CWDM Solution for 500m SMF Economical Feasibility

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Outline

- **Summary of Previous Studies**
- CWDM solution cost analysis
  - Transceivers Cost
  - Double Link Cost
- CWDM module cost reduction analysis
- CWDM Link Budget Proposal
- Conclusions

Straw Poll in Jan 2013 meeting – CWDM gained the most support as 100G 500m SMF solution

Straw Poll # 1

I would support a baseline proposal for a SMF PMD based on:

a) CWDM
b) C-BAND
c) DMT
d) PSM4
e) PAMn
f) none of the above - rely on LR4 with CAUI-4.

a) 23 b) 1 c) 12 d) 16 e) 19 f) 11
Room count = 97

From the straw polling, it is clear that technical feasibility is well established for CWDM. This presentation is an additional demonstration of economical feasibility and broad support.

Straw Poll # 11

- Do you believe this proposal is technically feasible:

a) CWDM Y: 63 N: 5
b) DMT Y: 32 N: 20
c) PSM4 Y: 63 N: 0
d) PAMn Y: 28 N: 35

Straw Poll # 12

- Do you believe this proposal is economically feasible:

a) CWDM Y: 36 N: 28
b) DMT Y: 30 N: 24
c) PSM4 Y: 45 N: 19
d) PAMn Y: 29 N: 34
e) LR4 Y: 18 N: 47

Straw Poll # 13

- Do you believe this proposal has broad market potential :

a) CWDM Y: 32 N: 27
b) DMT Y: 32 N: 20
c) PSM4 Y: 29 N: 28
d) PAMn Y: 36 N: 23
e) LR4 Y: 15 N: 36

CWDM is a low cost and low power solution for 100G >500m optical interface

We propose CWDM as 100G, >500m optical interface because CWDM enables

1. **Use uncooled packaging technology, Chip on Board package combining with hybrid integration, CWDM transceivers can be about 62% lower cost than LR4 transceivers;**
2. **Use uncooled packaging technology for transceiver, CWDM can have low power consumption satisfying QSFP package requirement;**
3. **SMF duplex solution allows use of existing fiber, save on PSM installation cost;**
4. **An optical mux/demux solution inside the transceivers instead of passing to customers the PSM handling issue;**
5. **No FEC to avoid latency;**
6. **SMF duplex for low link cost.**

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Cost Analysis of LWDM, CWDM and PSM4 Transceivers (No Link Cost)

- Applies all potential cost reduction measures in our cost analysis on LWDM, CWDM and PSM4.
- Cost analyses are projected cost with all these measures realized in 2~3 years time frame.
- In our transceiver cost analysis, reference all costs to LWDM with similar cost reduction paths, including volume and learning curves in 2~3 years time frame.

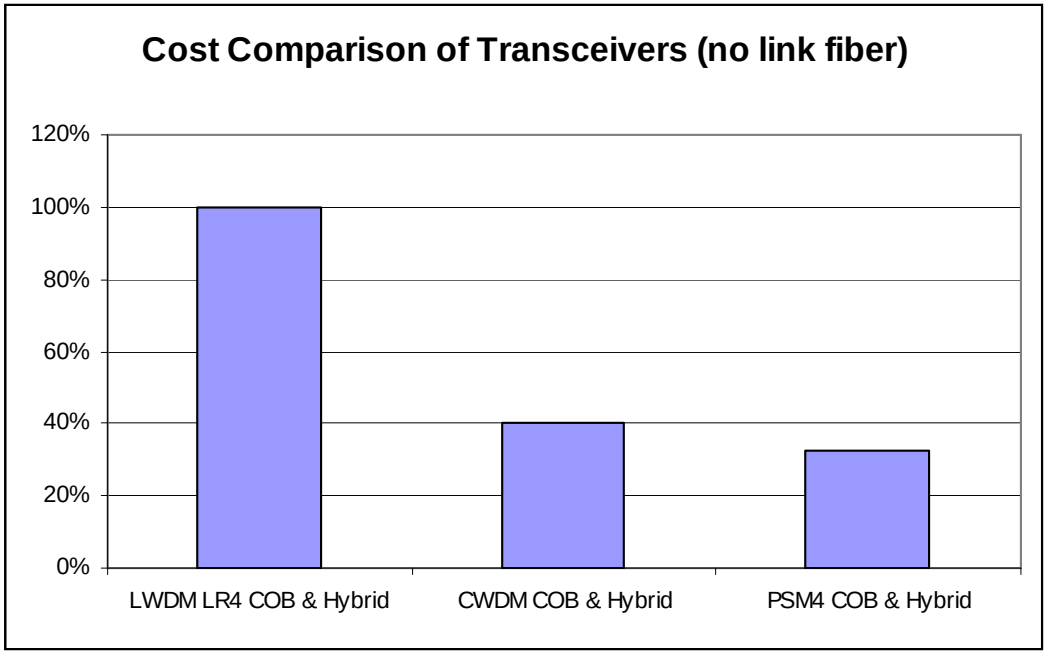
Relative Cost of LR4, CWDM and PSM4 Transceivers (No Link Cost)

After applying all potential cost reduction measures:

	Cost reduced LR4	CWDM	PSM4
Transceivers cost	**2.5**	**1**	**0.8**

Cost reduction → 62%

Cost reduction → 68%



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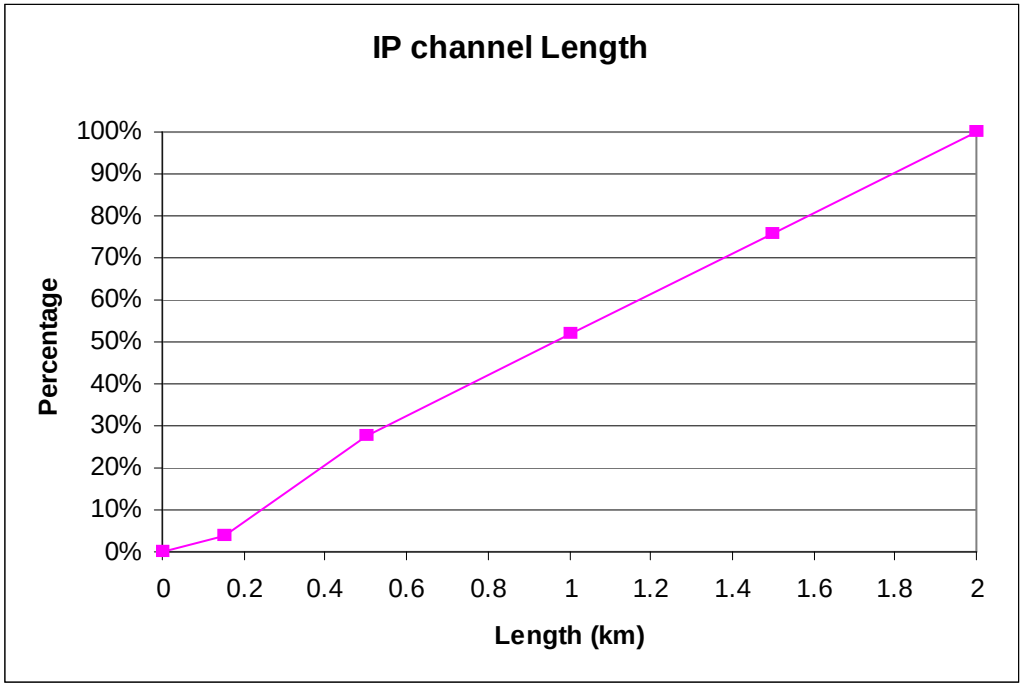
Cost Analysis of Double Link Cost

Cost analysis of double link cost including transceivers w/wo FEC and cabling cost of LWDM, CWDM and PSM4 using Cost Centroid Length (CCL) methodology.

Carrier IP CCL 0km to 2km Sector



CCL = 1 km

We shall use **1km** for our cost analysis of the Carrier IP market for the 802.3 objective.

Data Center Cost Centroid Length

We shall use data center Cost Centroid Length of 200m as reported in + kolesar_01a_0512 .

CCL of Data Center, Carrier IP and 802.3 Objective

Channel Type	Single-link		Double-link		
Fiber Type	100m	300m	100m	300m	500m
2f OS2 SMF	1	1.5	1.5	2	2.5
8f OS2 SMF	4	6	6	8	10

+ cole_01a_0512

Double-Link	
1km	**2km**
6.5	**12**
26	**48**

Data Center using relative cabling cost at CCL = 200m

- 200m 2-f OS2 double-link channel = 1.75
- 200m 8-f OS2 double-link channel = 7

+ kolesar_01a_0512

Carrier IP using relative cabling cost at CCL = 1km

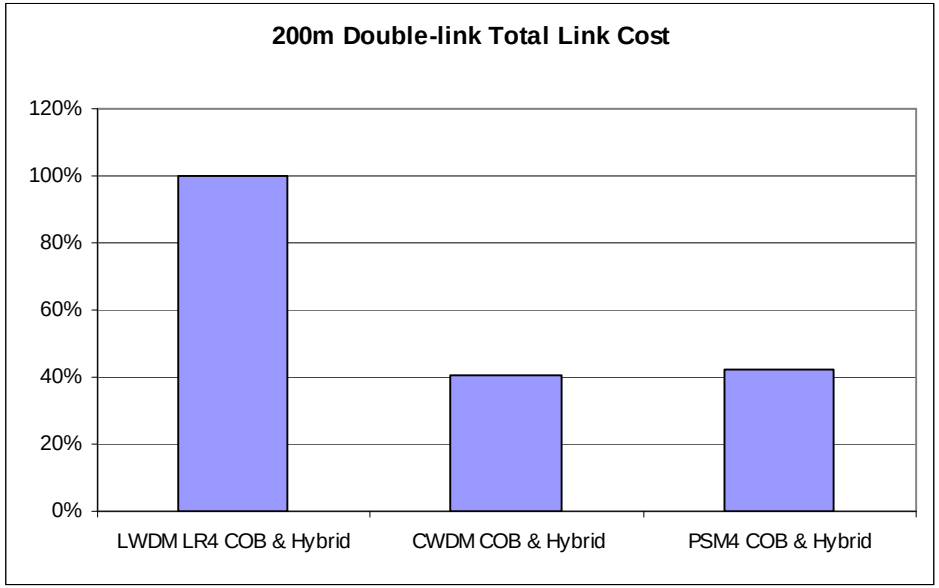
- 1km 2-f OS2 double-link channel = 6.5
- 1km 8-f OS2 double-link channel = 26

802.3 using relative cabling cost at objective > 500m

- 500m 2-f OS2 double-link channel = 2.5
- 500m 8-f OS2 double-link channel = 10

Relative Total Link Cost at CCL=200m of Data Center

	Cost Reduced LR4	CWDM	PSM4
Total Link Cost	**2.4**	**1**	**1**



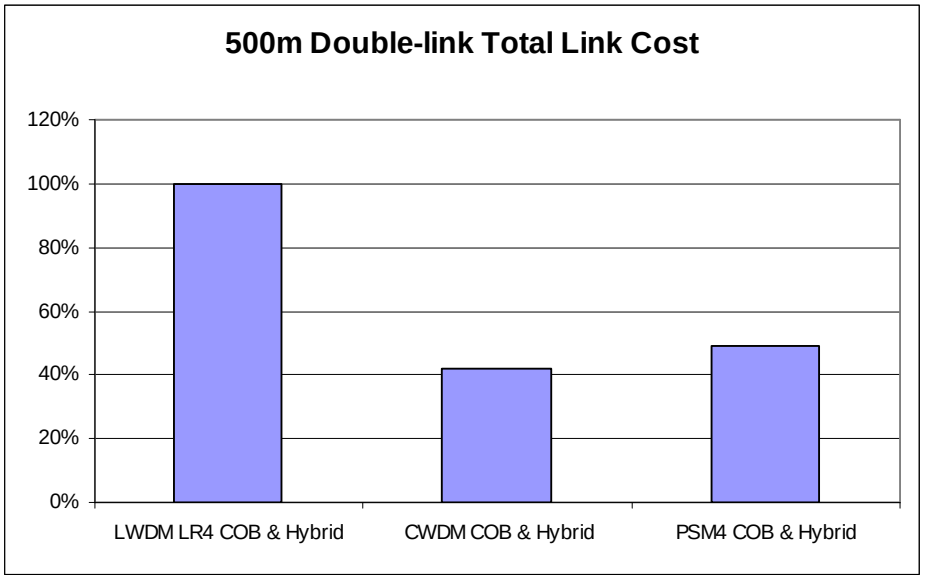
	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

Data Com using relative cabling cost at CCL = 200m + cole_02_0512

- 200m 2-f OS2 double-link channel = 1.75 + kolesar_01a_0512
- 200m 8-f OS2 double-link channel = 7

Relative Total Link Cost at >500m of 802.3 Objective

	Cost Reduced LR4	CWDM	PSM4
Total Link Cost	**2.4**	**1**	**1.1**



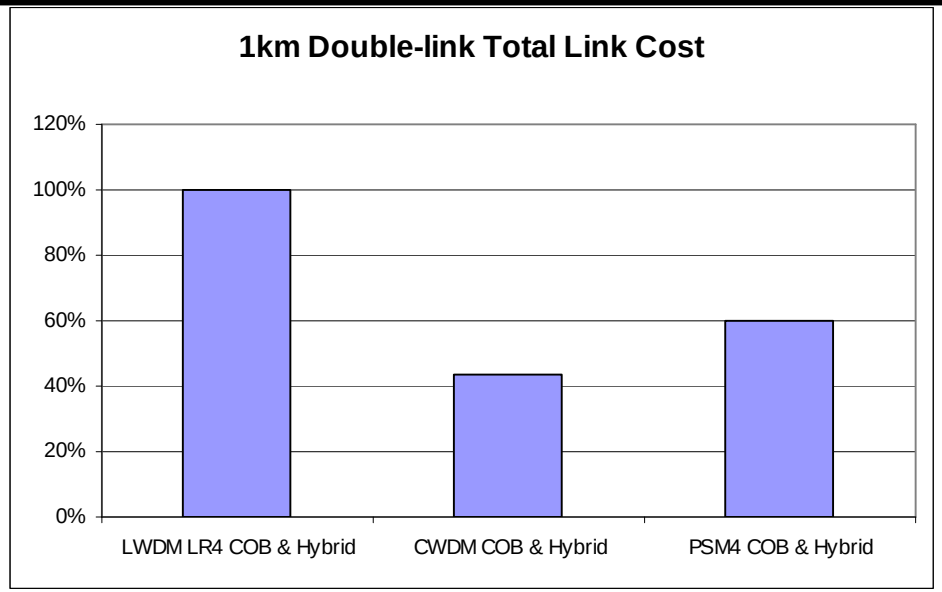
	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

802.3 using relative cabling cost at objective > 500m

- 500m 2-f OS2 double-link channel = 2.5
- 500m 8-f OS2 double-link channel = 10

Relative Total Link Cost at CCL=1km of Carrier IP

	Cost Reduced LR4	CWDM	PSM4
Total Link Cost	**2.2**	**1**	**1.4**

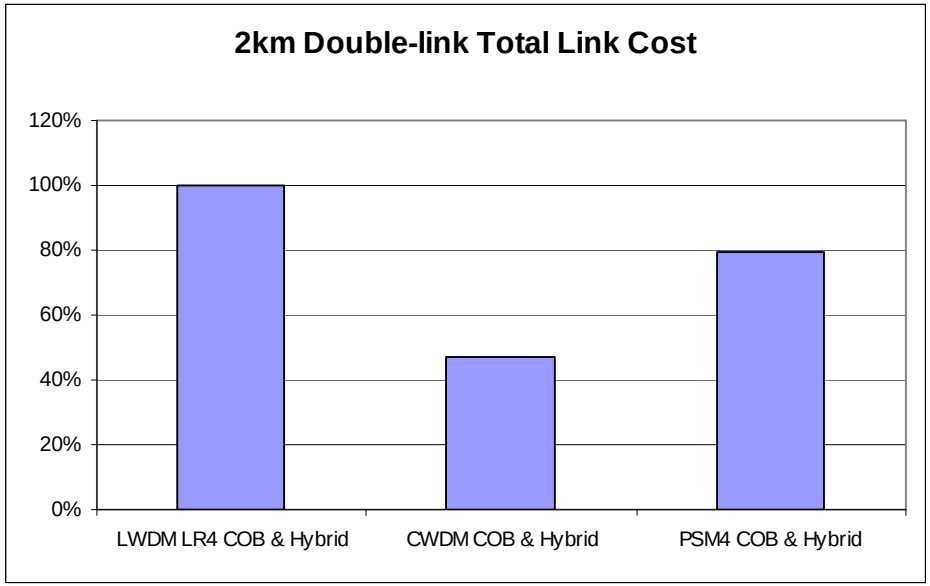


	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

IP channel using relative cabling cost at CCL = 1km
1km 2-f OS2 double-link channel = 6.5
1km 8-f OS2 double-link channel = 26

Relative Total Link Cost at 2km of Carrier IP (for information only).

	Cost Reduced LR4	CWDM	PSM4
Total Link Cost	**2.1**	**1**	**1.7**



	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

IP channel = 2km (for information only)
2km 2-f OS2 double-link channel = 12
2km 8-f OS2 double-link channel = 48

Summary of cost analysis

Summary of cost analysis

- **CWDM and PSM4 transceivers have about the same cost, with LR4 cost about 2.5 times higher.**
- **For Data Center market at CCL=200m CWDM and PSM4 solutions have about the same total link cost, with LR4 total link cost about 2.4 times higher.**
- **For 802.3 Objective of >500m, including the Carrier IP market, CWDM has the lowest total link cost.**

Advantage of CWDM over PSM4

- **For the 802.3 Objective >500m, which covers markets such as carrier IP and enterprise, CWDM link cost is lower than PSM4.**
- **CWDM solution use duplex fiber, which allows use of existing fiber in data centers and enterprises, where the fibers are already installed.**
- **No FEC in CWDM solution means no latency issue.**
- **From system point of view, placing FEC on the board is not an acceptable solution, as it presents interoperability issue. Furthermore, putting the FEC on line cards makes the line cards application specific and hence segment the market, and makes the line card more expensive.**

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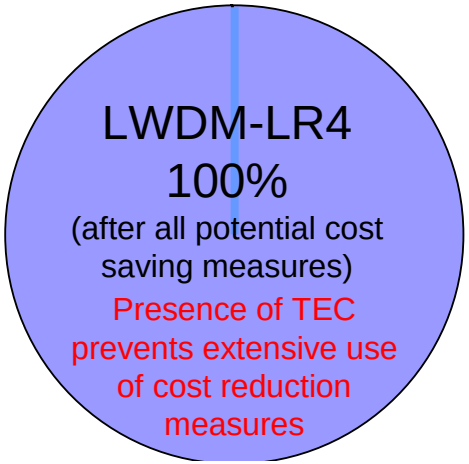
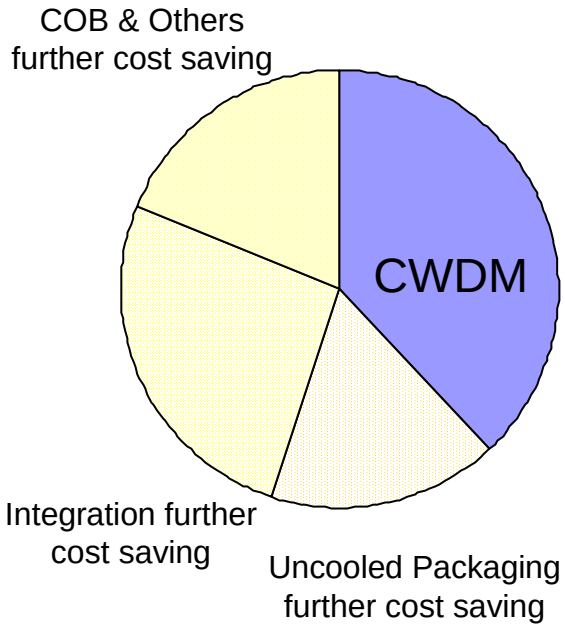
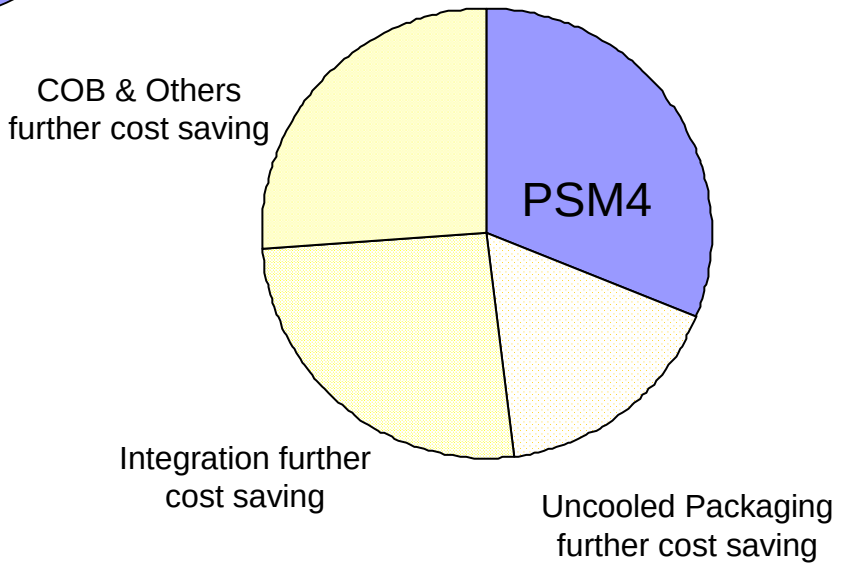
Further Cost Reduction in Transceivers in CWDM compared with Cost Reduced LR4



Presence of TEC prevents these cost reduction measures from being applied to LR4.





Cost Reduction Opportunities in CWDM compared with LR4 (1)

Uncooled Packaging		
Cost reducing item	**LWDM**	**CWDM**
TEC	**Yes**	**No**
Assembly	**TEC assembly and parts**	**No TEC Assembly**
Testing	**TEC related testing**	**No TEC related testing, including TEC aging**
Control circuit	**1. Need TEC automatic temperature control circuit; 2. Need TEC driver chips**	**1. Absence of TEC automatic temperature control circuit; 2. No TEC driver chips**
yield	**Impact on yield due to TEC failure**	**No yield impact on TEC failure**

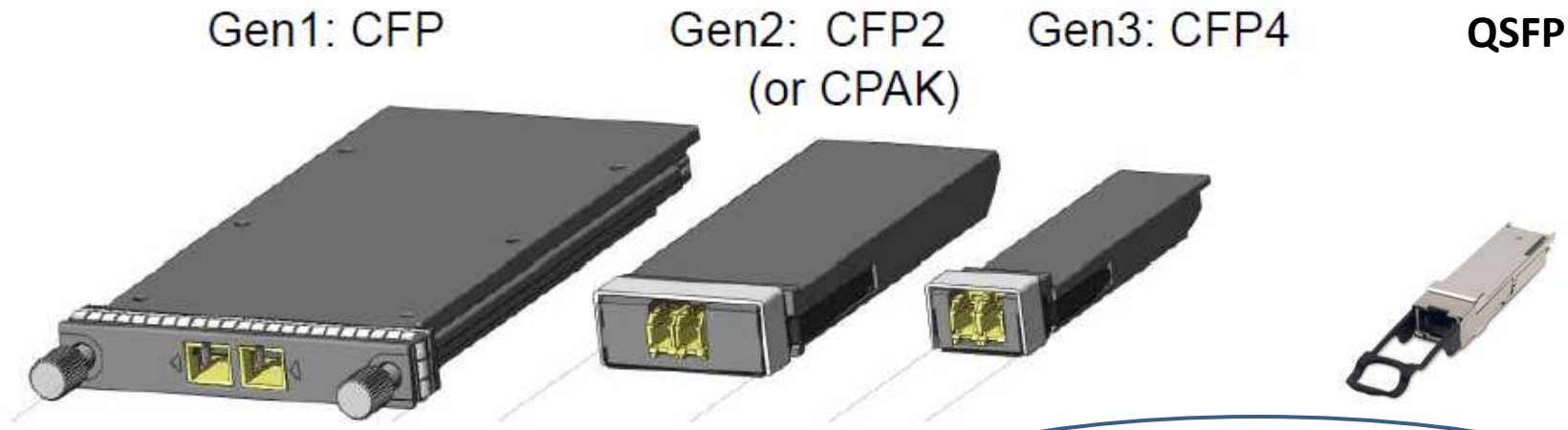
Cost Reduction Opportunities in CWDM compared with LR4 (2)

O/E Integration		
Cost reducing item	**LWDM**	**CWDM**
O/E integration	**Presence of TEC prevents extensive OEIC integration**	**Removing TEC enables extensive OEIC integration**
Package type	**Discrete piece part type of packaging**	**Chip set type packaging**
Package size	**TEC drives large package size and high cost**	**Small package size and low cost**
Packaging process	**Complicated packaging processes**	**Simple chip set packaging processes**

Cost Reduction Opportunities in CWDM compared with LR4 (3)

COB and others		
Cost reducing item	**LWDM**	**CWDM**
COB	**Presence of TEC prevents extensive CoB packaging**	**Removing TEC enables CoB package in Tx side, the costly part in the whole transceiver**
Gold Box	**Existing of high cost Gold Boxes, major contribution to overall cost**	**No Gold Box**
Assembly	**Hermetic Seal Package**	**1. Non-hermetic seal package option; 2. Save on absence of leakage tests**
Yield	**Impact on yield due to hermetic seal leakage**	**Absence of hermetic seal issues**
Wavelength precision	**Need more precise wavelength control, resulting in lower yield in wavelength sensitive components**	**Relaxed wavelength control, resulting in higher yield in wavelength sensitive components**

CWDM enables low power consumption and high density optical modules



Power consumption:<24 W
Density: 1 or 2 port system

Power consumption:<12 W
Density: >8 port system

Power consumption:<5 W
Density: 16 port system

Power consumption:<3.5 W
Density: >20 port system

CWDM is not only saving TEC related cost, but also:

- Makes monolithic or high density O/E integration possible, without heat dumping to TEC
- It further reduces cost and power consumption of CFP4 module
- It enables low cost and low power consumption QSFP module which has the highest density for this application.

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CWDM 802.3 100GBASE Link Budget Proposal

Transmitter and Receiver 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
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	
Optical modulation amplitude (OMA), each lane (min)	-1.3	-1.3	dBm
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
Extinction ratio (min)	4	4	dB
Receiver sensitivity (OMA), each lane (max)	-8.6	-6.3	dBm
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[a]	dB
Allocation for penalties (for maximum TDP)	2.2	2.2[b]	dB
Additional insertion loss allowed	0	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.

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CWDM solution is the most potential economical solution for NG100GE using SMF at least 500m reach, offering:

- **Lowest link cost;**
- **Small size and low power consumption to support up 40 ports in 10U front panel（QSFP）;**
- **No FEC means no concern of latency issue;**
- **Reach is at least 500m;**
- **Wide potential market: Data Center and Carrier IP, Enterprise markets.**
- **Compatibility of CWDM with installed-fiber base in Data Center avoids new parallel fiber installation and benefits upgrading existing networks.**

Thank you

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