Comparison

400G 10km specs minus LR4 specs 4x25G NRZ no FEC MOD & DML	8x50G NRZ BCH FEC MOD	8x50G PAM-4 BCH FEC MOD DML	4x100G PAM-4 BCH FEC MOD	4x100G DMT-K BCH FEC 25G DML	
TX OMA delta (pre-Mux) dB	1.3	1.5	1.1	2.8	2.6
RX Sens. delta (post-DeMux) dB	-2.2	-3.4	-3.4	-5.3	

Every RX Sens. delta is idealized, incomplete, and optimistic

Optical Specifications of SMF PMDs Study

Thank you