

# Updated baseline proposal for the 100 Gb/s MMF objective using two-wavelength PAM4 modulation

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# Adopted MMF objectives

- Define a single-lane 50 Gb/s PHY for operation over MMF with lengths up to at least 100 m
- Define a two-lane 100 Gb/s PHY for operation over MMF with lengths up to at least 100 m
- Define 200 Gb/s PHYs for operation over MMF with lengths up to at least 100 m

# Motivation

- Broad market potential for a duplex MMF solution at 100 Gb/s
- Technical feasibility of FEC-supported 26.5625 GBd PAM4 modulation demonstrated using uncooled VCSELs, building on NRZ electronics and optoelectronics developed for 25 Gb/s lanes in multiple 802.3 and T11 standards
- Large industry investment in multimode WDM in recent years, evidenced by: (i) field-proven products such as Cisco 40G Bi-Di; (ii) 100 Gb/s demonstrations by multiple vendors at OFC and ECOC; (iii) formation of SWDM Alliance to encourage adoption of cost-effective solutions for duplex MMF; (iv) recent completion of TIA-492AAAE WBMMF standard

# Motivation (cont.)

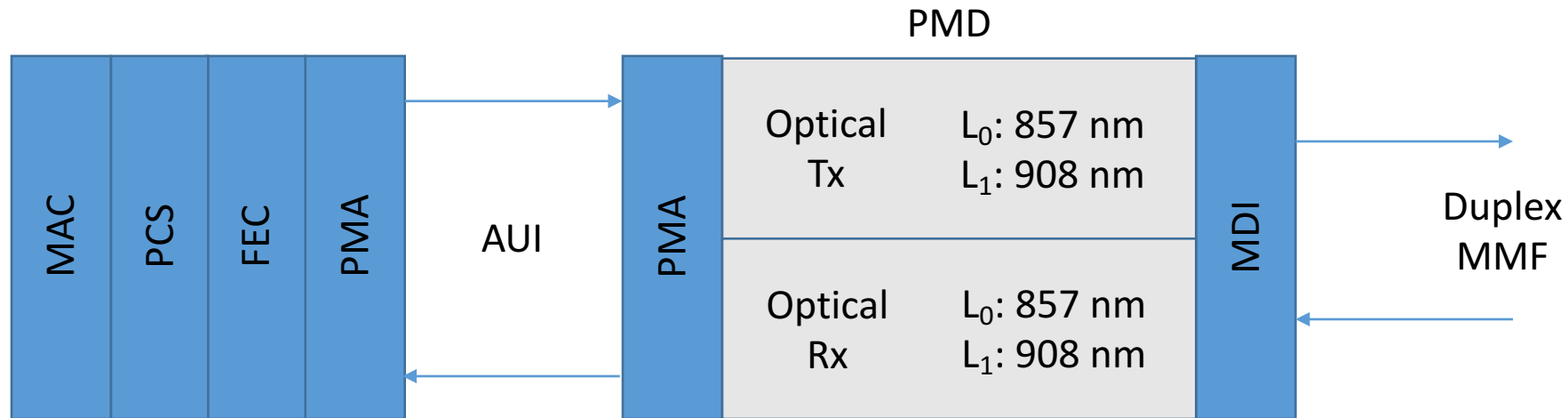
- A two-fibers-per-direction solution is unconventional and poorly matched to the requirements of typical cabling installations
- Transceiver cost for a two-wavelengths-per-direction solution is expected to be similar to a two fibers per direction solution
- A two-wavelengths-per-direction solution provides a compelling route to a future 400 Gb/s PMD based on four fibers per direction
- Maintains the attractiveness of MMF cabling infrastructure
- The newly-standardized WBMMF supports links up to 150 m

# OM3 & OM4 MMF performance

- Guidance from fiber manufacturers has been received regarding performance of OM3 and OM4 MMF in the 900 nm to 916 nm wavelength range
- Field-proven WDM products exist using OM3 and OM4 MMF with transmission in the 900 nm to 916 nm wavelength range
- Independent verification of feasibility of transmission over OM3 and OM4 in the 900 nm to 916 nm wavelength range:
  - “Evaluation of extended reach capability of 40G Bi-Di VCSEL-based WDM transmission over OM4 multimode fibers”
  - X. Chen, J. E. Hurley, S. Bickman, J. Abbott, B. Chow, D. Coleman, M.-J. Li
  - Proc. SPIE, vol. 9772, February 2016

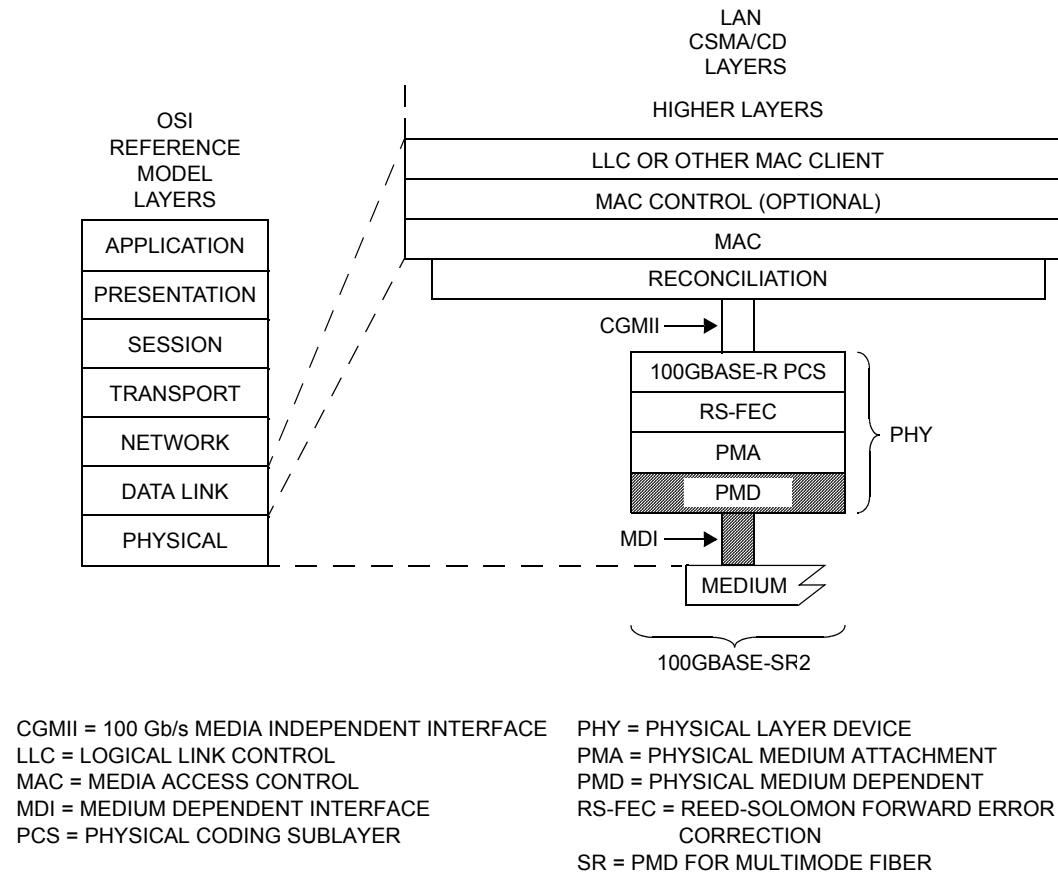
# Baseline proposal for 100GBASE-SR2

- Co-directional WDM transmission (with center wavelengths of 857 nm for  $L_0$  and 908 nm for  $L_1$ ) over 70 m OM3, 100 m OM4 and 150 m WBMMF
- If the project chooses RS(544, 514) FEC, then for each lane: 26.5625 GBd PAM4 modulation with pre-FEC BER target of  $2.4 \times 10^{-4}$





# Position in 802.3 architecture



# WDM lane assignments

Lane	Center wavelength	Wavelength range
L <sub>0</sub>	857 nm	844 nm to 870 nm
L <sub>1</sub>	908 nm	900 nm to 916 nm

# Transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Lane wavelength range: lane L <sub>0</sub>	844 to 870	nm
lane L <sub>1</sub>	900 to 916	nm
Modulation format	PAM4	
RMS spectral width	0.6	nm
Total average launch power (max)	+6.5	dBm
Average launch power, each lane (max)	+3.5	dBm
Average launch power, each lane (min)	-5	dBm
OMA <sub>outer</sub> , each lane (max)	+3	dBm
OMA <sub>outer</sub> , each lane (min) <sup>a</sup>	-3 TBC	dBm
OMA <sub>outer</sub> – TDECQ, each lane (min)	-4 TBC	dBm
TDECQ, each lane (max)	4 TBC	dB
Average launch power of OFF transmitter, each lane (max)	-30	dBm
Extinction ratio (min)	3	dB
Encircled flux	≥ 86% @ 19 μm, ≤ 30% @ 4.5 μm	

Transmit characteristics are at TP2

TDECQ is under development in P802.3bs for SMF PMDs; TDECQ configuration (including reference receiver) for MMF PMDs is TBD

<sup>a</sup> Even if TDECQ < 1 dB, OMA<sub>outer</sub> must be at least this value

# Receive characteristics

Description	Value	Unit
Signaling rate, each lane (range)	26.5625 ± 100 ppm	GBd
Lane wavelength range: lane L <sub>0</sub>	844 to 870	nm
lane L <sub>1</sub>	900 to 916	nm
Modulation format	PAM4	
Damage threshold (min)	+7.5	dBm
Average receive power, each lane (max)	+3.5	dBm
Average receive power, each lane (min)	-6.9	dBm
Receive power, each lane (OMA <sub>outer</sub> ) (max)	+3	dBm
Receiver reflectance (max)	-12	dB
Stressed receiver sensitivity, each lane (OMA <sub>outer</sub> ) (max)	-1.9 TBC	dBm
Receiver sensitivity, each lane (OMA <sub>outer</sub> ) (max) <sup>a</sup>	-6 TBC	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure (SECQ), lane under test	4 TBC	dB
OMA of each aggressor lane	+3	dBm

Receive characteristics are at TP3

TDECQ and SECQ are under development in P802.3bs for SMF PMDs; TDECQ and SECQ configuration (including reference receiver) for MMF PMDs is TBD

<sup>a</sup> Receiver sensitivity is informative

# Illustrative link power budget (850 nm)

Parameter	OM3	OM4	WBMMF	Unit
Effective modal bandwidth at 850 nm	2000	4700	4700	MHz km
Power budget for max TDECQ	6	6	6	dB
Operating distance	70	100	150	m
Channel insertion loss	1.8	1.9	1.9	dB
Allocation for penalties (for max TDECQ)	4.1 TBC	4.1 TBC	4.1 TBC	dB
Additional insertion loss allowed	0.1	0	0	dB

# Illustrative link power budget (916 nm)

Parameter	OM3	OM4	WBMMF	Unit
Effective modal bandwidth at 916 nm	1400	1900	2950	MHz km
Power budget for max TDECQ	6	6	6	dB
Operating distance	70	100	150	m
Channel insertion loss	1.7	1.8	1.8	dB
Allocation for penalties (for max TDECQ)	4.1 TBC	4.1 TBC	4.1 TBC	dB
Additional insertion loss allowed	0.2	0.1	0.1	dB

# Conclusions

- Baseline proposal for 100GBASE-SR2 based on FEC-supported 26.5625 GBd PAM4 modulation
- Two wavelengths per direction allows support of duplex MMF with broad market potential
- FEC-supported 26.5625 GBd PAM4 approach is re-used from proposed 50GBASE-SR and 200GBASE-SR4, facilitating easy standardization, using same metrics, e.g. TDECQ
- Builds on substantial industry investment in multimode WDM by multiple vendors
- OM3 & OM4 MMF performance at the proposed wavelengths is field proven
- WBMMF support allows 150 m reach
- Provides a path to a future four-fiber 400 Gb/s PMD