400G-SWDM4.2

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400G-SWDM4.2 status quo

- 4 fibres, 2 wavelengths/fibre x 50 Gb/s PAM4 per wavelength = 400 Gb/s
- Choice of wavelengths resolved
  - Nominal 850 nm and 910 nm
    http://www.ieee802.org/3/cm/public/adhoc/king_3cm_adhoc_01_062818.pdf
    - 0.7 dB link budget penalty but wider availability of 910 nm VCSELs
- Choice of directionality to be determined, with proposals for
  - Co-directional (4 fibres per direction)
    http://www.ieee802.org/3/cm/public/May18/king_3cm_02_0518.pdf
    - Follows usual 802.3 optics convention of distinct transmit and receive fibres
  - Bi-directional (8 fibres, both directions on each)
    http://www.ieee802.org/3/cm/public/May18/ingham_3cm_01_0518.pdf
    - .. doesn't

Contents (addressing questions raised in P802.3cm May interim)

- Breakout compatibility
  - Implications for power, cost and BMP
- Board layout/PHY availability, and BMP
- Eye-safety limits for co-directional 400GBASE-4.2
- Launch optics with more than 1 wavelength per fibre end
- Specific transmitter, receiver and link budget specs for a co-directional 400G SWDM 4.2

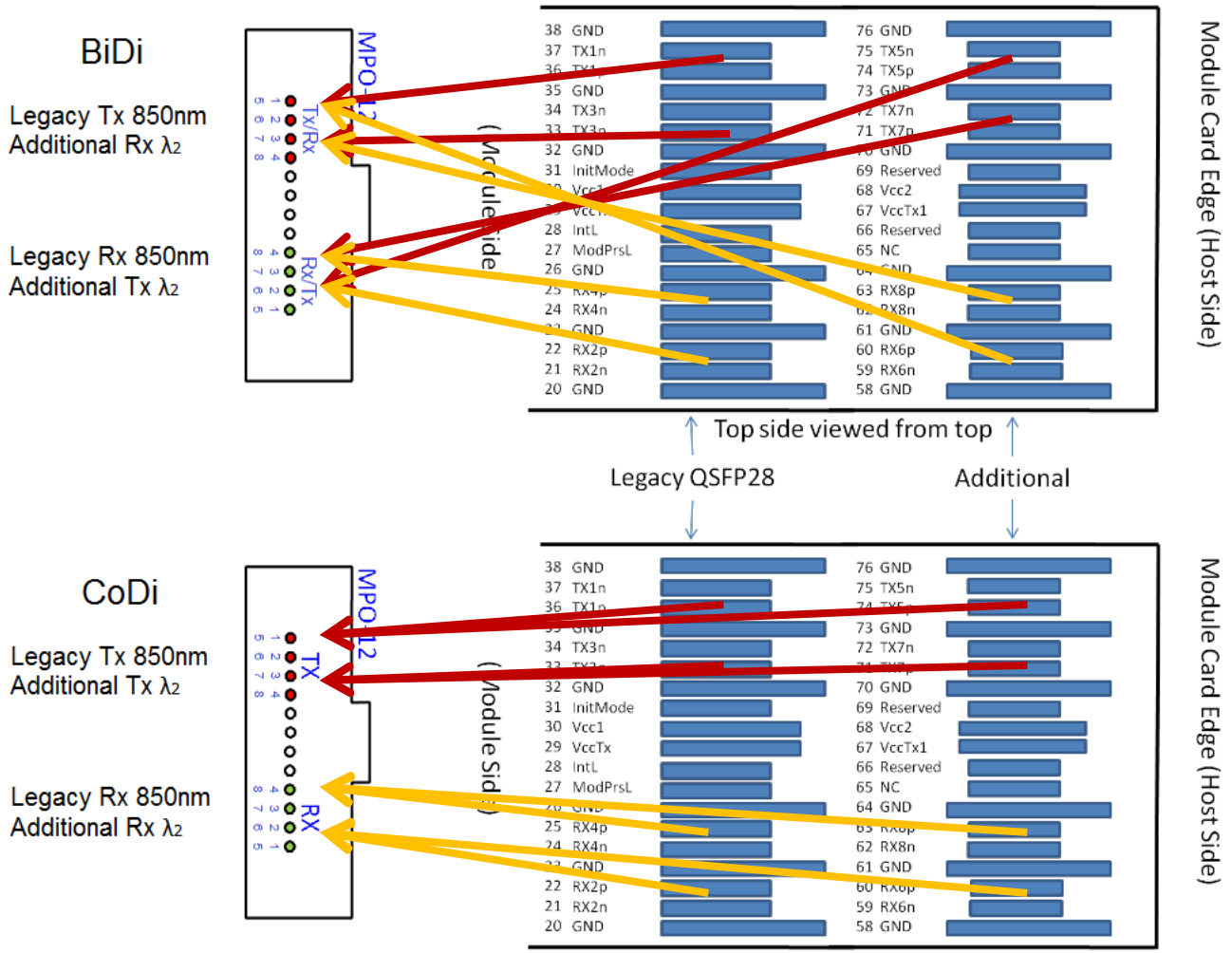
Breakout

- Bi-directional proposal claims compatibility with breakout to existing 100G-SWDM2 bidi
  - As revealed in May, the 100G-SWDM2 bidi relies on a proprietary FEC which is incompatible with KP4 FEC (clause 91)
  - To be compatible with KP4 FEC hosts, and breakout to existing 100G-SWDM2 bidi, FEC conversion would be required inside a 400G bidi module
    - Burdens the 400GBASE-4.2 module with PCS and FEC inside the module, adding cost and power
    - Currently, such a FEC convertor is not broadly available
- Co-directional proposal would be compatible with a future KP4 supported 100G-SWDM2 module, with a manufacturing platform similar to 100GBASE-SR2.
  - Specs for 100GBASE-1.2 would fall out of the 400GBASE-4.2 co-di proposal

Co-di vs bi-di: board routing

Assumptions:

- Legacy lane mapping from QSFP will not be changed
- Legacy lanes must operate at 850nm wavelength
- Additional optical lane 5 maps to legacy 1, 6 to 2, 7 to 3, 8 to 4



- Co-di has simpler layout, enables a common manufacturing platform with 400G-SR8
- Bi-di needs signal lane cross-overs – a signal integrity challenge, and higher cost on PCB – or a bidi compatible PHY with crossovers inside the IC

Eye safety for co-directional 400GBASE-SR4.2

Class 1 , 1M Emission Limits for range: 700 nm to 1400 nm

Parameter	Lane 1	Lane 2	Units	Notes
λ =	840	910	nm	Wavelenghts, each lane
Power =	4	4	dBm	Power each lane
NA =	0.18	0.18	-	Numerical Aperture - tolerance
d_0 =	7.0		*mm*	Stop aperture
L =	100.0		*mm*	*Source-aperture distance*
N_{fibers}	4.0			Number of fibers
D_{fibers}	0.25		*mm*	Fiber Separation
Source size (one)	0.05			MMF diameter or SMF MFD
alpha (worst)	2.50			Subtense source angle
T2	10.24		*sec*	Emission duraiton
d_{63} =	21.18		*mm*	Beam diam. 63%
A =	0.00		m^2	App. Area
C_4 =	1.905	2.630	-	Correction factor 4
C_6 =	1.333		-	Correction factor 6
Worst Comb_C_6 size	2.000			
C_7 =	1.0	1.0	-	Correction factor 7
η =	0.104		-	Fraction Power accessible

Accessible Emission Level

Power_AEL	**0.497**	**0.686**	mW	XCVR CLASS 1M LEVEL
	-3.04	**-1.64**	dBm	**COMPLIANT**
Max Power	**4.803**	**6.630**	mW	
Hazard_1=	**6.81**	**8.21**	dBm	
				XCVR HAZARD LEVEL FOR 1M
Hazard Levels	**0.523**	**0.379**		**0.902**
Eye Safety:	**SAFE**	**SAFE**		**SAFE**

- Four fibres with 2 wavelengths per fibre
  - Co-di has ~3dB lower maximum eye-safety power per wavelength than a bi-di approach
- This is not a practical concern for a co-di approach:
  - +4 dBm max average power per wavelength
  - 4 adjacent MMF fibres (250um spacing between fibre centres)
- 400GBASE-SR4.2 co-di can be consistent with a Hazard level 1M classification for IEC 60825-2, Edition 3.2 (December 2010)

http://www.ieee802.org/3/cm/public/May18/castro_3cm_02a_0518.pdf

Launch optics for co-directional 400GBASE-4.2

- The optics for launching multiple wavelength sources into a single-mode fibre are well understood and have been incorporated into many established high volume products.
  - Examples: 100GBASE-LR and -ER, 400GBASE-FR, -LR, etc

- The optics get easier for launching multiple wavelengths into multimode fibre, where alignment tolerances are significantly relaxed compared to SMF
- Tolerances are compatible with plastic optics and conventional VCSEL alignment procedures
  - Example: 40G-SWDM4
    - *http://www.swdm.org/msa*

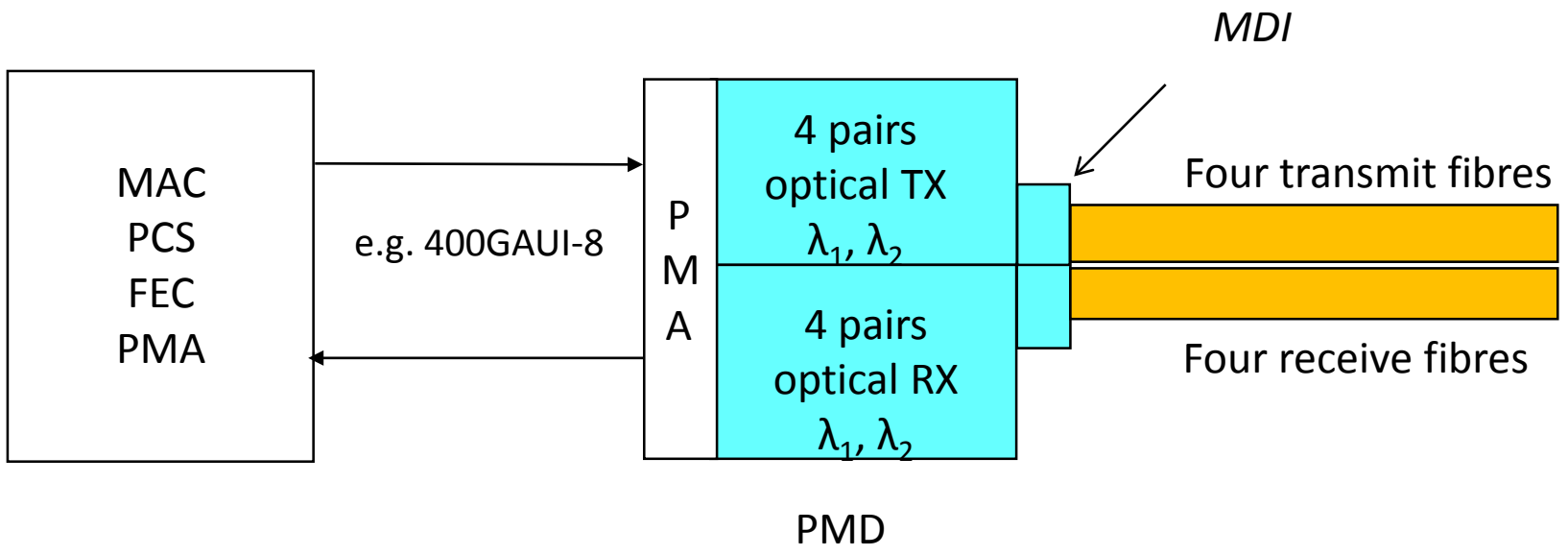
Specific Tx, Rx, and link specs for 400GBASE-SR4.2 co-di

Notes

- 4 pairs MMF, 1 fibre per direction, two wavelength per fibre
  - i.e. clearly identifiable ‘transmit’ fibres and ‘receive’ fibres
- 850 nm and 910 nm sources and receivers
  - Wide spaced wavelengths make mux/demux easier to make
  - OM3 and OM4 EMBs are subject to study by TIA and IEEE (Next Generation MMF - study group for 400G SWDM)
  - Multiple suppliers of suitable VCSELs
  - Multiple suppliers of PHYs, common manufacturing platform with 400GBASE-SR8
  - No proprietary components, FECs, or specs

Proposal snapshot

- Four optical fibres per direction, two wavelengths per fibre, co-directional propagation
- Each wavelength @ 26.5625 GBd PAM4 over 100 m OM4 fiber.
  - Assumes re-use of KP4 FEC
- 850 nm and 910 nm sources and receivers
  - Assumes target BER (prior to error correction) of 2.4×10^{-4} and random error statistics



Optical transmitter characteristics

Description	850nm channel	910nm channel	Unit
Signaling rate, each wavelength, (range)	26.5625 ± 100ppm		GBd
Modulation format	PAM4	PAM4	
Center wavelength (range),	840 – 863	900 – 918	nm
RMS spectral width (max)	0.6	0.65	nm
Average launch power, each lane (max)	+4		dBm
Average launch power, each lane (min)	-6.5		dBm
Optical Modulation Amplitude (OMA_{outer}), each lane (max)	+3		dBm
Optical Modulation Amplitude (OMA_{outer}), each lane (min)	-4.5		dBm
Launch power in OMA_{outer} minus TDECQ (min)	-5.9		dBm
TDECQ, each lane (max)	4.5		dB
Transmitter transition time, each lane	34		ps
$RIN_{12}OMA$ (max)	-128		dB/Hz
Average launch power of OFF transmitter, each lane (max)	-30		dBm
Extinction ratio (min)	3		dB
Optical return loss tolerance (max)	12		dB
Encircled Flux	≥ 86% at 19 μm ≤ 30% at 4.5 μm		

Optical receiver

Description	Value	Unit
Signaling rate, each wavelength, (range)	26.5625 ± 100ppm	GBd
Modulation format	PAM4	
Center wavelengths (ranges),	840 – 863 900 – 918	nm
Damage threshold (min)	+5	dBm
Average receive power, each lane (max)	+4	dBm
Average receive power, each lane (min)	-8.4	dBm
Receive power, each lane (OMA_{outer}) (max)	+3	dBm
Receiver reflectance (max)	-12	dB
Stressed receiver sensitivity (OMA_{outer}), each lane (max)[a]	-3.5	dBm
Receiver sensitivity (OMA_{outer}), each lane (max)[b]	Follow method in clause 138 - TBC	dBm
Conditions of stressed receiver sensitivity test		
Stressed eye closure (SECQ), for 850 nm channel	4.5	dB
Stressed eye closure (SECQ), for 910 nm channel	4.5	dB
OMA of each aggressor lane	+3	dBm

a) At BER = 2.4×10^{-4}

b) Informative

Link budget

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 850 nm	2000	4700	4700	MHz.km
Power budget (for max TDECQ) for 850 nm and 910 nm channels	6.6			dB
Operating distance	70	100	150	m
Channel insertion loss	1.8	1.9	2.0	dB
Allocation for penalties (for max TDECQ)	4.6			dB
Additional insertion loss allowed	0.2	0.1	0.0	dB

Summary

- A 400GBASE-SR4.2 baseline is described
  - 4 fibres, 2 wavelengths/fibre x 50 Gb/s PAM4 per wavelength,
  - With
    - 850 nm and 910 nm wavelengths
      - *for source availability*

    and
    - Co-directional propagation (4 transmit fibres and 4 receive fibres)
      - *for lowest cost, lowest technical risk*
      - *broad market potential, with widest base of suppliers for critical sub-components*