IEEE P802.3bs 400Gb/s Ethernet: Study of 400Gb/s MMF PMD Options

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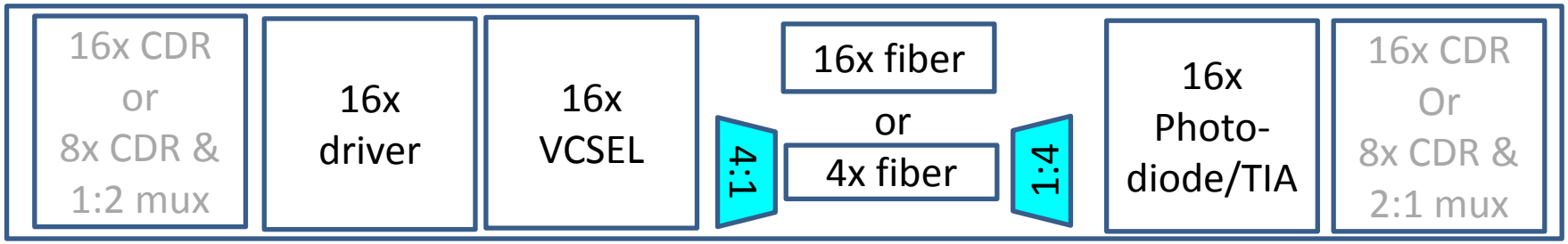
Study of 400 Gb/s options for MMF PMDs

- These are illustrative examples, not an exhaustive set
  - An initial study, not a set of spec proposals.
  - More work needed to investigate the details.

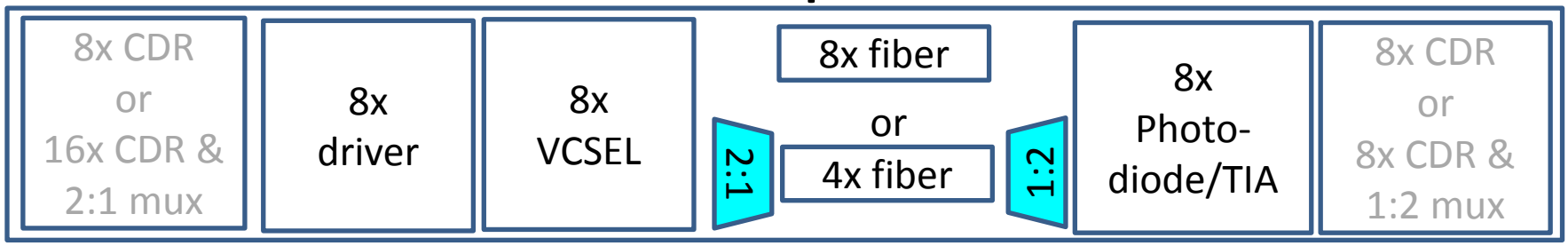
- 16 x 25 Gb/s optical - NRZ
  - 16 parallel fibers per direction;
  - Fewer fibers possible with use of shortwave WDM
- 8 x 50 Gb/s optical - NRZ or PAM4
  - 8 parallel fibers per direction
  - Fewer fibers possible with use of shortwave WDM

16 x 25 Gb/s per VCSEL



- 16 x 25 Gb/s – NRZ, 16 parallel fibers per direction
  - Follow 100GBASE-SR4 spec's with small tweak to support 10^{-13}
  - Shortwave WDM allows fewer fibers, e.g. 4 λ/fibre, 4 fibres per direction
    - WDM mux/demux losses would need better performing Tx and Rx
    - Fibre performance vs wavelength needs to be accounted for.
    - Eye safety ?

8 x 50 Gb/s per VCSEL



- 8 x 50 Gb/s - NRZ or PAM4, 8 fibres per direction
  - Shortwave WDM allows fewer fibers, e.g. 2 λ/fibre, 4 fibres per direction

400 Gb/s options for 100m MMF: Tx parameters

Parameter	400GbE-SR16	NRZ VCSEL w/ KR4 FEC	PAM-4 VCSEL w/ KR4 FEC	PAM-4 VCSEL w/ KR4 FEC
Symbol Rate, Gbaud	25.8	51.6	25.8	25.8
Operating BER	3.9E-5	3.9E-05	3.9E-05	3.9E-05
λs, RMS spectral width, nm	850, 0.6	850, **0.5**	850, **0.5**	850, **0.5**
Tx rise/fall time, 20-80%, ps	**21**	**10**	**21**	**21**
TX OMA (11/00)[a] min @ TDP (max), dBm	-3	**-1**	-3	**0**
ER (11/00)[a] min, dB	3	3	3	3
TX OMA (11/10)[b] @ TDP (max)	NA	NA	-8	-5
ER (11/10)[b] (min), dB	NA	NA	0.8[b]	0.8[b]
Allocation for penalties, dB	6.3	6.4	4	4
TX OMA (LSB) -TDP each lane (min), dBm	-9.3	-7.4	-12	-9

e.g. $RIN_{12}OMA$=-128.5 dB/Hz

$RIN_{12}OMA$=-130 dB/Hz
Equivalent to -140 dB/Hz at min ER

$RIN_{12}OMA$ = -126 dB/Hz
Equivalent to -147 dB/Hz at min ER

a: Highest/lowest optical power
b: OMA between the highest two optical power levels

400 Gb/s options for 100m MMF: Rx parameters

Parameter	400GbE-SR16	NRZ VCSEL w/ KR4 FEC	PAM-4 VCSEL w/ KR4 FEC	PAM-4 VCSEL w/ KR4 FEC
Symbol Rate, Gbaud	25.8	51.6	25.8	25.8
TX OMA (LSB) -TDP each lane (min), dBm	**-9.3**	**-7.4**	**-12**	**-9**
Channel Insertion Loss, dB	1.9	1.9	1.9	1.9
RX Sens. OMA pre-FEC each lane (max), dBm	**-11.2**	**-9.3**	**-13.9**	**-10.9**
For comparison to SR4				
BW & Other Penalties (vs. 25G limiting Rx), dB	*0.0*	*-2.5[c]*	*-1[d]*	*-1[d]*
Rx Sens. OMA SR4 equiv each lane (max), dBm	*-11.2*	*-11.8*	*-14.9*	*-11.9*

c: noise penalty for 50 Gb/s Rx
d: noise penalty for linear 25Gb/s Rx

Observations

- 16 x 25 Gb/s NRZ
  - Follow 100GBASE-SR4 specs with minor tweak to guarantee BER=10^{-13}
    - Low risk
  - Similar PMD specs for SWDM, but with higher performance Rx & Tx optics to account for mux/demux losses and fibre performance
    - Needs new VCSEL wavelengths
- 8 x 50 Gb/s NRZ
  - Needs VCSELs at least twice as fast as for 25 Gb/s to close link, and higher output power.
  - Would benefit from linear equalization at Tx and Rx, to relax OMA and sensitivity specs.
- 8 x 50 Gb/s PAM4
  - Link budget is challenging: Needs 25 Gb/s VCSELs with higher output power and much lower RIN.
  - Would benefit from Tx and Rx equalization to close link.
- Both 50 Gb/s NRZ and PAM4 would benefit from stronger FEC.