Towards a baseline proposal for a 400 Gb/s optical PMD supporting four MMF pairs

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Adopted physical layer specification objectives

- Define a physical layer specification that supports 400 Gb/s operation over 4 pairs of MMF with lengths up to at least 100 m

- Define a physical layer specification that supports 400 Gb/s operation over 8 pairs of MMF with lengths up to at least 100 m

Motivation (1)

- Expect broad market potential for a four-fiber-pair MMF PMD at 400 Gb/s. For example, this provides an attractive upgrade path for users of the successful 100GBASE-SR4 PMD

- Current MMF infrastructure is mainly single-fiber-pair or four-fiber-pair. Hence, standardization of a four-fiber-pair MMF PMD at 400 Gb/s helps to maintain the relevance of this infrastructure

- Large industry investment in MMF WDM in recent years:

  (i) proven and widely-adopted two-wavelength transceivers such as 40G Bi-Di and 100G Bi-Di
  (ii) SWDM MSA four-wavelength specifications
  (iii) completion of TIA-492AAAE and subsequent OM5 standardization

Motivation (2)

- Technical feasibility already demonstrated for RS(544, 514) FEC-supported 26.5625 GBd PAM4 modulation using uncooled VCSELs
- The above is under standardization as 50GBASE-SR, 100GBASE-SR2 and 200GBASE-SR4 in Clause 138 and is expected to form the basis of a “400GBASE-SR8” PMD
- Existing two-wavelength WDM products, such as 40G Bi-Di and 100G Bi-Di, support MMF with transmission in the 847 to 863 nm and 900 to 916 nm ranges
- In particular, 100G Bi-Di uses RS(544, 514) FEC and 26.5625 GBd PAM4 modulation to achieve 70 m, 100 m and 150 m reach over OM3, OM4 and OM5, respectively

OM3 and OM4 performance

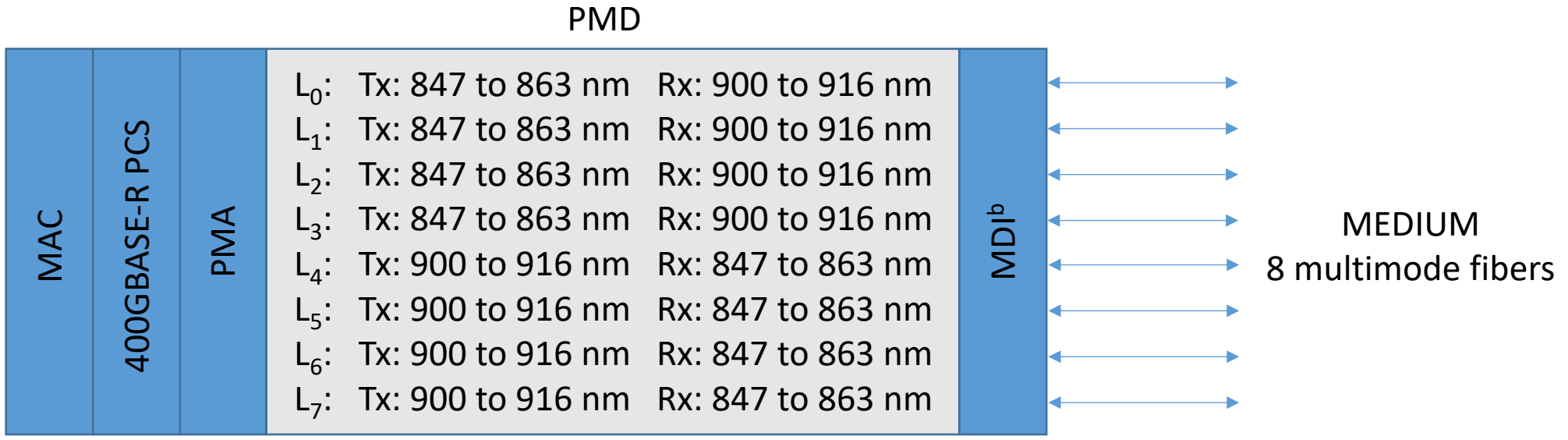
- Field-proven WDM products exist using OM3 and OM4 with transmission in the wavelength ranges in this proposal
- Guidance from fiber manufacturers has been received regarding performance of OM3 and OM4 in these wavelength ranges
- Furthermore, TIA and IEC are expected to provide formal guidance on OM3 and OM4 bandwidth over the entire 840 to 953 nm wavelength range (see kolesar_NGMMF_02_jan18)

Bi-directional approach

- Both bi-directional and co-directional approaches are technically feasible
- A bi-directional approach offers the simplicity of only one VCSEL launch into each end of a fiber. Hence it is easier to condition the launch to meet encircled flux requirements. It is also preferable for eye safety
- Furthermore, a bi-directional approach has the significant advantage of allowing breakout from a “400GBASE-SR4.2” transceiver to four 100G Bi-Di transceivers
- 100G Bi-Di is a multi-vendor solution

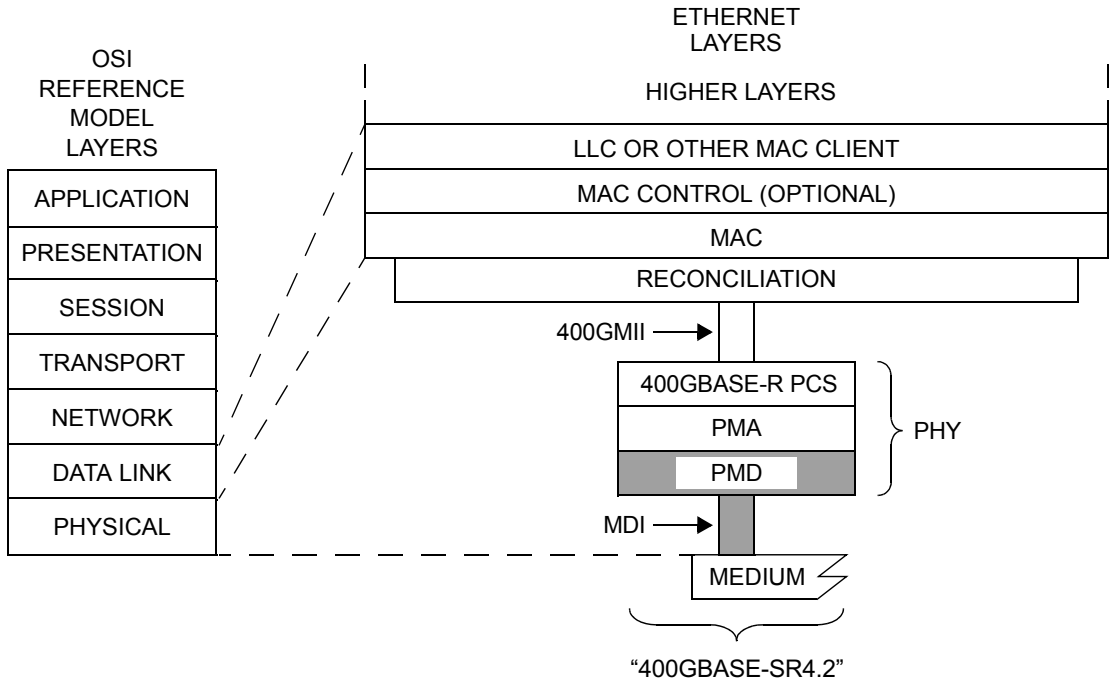
Baseline proposal

- Bi-directional WDM transmission with required operating range of 0.5 m to 70 m OM3, 0.5 m to 100 m OM4 and 0.5 m to 150 m OM5
- Using the RS(544, 514) FEC in the 400GBASE-R PCS, then for each lane: 26.5625 GBd PAM4 modulation with a pre-FEC BER requirement[a] of 2.4×10^{-4}



[a]Provided that the error statistics are sufficiently random to meet an appropriate frame loss ratio requirement (to be determined).
[b]MDI lane assignment to be determined.

Position in 802.3 architecture



400GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

SR = PMD FOR MULTIMODE FIBER

Transmit center wavelength ranges

Lane	Transmit center wavelength range
L_0 to L_3	847 to 863 nm
L_4 to L_7	900 to 916 nm

- These ranges are proposed on the basis of being close to optimal for two-wavelength solutions
- The range for L_0 to L_3 is shifted higher than the conventional 840 to 860 nm range in order to benefit from improved VCSEL speed
- ≈40 nm guard band allows very low cost filter technology
- VCSELs with these specifications are commercially available from component vendors
- Mature VCSEL technology and volume production due to use in 40G Bi-Di and 100G Bi-Di transceivers. For each range above, VCSEL shipments to date of several million with device hours in the tens of billions
- Interoperation with four-wavelength solutions is not expected to be required and therefore not a criterion in this wavelength proposal

Transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Center wavelength, L_0 to L_3 (range)	847 to 863	nm
Center wavelength, L_4 to L_7 (range)	900 to 916	nm
Modulation format, each lane	PAM4	
RMS spectral width, each lane[a] (max)	0.6	nm
Average launch power, each lane (max)	4	dBm
Average launch power, each lane (min)	–6	dBm
OMA_{outer}, each lane (max)	3	dBm
OMA_{outer}, each lane[b] (min)	–4	dBm
OMA_{outer} – TDECQ, each lane (min)	–5.9	dBm
TDECQ, each lane (max)	4.9	dB
Average launch power of OFF transmitter, each lane (max)	–30	dBm
Extinction ratio, each lane (min)	3	dB
Optical return loss tolerance, each lane (max)	12	dB
Encircled flux, each lane[c]	≥ 86% @ 19 µm, ≤ 30% @ 4.5 µm	

TDECQ methodology is assumed to be based on 138.8 (D3.2).
[a]RMS spectral width is the standard deviation of the spectrum.
[b]Even if TDECQ < 1.9 dB, OMA_{outer} (min) must exceed this value.
[c]If measured into type A1a.2, type A1a.3 or type A1a.4, 50 µm fiber, in accordance with IEC 61280-1-4.

Receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Center wavelength, L_0 to L_3 (range)	900 to 916	nm
Center wavelength, L_4 to L_7 (range)	847 to 863	nm
Modulation format, each lane	PAM4	
Damage threshold, each lane[a] (min)	5	dBm
Average receive power, each lane (max)	4	dBm
Average receive power, each lane[b] (min)	–8	dBm
Receive power (OMA_{outer}), each lane (max)	3	dBm
Receiver reflectance, each lane (max)	–12	dB
Stressed receiver sensitivity (OMA_{outer}), each lane[c] (max)	–3.1	dBm
Receiver sensitivity (OMA_{outer}), each lane[d] (max)	max(–6.1, SECQ – 8)	dBm
Conditions of stressed receiver sensitivity test[e]:		
Stressed eye closure (SECQ), lane under test	4.9	dB
OMA_{outer} of each aggressor lane	3	dBm

SECQ methodology is assumed to be based on 138.8 (D3.2).

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.

[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

[c]Measured with conformance test signal at TP3 (see 138.8.8 (D3.2)) for the BER specified (to be confirmed).

[d]Receiver sensitivity is informative.

[e]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

Illustrative link power budget (850 nm)

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 850 nm[a]	2000	4700	4700	MHz km
Power budget (for max TDECQ)	7	7	7	dB
Operating distance	70	100	150	m
Channel insertion loss[b]	1.8	1.9	2	dB
Allocation for penalties[c] (for max TDECQ)	5	5	5	dB
Additional insertion loss allowed	0.2	0.1	0	dB

[a]Per IEC 60793-2-10.
[b]The channel insertion loss is calculated using the maximum distance specified on Slide 8 and cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 138.10.2.2.1 (D3.2).
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Illustrative link power budget (916 nm)

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 916 nm[a]	1230	1890	2940	MHz km
Power budget (for max TDECQ)	7	7	7	dB
Operating distance	70	100	150	m
Channel insertion loss[b]	1.8	1.9	2	dB
Allocation for penalties[c] (for max TDECQ)	5	5	5	dB
Additional insertion loss allowed	0.2	0.1	0	dB

[a]Per kolesar_NGMMF_01_jan18 (subject to confirmation by TIA and IEC).
[b]The channel insertion loss is calculated using the maximum distance specified on Slide 8 and cabled optical fiber attenuation of 3.5 dB/km at 916 nm plus an allocation for connection and splice loss given in 138.10.2.2.1 (D3.2).
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Summary

- Slides 8 to 14 provide the basis for a baseline proposal for “400GBASE-SR4.2” based on FEC-supported 26.5625 GBd PAM4 modulation
- Transmit and receive characteristics are based on Clause 138 (D3.2) facilitating easy standardization using established metrics, notably TDECQ and SECQ
- OM3 and OM4 performance in the proposed wavelength ranges is field proven and formal guidance is expected from TIA and IEC
- Bi-directional approach allows breakout to multi-vendor 100G Bi-Di transceiver