100GBASE-CWDM Baseline Proposal

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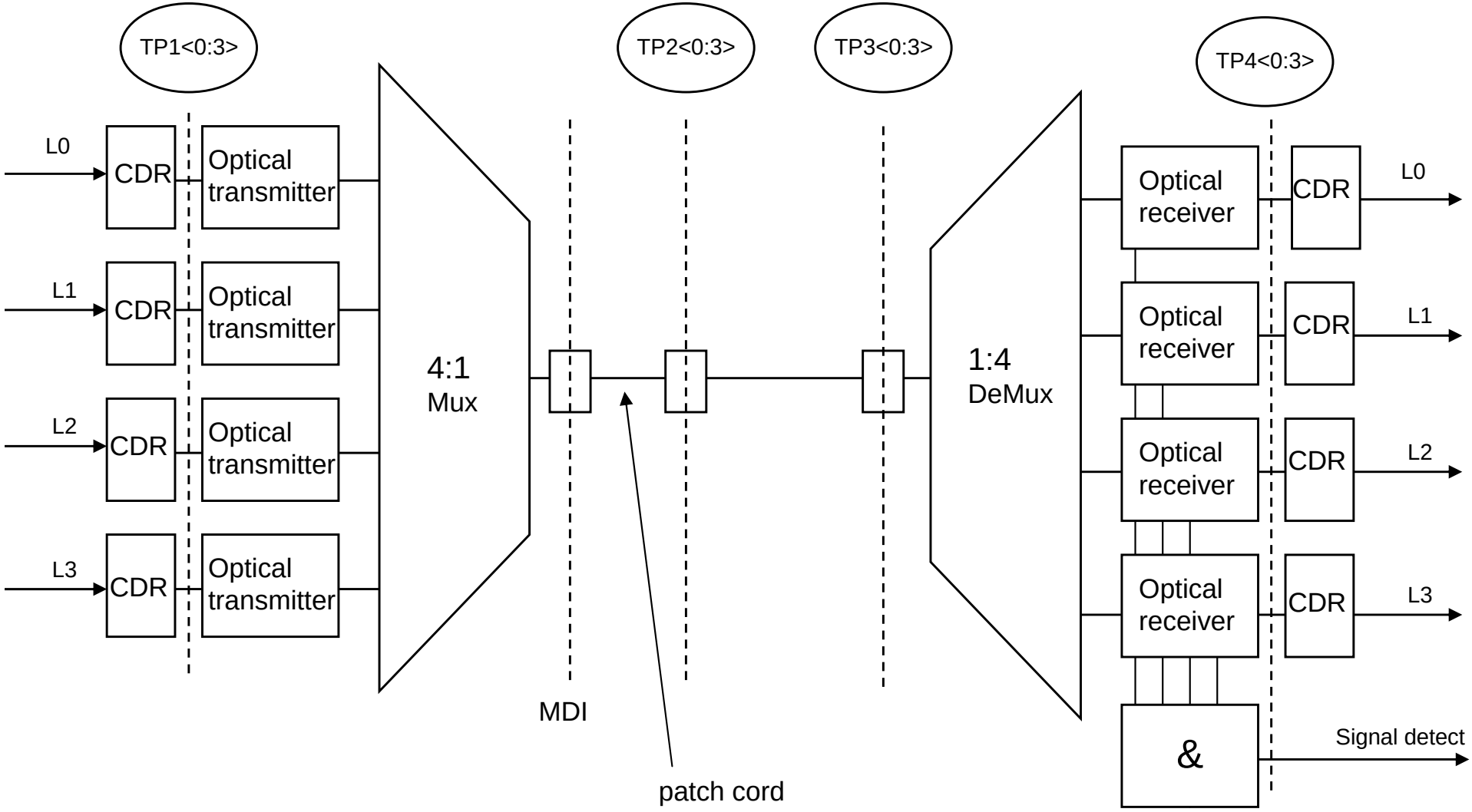
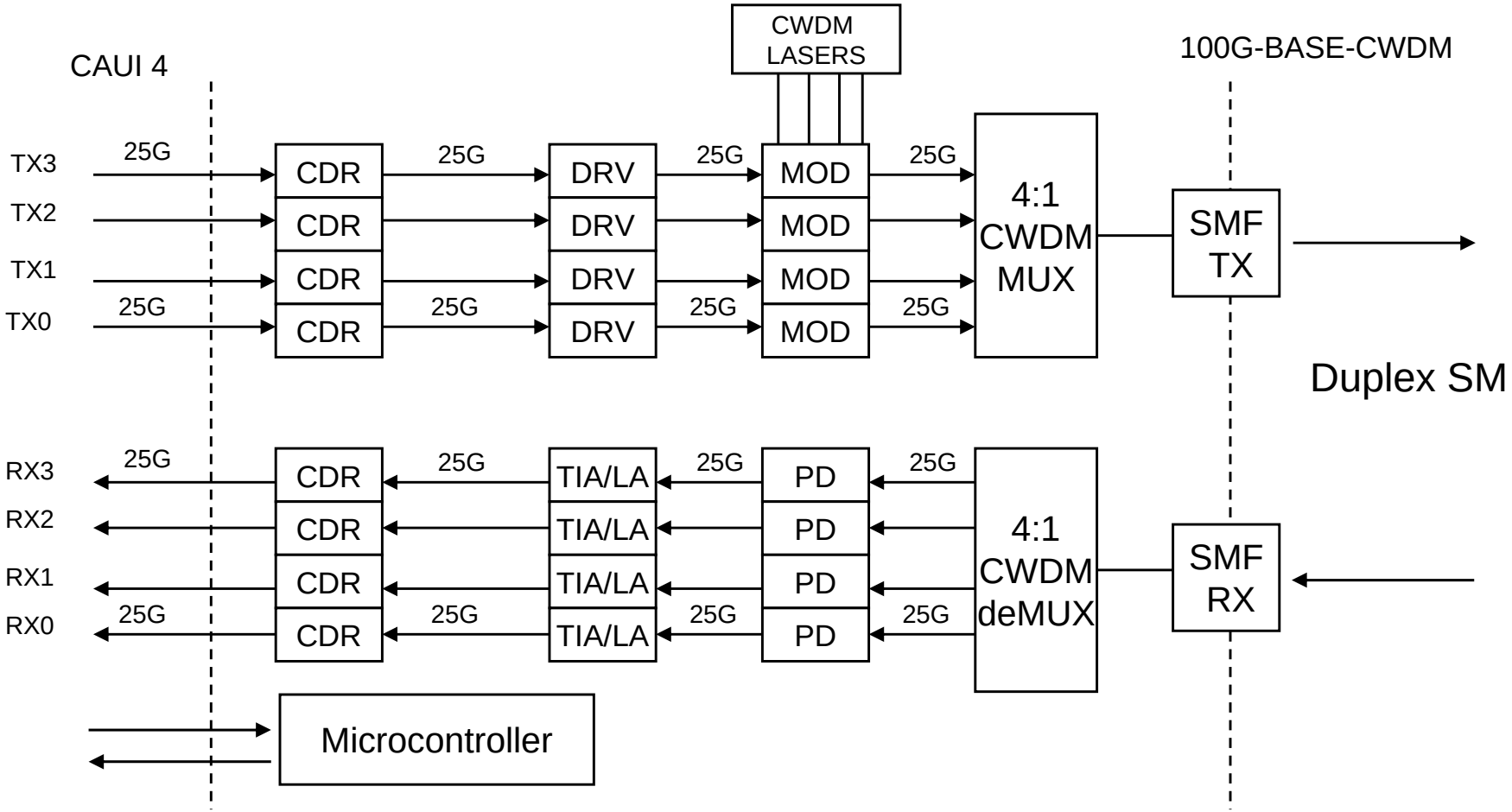
Proposed link architecture



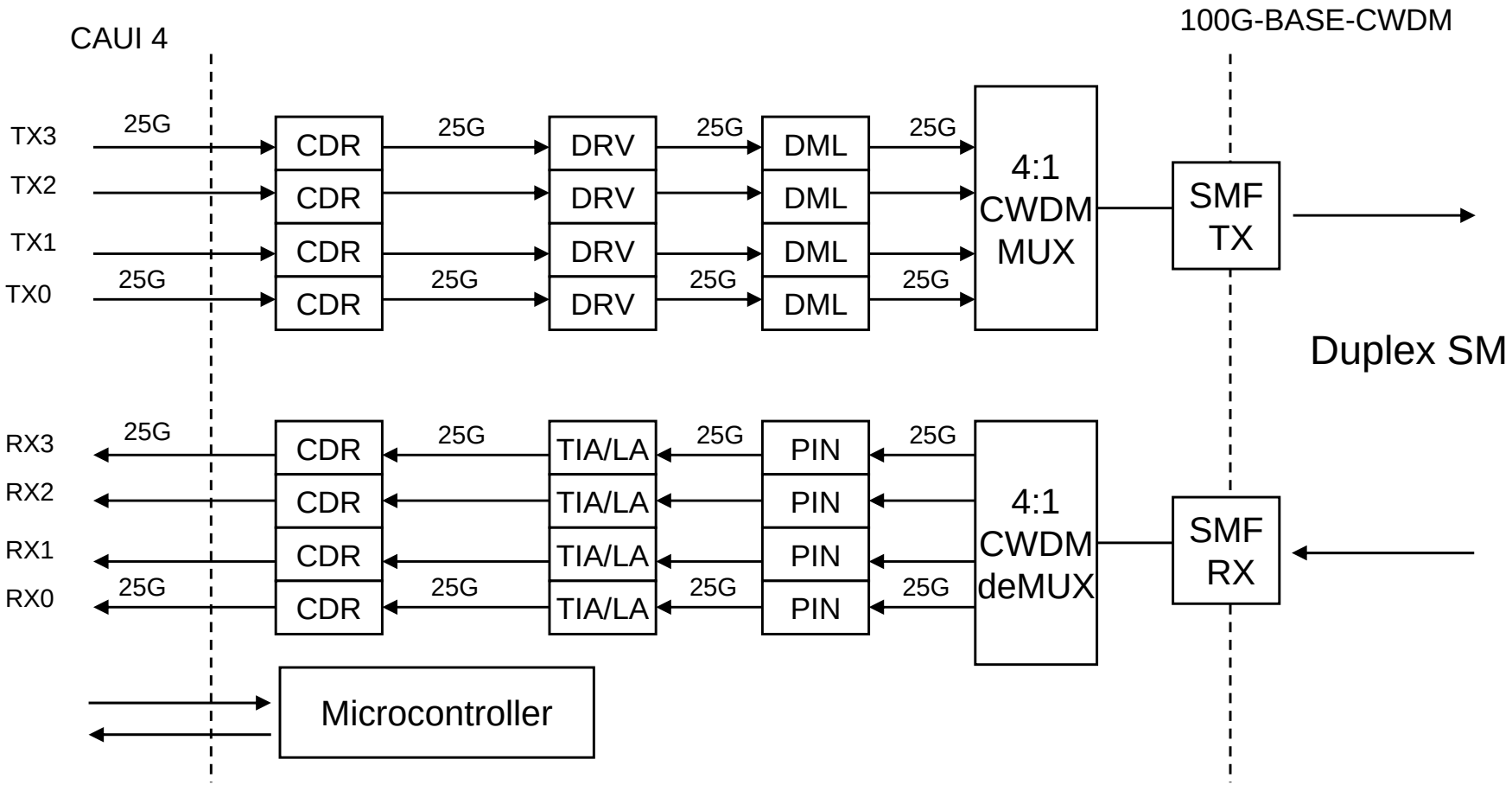
Retimers are a part of PMA. They can be incorporated into a host module or in the optical module. TP1 and TP4 remain as points on the PMD service interface, however not necessarily exposed.

100GBASE-CWDM block diagram



- Uncooled
- Retimed
- Various technology implementations feasible - Si Photonics, EML DFB, etc.

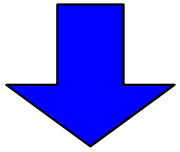
Alternative 100GBASE-CWDM block diagram



- Various technology implementations feasible:
  - 4 CWDM DML DFB lasers
  - 4 channel CWDM DML DFB laser array

Cost reduction 1: CWDM vs LR4

- Remove TEC
  - Save TEC related cost in BOM, Assy and Test
  - Enables CoB and other advanced packaging
  - Enables monolithic or high density O/E integration



Need CWDM grid instead of LAN to accommodate temperature drifts in TX and RX

Expected cost reduction with some technologies and with volumes up to 62% relative to cost-reduced LR4 (e.g. shen_01a_0313_smf)

Example: Table on page 9 of shen_01a_0313

After applying all potential cost reduction measures:

	Cost reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

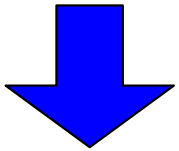
100GBASE-CWDM lane assignment

Parameter	100GBASE-CWDM	Unit
L0 lane central wavelength	1271	nm
L0 lane wavelength (range)	1264.5 to 1277.5	nm
L1 lane central wavelength	1291	nm
L1 lane wavelength (range)	1284.5 to 1297.5	nm
L2 lane central wavelength	1311	nm
L2 lane wavelength (range)	1304.5 to 1317.5	nm
L3 lane central wavelength	1331	nm
L3 lane wavelength (range)	1324.5 to 1337.5	nm

Note: CWDM grid as defined in ITU-T G694.2 Table.1

Cost reduction 2: CWDM vs LR4

- Decrease link budget
  - Enables monolithic or high density O/E integration
  - Enables advanced assembly and packaging
  - Low power CW DFB laser



Need to decrease RX sensitivity to accommodate loss in WDM demux

Expected cost reduction with some technologies and with volumes up to 67% relative to cost-reduced LR4 (e.g. vlasov_01a_1112_optx)

Example: Table in page 16 of vlasov_01a_1112

Typo, should be LR4(CFP4)

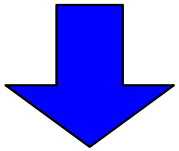
Table 1. Module cost

Reference LR4 (CFP4) taken from cole_02_0512_optx.pdf
LR4 (CFP)/LR4 (CFP4) = 1.75; LR4(CFP)/SR4 = 4

	LR4	PAM8	PSM4	WDM4	Notes
Total module cost	3	2	1.5	1	This presentation

Cost reduction 3: CWDM vs LR4

- Channel insertion loss of 4dB
  - Compatible with maximum attenuation of 4dB as defined in ITU-T VSR2000 for cables with attenuation category R



Potential for serving multiple markets including datacenters, carrier IP, server backplanes, etc.

Client Optics Overview

Client optics application & media type(s)	High density data center duplex or parallel MMF	Structured data center duplex or parallel SMF	data center & central office duplex (or parallel) SMF	General data center duplex SMF	Metro inter-data center duplex SMF
nominal reach (determines min. penalty)	100m	500m	2km	10km	20, 30, 40km
minimum loss budget	2dB	2.5dB*	4dB	6dB	11 to 21dB
bits/sec cost baseline	10G VCSEL MMF	10G VCSEL MMF	10G DFB laser SMF	10G DFB laser SMF	10G EML SMF
10G standard	10GE-SR	none	OC-192 SR-1 G.693 10G	10GE-LR	10GE-ER G.959.1 10G
40G standard	40GE-SR4	none	40GE-FR G.693 40G	40GE-LR4 G.695 10G	40GE-ER4
100G standard	100GE-SR10 100GE-SR4	100GE-nR4?	100GE-FR4?	100GE-LR4 G.959.1 25G	100GE-ER4 G.959.1 25G

Page 3 in cole_01_0313_optx

Additional significant cost reduction is expected from economy of scale

Link transmit and receive characteristics

1. To satisfy the TF objective the reach of up to at least 500m is considered

2. Minimal launched power OMA_{min} is defined as -1.3dBm
   - Compatible with 100GBASE-LR4

3. The channel insertion loss is defined as 4dB following kolesar_01_0213_smf
   - Allocation of 3.66 dB total connection and splice loss
   - Allocation of 0.25dB for 500m outdoor SMF cable loss
   - Compatible with maximum attenuation of 4dB as defined in ITU-T VSR2000 for cables with attenuation category R (e.g. G693 (11/09))

4. Maximum TDP is defined as 2.2dB
   - Same as in 100GBASE-LR4 following Isono_01_0708; Cole_01_0708

5. Minimal launched power (OMA_{min}-TDP) is defined as -2.3dBm
   - Same as in 100GBASE-LR4

6. Receiver OMA sensitivity is defined as -6.3dBm
   - to accommodate additional insertion loss in WD demux

100GBASE-CWDM transmit characteristics

Parameter	**100GBASE-CWDM**	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	Gbd
Single-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	9	dBm
Average launch power, each lane (max)	3	dBm
Average launch power, each lane (min)	-4.3	dBm
Optical modulation amplitude (OMA), each lane (max)	3	dBm
Optical modulation amplitude (OMA), each lane (min)	-1.3	dBm
Difference in launch power between any two lanes (OMA), (max)	4	dB
Launch power in OMA minus TDP, each lane, (min)	-2.3	dBm
Transmitter and dispersion penalty (TDP), each lane (max)	2.2	dB
Average launch power of OFF transmitter, each lane (max)	-30	dBm
Extinction ratio (min)	4	dB
$RIN_{20}OMA$ (max)	-130	dB/Hz
Optical return loss tolerance (max)	20	dB
Transmitter reflectance (max)	-12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}	

100GBASE-CWDM receive characteristics

Parameter	**100GBASE-CWDM**	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	Gbd
Receiver sensitivity (OMA), each lane (max)	-6.3	dBm
Receiver 3dB electrical upper cutoff frequency, each lane (max)	31	GHz

Note: -6.3dBm receiver sensitivity allows to accommodate up to 7dB insertion loss shared between input fiber coupler, polarization management and WDM demux

100GBASE-CWDM illustrative link power budget

Parameter	100GBASE-CWDM	Unit
Power budget (for maximum TDP)	6.2	dB
Operating distance	0.5	km
Channel insertion loss	4.0[a]	dB
Maximum discreet reflectance	-26	dB
Allocation for penalties (for maximum TDP)	2.2[b]	dB
Additional insertion loss allowed	0	dB

[a] The channel insertion loss is calculated using maximum distance of 0.5km and fiber attenuation of 0.5dB/km at 1264.5nm plus an allocation for connection and splice loss of 3.75dB

[b] Assumes 1dB CD max penalty and 1.2dB other penalties following Isono_01_0708; Cole_01_0708 (see also backup material)

Relevance to 802.3bm Distinct Identity:

"The amendment will define a new 100 Gb/s SMF PMD in addition to these if it can be shown that a SMF PMD with a shorter reach than 100GBASE-LR4 has sufficient cost, density, or power difference to justify an additional SMF PMD type."

Both CFP4 and QSFP28 are feasible
<6W module power shen_01_0113_optx.pdf
<3.5W module power vlasov_01a_0113_smf.pdf

- WDM4 PMD provides a significant module power reduction
- WDM4 PMD provides a significant reduction of a module form-factor
- WDM4 PMD provides smallest add-on latency

Summary and future steps

- 100GBASE-CWDM PMD baseline proposal is presented supporting SMF 500m objective of 802.3bm TF
- The proposal meets a required significant cost reduction (potentially over 60% vs cost-reduced 100GBASE-LR4) for reaching the 802.3bm TF objective
- The proposal meets a required broad market potential criteria by potentially serving several markets as datacenters, carrier IP, server backplanes, etc.
- Further work is needed to fine tune specifications

Back up slides

Comparison with 100GBASE-LR4 and 40GBASE-LR4

100GBASE-CWDM SMF 500m lane assignment

Parameter	**IEEE Std 802.3ba** **100GBASE-LR4** 10km	**100GBASE-CWDM** 500m	Unit
Lane wavelength (range) (nm)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm

100GBASE-WDM4 SMF 500m reach transmit characteristics

Parameter	**IEEE Std 802.3ba 100GBASE-LR4** 10km	**100GBASE-CWDM** 500m	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	25.78125 ± 100 ppm	Gbd
Single-mode suppression ratio (SMSR), (min)	30	30	dB
Total average launch power (max)	10.5	9	dBm
Average launch power, each lane (max)	4.5	3	dBm
Average launch power, each lane (min)	-4.3	-4.3	dBm
Optical modulation amplitude (OMA), each lane (max)	4.5	3	dBm
Optical modulation amplitude (OMA), each lane (min)	-1.3	-1.3	dBm
Difference in launch power between any two lanes (OMA), (max)	5	4	dB
Launch power in OMA minus TDP, each lane, (min)	-2.3	-2.3	dBm
Transmitter and dispersion penalty (TDP), each lane (max)	2.2	2.2	dB
Average launch power of OFF transmitter, each lane (max)	-30	-30	dBm
Extinction ratio (min)	4	4	dB
$RIN_{20}OMA$ (max)	-130	-130	dB/Hz
Optical return loss tolerance (max)	20	20	dB
Transmitter reflectance (max)	-12	-12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}	{0.25, 0.4, 0.45, 0.25, 0.28, 0.4}	

100GBASE-WDM4 SMF 500m reach receive characteristics

Parameter	**IEEE Std 802.3ba** **100GBASE-LR4** 10km	**100GBASE-CWDM** 500m	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	25.78125 ± 100 ppm	Gbd
Receiver sensitivity (OMA), each lane (max)	-8.6	-6.3	dBm
Receiver 3dB electrical upper cutoff frequency, each lane (max)	31	31	GHz
Stressed receiver sensitivity (OMA), each lane (max)	-6.8		dBm

100GBASE-WDM4 SMF 500m reach illustrative link power budget

Parameter	**IEEE Std 802.3ba 100GBASE-LR4** 10km	**100GBASE-CWDM** 500m	Unit
Power budget (for maximum TDP)	8.5	6.2	dB
Operating distance	10	0.5	km
Channel insertion loss	6.3	4.0	dB
Maximum discreet reflectance	-26	-26	dB
Allocation for penalties (for maximum TDP)	2.2	2.2	dB
Additional insertion loss allowed	0	0	dB

TDP definition for 100GBASE-CWDM

Parameter	40GBASE-LR4 CD for 10km reach	100GBASE-CWDM CD for 0.5km reach	Unit
L0 lane 1271nm center	-59.5/0	-3.0	ps/nm
L2 lane 1291nm center	-39/0	-2.0	ps/nm
L2 lane 1311nm center	-19/+16	-1.0/+0.8	ps/nm
L3 lane 1331nm center	0/+33.5	0/+1.7	ps/nm

References:

1. 40GBASE-LR4
2. ITU contribution of P. Anslow, WD6-07, Sunnyvale, March 2009
3. C. Cole contribution to 802.3ba, Cole_01_0708, July 2008

Presentation Isono_01_0708 indicate that TDP penalties for DML as they were measured 5 years back should be expected as less than 1dB for 0.5km reach link