Comparison of options for 40 Gb/s PMD for 10 km duplex SMF and recommendations

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July 2008

Supporters

Outline

- Example 40 Gigabit Ethernet implementations
- High level one page summary for each SMF option
- Comparison tables
- Summary
- Proposed baseline specification tables for 2 x 20G WDM or BiDi PMD for duplex SMF

Context

Question from May meeting, comparing 4 x 10G CWDM with 1 x 40G serial

Straw Poll #11: I believe that a baseline proposal for the 40GBE 10-km SMF PMD should be based on:

A) 4x10G CWDM (as per “cole_03_0508.pdf”)

B) 40G Serial (as per “jewell_03_0508.pdf”)

C) I need more information and presentation material before deciding.

D) I will abstain now and later.

Results:

A) 25

B) 23

C) 35

D) 6

Approximate Room Count: 108

Debate expressed in terms of either-or

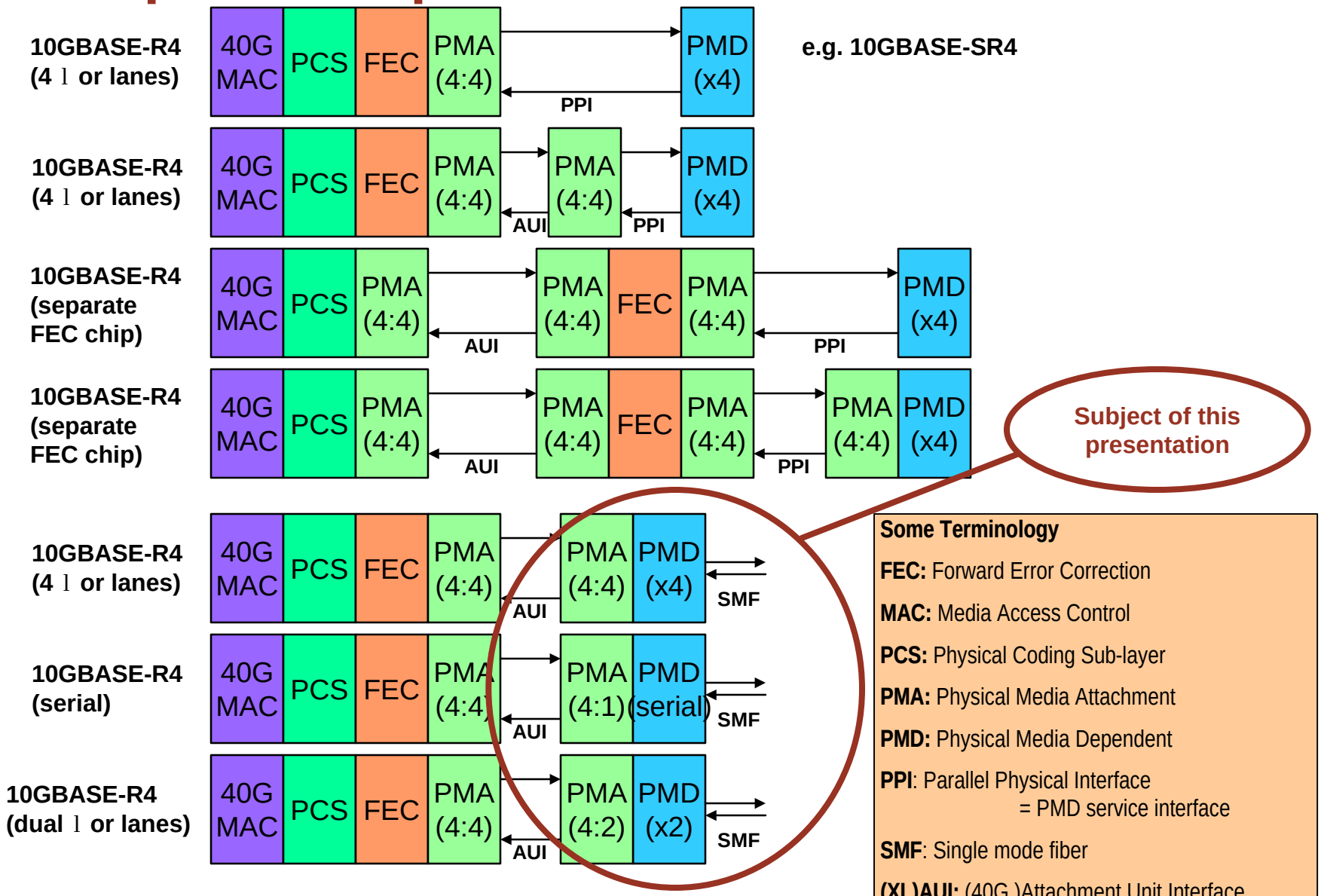
But would a compromise between these be better?

Meanwhile,

- kropp_01_0508 proposed 2 x 20G for MMF
- Several presentations have considered 25 GBd direct modulated lasers – cutting edge
- Fibre Channel FC-PI-5 are working on 14.025 or 17 GBd serial

But not 2 x 20G for SMF. This presentation fills this gap

Example 40G implementation architectures



Some Terminology

FEC: Forward Error Correction

MAC: Media Access Control

PCS: Physical Coding Sub-layer

PMA: Physical Media Attachment

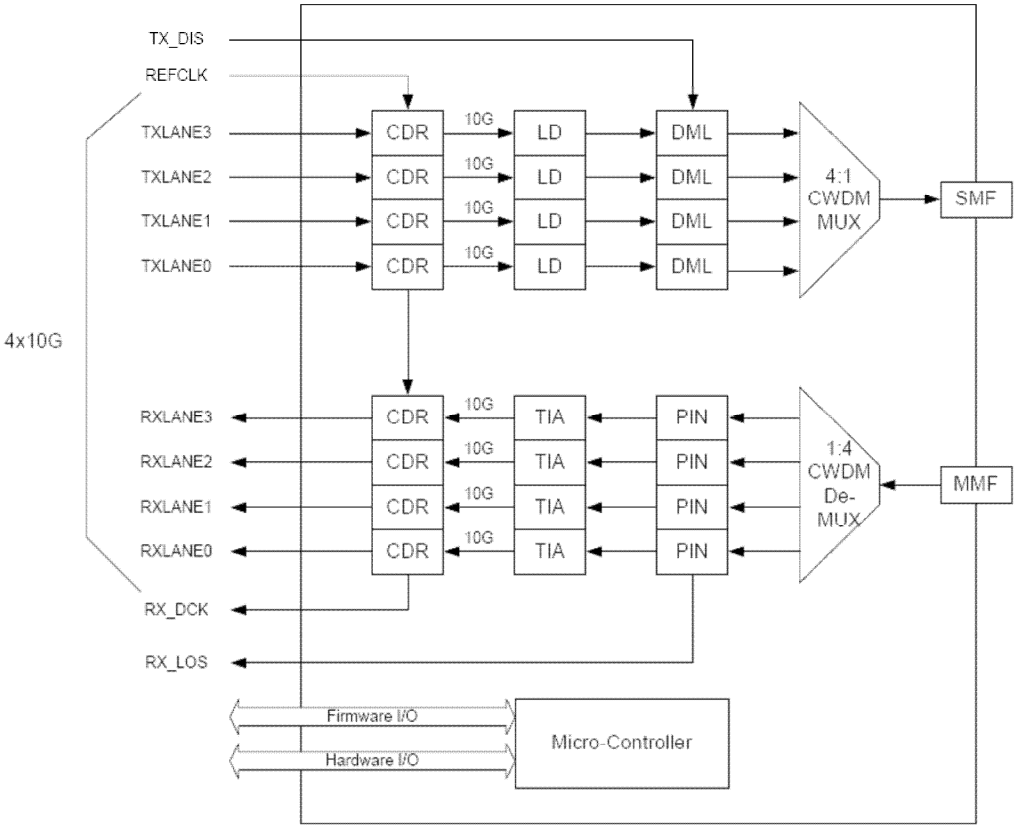
PMD: Physical Media Dependent

PPI: Parallel Physical Interface
= PMD service interface

SMF: Single mode fiber

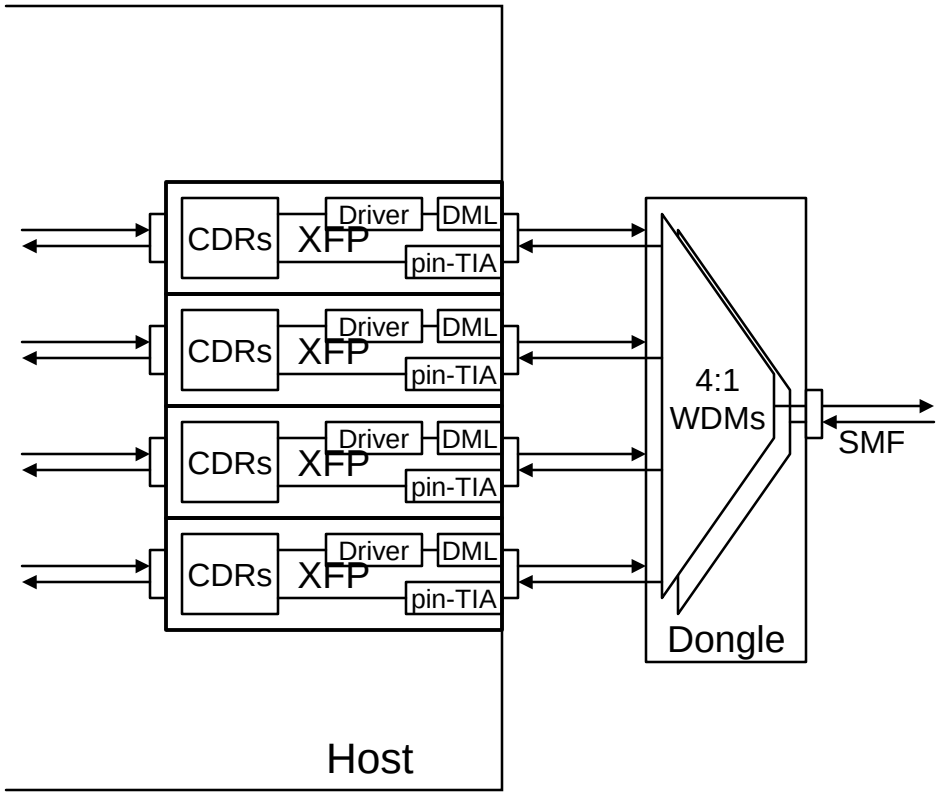
(XL)AUI: (40G)Attachment Unit Interface

40G SMF: 4 x 10G CWDM
The past



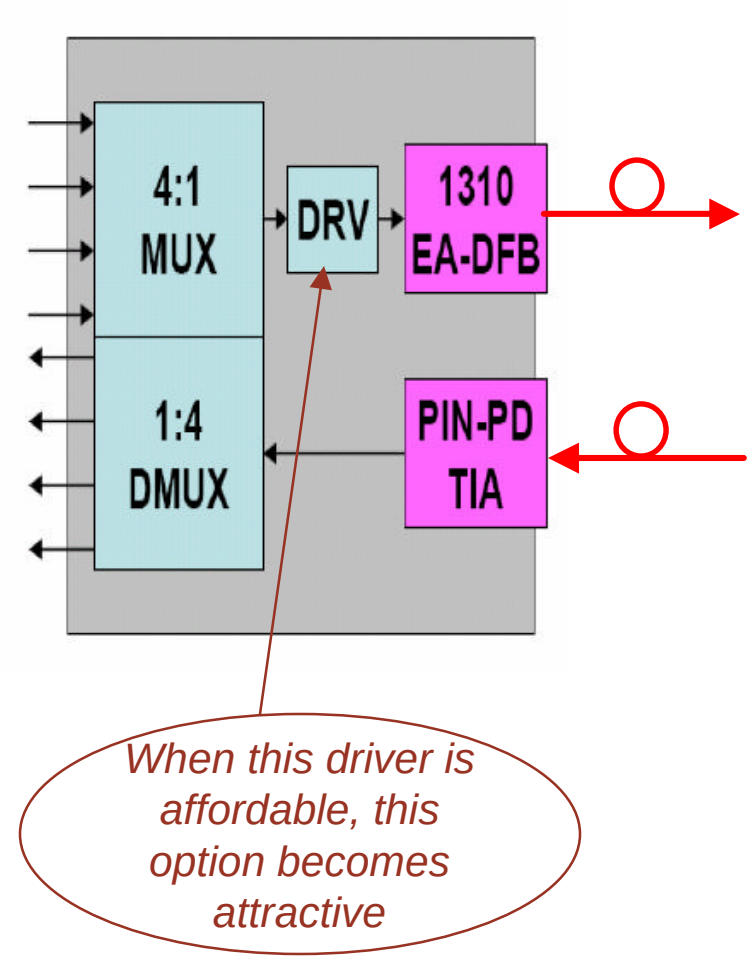
- **4-wavelength CWDM near 1310 nm**
- **Internal optical mux and de-mux**
- **SMF:** 10 km
- **OM1-3:** < 75 m without EDC. MMF compromises Rx WDM demux and PIN. But, the MMF specification is not part of the 40G standards proposal
- **10G Optics and electronics**
- **Power dissipation:** ~ 6 W
- **Size:** Large ~ XENPAK form-factor
- **Cost:** High due to complex WDM-Opto-mechanical design and 4 x 10G optical channel elements. Too much NRE for the volume/lifespan to be worth fixing.

40G SMF: 4 x 10G CWDM Alternative



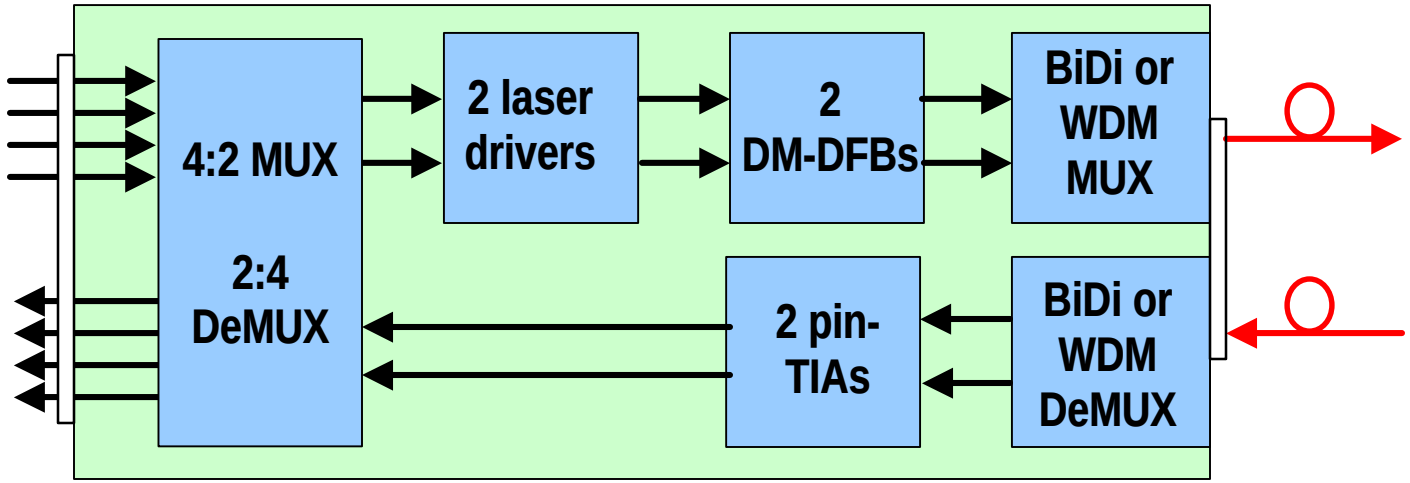
- **4-wavelength CWDM near 1310 nm**
- **External optical mux and de-mux**
- **SMF:** 10 km
- **OM1-3:** < 75 m without EDC. MMF compromises Rx WDM demux and PIN. But, the MMF specification is not part of the 40G standards proposal
- **10G Optics and electronics**
- **Power dissipation:** ~ 6 W
- **Size:** Large e.g. 4 x XFP
- **Cost:** High due to WDM, 4 x 10G optical channel elements and cases, **but** much lower NRE and can pay-as-you-grow
- **Comments:** Best short term option.Too easy? As power hungry as previous slide. If you don't like this you should like the previous slide even less

40G serial NRZ modulation
The future



- **Single wavelength near 1310 nm**
- **SMF:** 10 km
- **OM1-3:** < 20 m without EDC. MMF badly compromises PIN. But, the MMF specification is not part of the 40G standards proposal
- **40G Optics:**
  - cooled EAM-DFB
- **40G electronics:**
  - InP laser driver and TIA
  - SiGe mux and demux
- **Power dissipation:** ~ 5 W
- **Size:** Big ~ X2 form-factor
- **Cost:** High due to 40G InP optical and electronic components

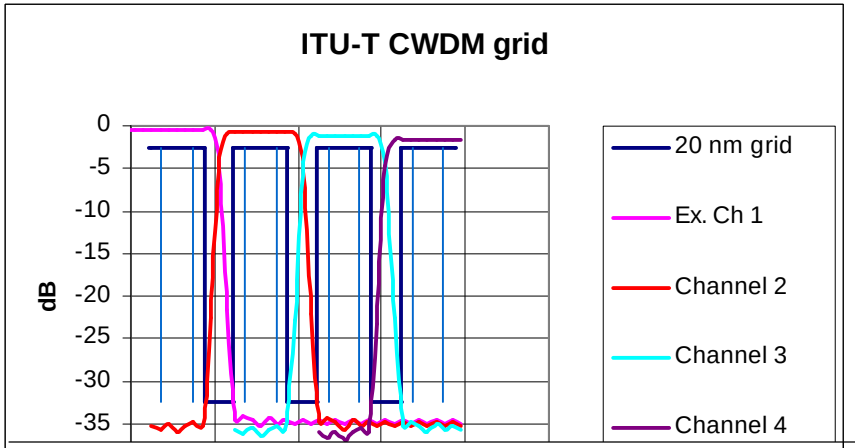
40G SMF: 2 x 20G, 1310 nm, BiDi or WDM

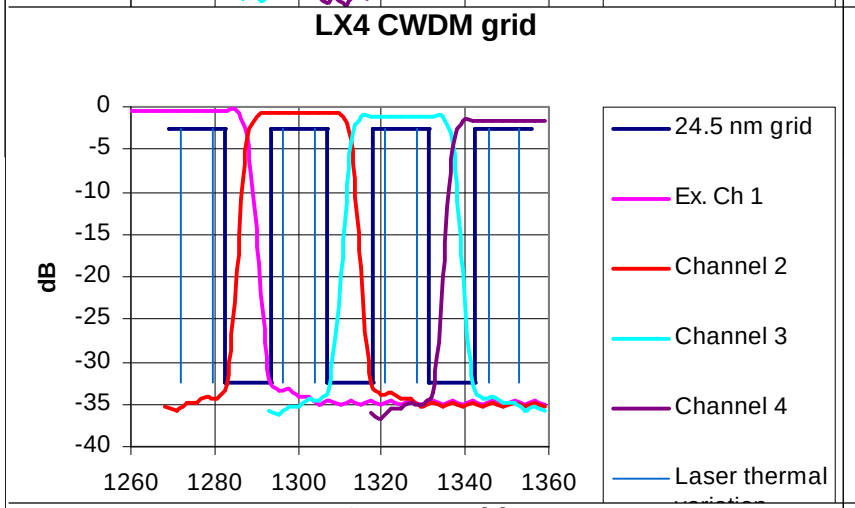


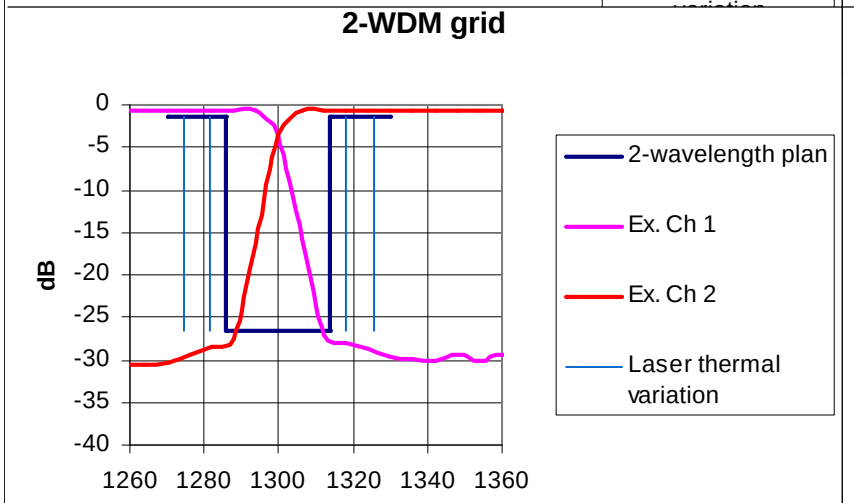
- **Wavelength plan: Two wavelengths in 1310 nm window:** up to 10 km, SMF only
  - Either both transmitters on same fiber ("regular WDM" or one on each ("BiDi")
- **Optics:** Direct-modulated DFB, 20 GBd grade TIA: very similar to FC-PI-5 (14.025 or 17 GBd). Routing for BiDi would cross over (not shown for simplicity). No cooler.
- **Electronics:** SiGe BiCMOS compatible. No exotic IC technology.
- **Power Dissipation:** ~ 3 W, much less than the other SMF 40G options being considered
- **Size:** Small, compatible with QSFP form-factor (3.5 W max)
- **Cost:** Low compared to the other 40G options being considered

Are two wavelengths really that much better than four?

- In a typical 4-CWDM mux or demux component, there are 3 different dichroic mirror filters and one lane (wavelength) goes through all 3
- With 2 wavelengths there is only 1 filter. Less loss, much simpler optical path
- Wider wavelength bands allow for wider wavelength spec on lasers (yield/cost), and wider operating temperature range enabled
- Wider keep-out band between channels allows for filters with fewer dielectric layers – lower loss again
- Three fewer channels to cause crosstalk, relaxes rejection ratio spec by 5 dB
- In 2-wavelength plan, the filter steepness needed is fully 3x easier than ITU-T CWDM, allowing more technology choices
- Plus the basic benefits e.g. fewer lasers
- Summary: yes







Power dissipation comparison table

40G 10km 4-CWDM	2009 power (W)	2011 power (W)	40G 10 km serial	2009 power (W)	2011 power (W)	40G 10 km 2-WDM	2009 power (W)	2011 power (W)
4x DML, TOSA-WDM Mux	0	0	EML TOSA/TEC	1.5	1.0	2x DML, TOSA-Mux	0	0
4x DML driver	2.1	1.7	EML driver	0.8	0.6	2x DML driver	1.3	1.0
4x XFI Tx-Rx CDRs	1.8	1.0	4:1 & 1:4 MUX-CDR	2.0	1.5	4:2 & 2:4 MUX & deMux	1.7	0.9
4x PIN-TIA ROSA-deMux	0.7	0.5	PIN-TIA	0.4	0.3	2x PIN-TIA ROSA-deMux	0.6	0.5
Other	0.4	0.4	Other	0.1	0.1	Other	0.1	0.1
Total power	5	3.6	Total power	4.8	3.5	Total power	3.7	2.5
Ratio to CWDM	1	1	Ratio to CWDM	0.96	0.97	Ratio to CWDM	0.74	0.69

Based on jewell_03_0508

- Apples to apples comparison – aggressive
- Clearly, 2 x 20G WDM or BiDi is the lowest power option

Relative cost comparison table

40G 10km 4-CWDM	Cost factor 2009	Cost factor 2011	40G 10 km serial	Cost factor 2009	Cost factor 2011	40G 10km 2-WDM	Cost factor 2009	Cost factor 2011
4x DML, TOSA-WDM Mux	1	1	EML TOSA/TEC	2-3x	1x	2x DML, TOSA-Mux	0.7x	0.6x
4x DML driver	1	1	EML driver	4x	<1x	2x DML driver	0.6x	0.5x
4x XFI Tx-Rx CDRs	1	1	4:1 & 1:4 MUX-CDR	3x	2x	4:2 & 2:4 Mux deMux	1.3x	1.1x
4x PIN-TIA ROSA-deMux	1	1	PIN-TIA	4x	1x	2x PIN-TIA ROSA-deMux	0.7x	0.6x
Form-factor	1	1	Form-factor	1x	1x	Form-factor	0.25x	0.25x
Total Cost	1	1	Total Cost	2.8x	1x	Total Cost	0.8x	0.65x
Based on jewell_03_0508			Form factor row is our addition					

- Cost/benefit of PCB real-estate and data center air-conditioning with significantly smaller, lower-power module not included

- Clearly, 2 x 20G WDM or BiDi is the lowest relative cost option

Comparison summary table

	4x10G 10 km CWDM one box	4x10G 10 km CWDM 4 boxes	40G 10 km serial	2 x 20G WDM or BiDi
Present situation	Highest power	Highest power	Highest cost now	*Lowest power, size and cost*
Form factor	Big	Big but ready now	Big now, can shrink somewhat	QSFP possible
Physical lanes	Too many	Too many	Too fast - for now	Just right
Prospects	Optical plumbing/ mechanical costs endure	Optical plumbing/ mechanical costs endure	Modulator driver technology/ cost evolution is key. Mechanical costs can shrivel, but stuck with cooler	Synergy with 16GFC and some synergy with 25G lanes in HSE
Summary	Dead-end technology	Existing technology	The future	Best in near term and more

Summary of comparison

- **For the 10 km 40G SMF objective, it has been clearly shown that the 2 x 20G WDM or BiDi PMD is optimum in terms of the relative power, cost, size and performance.**
- **As was said in kropp_01_0508, the 2 x 20G WDM or BiDi PMD can also leverage the components that will be developed for 16G Fibre Channel**
  - This will significantly decrease its relative cost
  - IC synergy with kropp_01_0708. Also some synergy with 25G lanes in P802.3ba
- **Both the 2 x 20G WDM or BiDi PMD and the 40G serial PMD will use new, efficient, and potentially compact technologies.**
  - Will 40G serial need a cooler forever?
- **But, the 40G CWDM PMD uses old, power hungry and bulky technologies.**
- **Proposal: Given the above it would seem that the wise decision would be to plan for both the 40G serial PMD and the 2 x 20G WDM or BiDi PMD:**
  - 40G serial for the future, however distant. Specs e.g. per jewell_03_0508. New CFI?
  - 2 x 20G WDM or BiDi for the near term, medium term and a bit of the long term too. Specs on following slides

Proposed baseline specification tables for the 2 x 20G WDM or BiDi SMF PMD 1/2

As is normal for all baseline PMD proposals these specifications would form the basis for the initial work but each item would be investigated and studied by the PMD subtask force.

40GBASE-LR2 transmit characteristics

Description	Type	Value	Unit
Signaling speed, each lane	nom	20.625	GBd
Signaling speed variation from nominal	max	± 100	ppm
Lane 1: Center wavelength	range	1270 to 1286 TBC	nm
Lane 2: Center wavelength	range	1314 to 1330 TBC	nm
Side mode suppression ratio	min	30	dB
Average launch power, two lanes	max	7	dBm
Average launch power, per lane	max	4	dBm
Average launch power, per lane	min	-2	dBm
Optical modulation amplitude	max	3.5	dBm
Optical modulation amplitude	min	-0.5	dBm
TWDP, 1 tap only: Lane 1, Lane 2	max	3.6 TBC	dB
and/or TDP	max	TBD	dB
Average launch power of OFF transmitter, per lane	max	-30	dBm
Extinction ratio, each lane	min	3.5	dB
Peak launch power	max	5	dBm
RIN_12_OMA	max	-135	dB/Hz
Optical return loss tolerance	min	-12	dB
Transmitter reflectance	max	-12?	dB

All transmit and receive powers at TP2, TP3 (after mux loss and before demux loss)

TWDP, 1 tap only, is precisely defined in FC-PI-4

For information: the chromatic dispersion ranges from –54 to +27 ps/nm with (old) G.652 specs

- DML chromatic dispersion penalty is better or negative with negative dispersion (short wavelength): see traverso_02_0308. Exact wavelengths to be optimised.

These parameters are chosen without FEC

Proposed baseline specification tables for the 2 x 20G WDM or BiDi SMF PMD 2/2

Characteristics of signal within, and at the receiving end of, a compliant 40GBASE-LR2 channel (informative)

Description	Type	Value	Unit
Highest power in OMA, each lane	max	3.5	dBm
Lowest power in OMA, each lane	min	-6	dBm
Highest average power, one lane	max	4	dBm
Lowest average power, one lane	min	-7.5	dBm
Highest average power, both lanes	max	7	dBm
Lowest average power, both lanes	min	-4.5	dBm
Peak power, one lane	max	5	dBm

40GBASE-LR2 receive characteristics

Description	Type	Value	Unit
Signaling speed, each lane	nom	20.625	GBd
Signaling speed variation from nominal	max	± 100	ppm
Lane 1: Center wavelength	range	1270 to 1286 TBC	nm
Lane 2: Center wavelength	range	1314 to 1330 TBC	nm
Stressed receiver sensitivity in OMA: Lane 1, Lane 2	max	-7.5	dBm
Overload in OMA, per lane	min	3.5	dBm
Vertical eye closure penalty: Lane 1, Lane 2	-	3 TBC	dB
Receiver reflectance	max	-12	dB

Next line for information in this presentation: not to go in the draft

Unstressed receiver sensitivity in OMA, each lane	max	-11	dBm

40GBASE-LR2 power budget (informative)

Parameter	Value	Unit
Power budget	10.5	dB
Operating distance	10	km
Channel insertion loss (max)	5.5	dB
Channel insertion loss (min)	0	dB
Allocation for penalties	5.0	dB
Additional insertion loss allowed	0	dB

The maximum channel insertion loss is based on the cable attenuation at the target distance and nominal measurement wavelength 1310 or 1550 nm). The channel insertion loss also includes the loss for connectors, splices and other passive components.

The allocation for penalties is the difference between the available power budget and the channel insertion loss; insertion loss difference between nominal and worst-case operating wavelength is considered a penalty.

Transmitter power tolerancing

Graphical representation of approximate region of signal compliance (informative)

Optical powers at lane transmitters and receivers are higher/ lower than TP2 / TP3 powers by the WDM losses