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CWDM Solution for 500m SMF Economical Feasibility

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List of Supporters

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Stefan Rochus	CyOptics
Song Shang	Semtech
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Bill Lee	InnoLight
Norman Kwong	BinOptics
Malcolm Green	BinOptic
Haiyi Zhang	CATR
Wenyu Zhao	CATR

Outline

- **Summary of Previous Studies**
- CWDM solution cost analysis
- CWDM module cost reduction analysis
- 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 for transceiver, leading to >34% cost reduction and low power consumption (<6W) satisfying the CFP4 package requirement;**

2. **Chip on Board package combining with hybrid integration, results in additional 28% cost reduction;**

3. **CWDM transceivers can be about 62% lower cost than LR4 transceivers**

3. **No FEC to avoid latency.**

4. **SMF duplex for low link cost.**

5. **Duplex fiber solution allow use of existing fiber and save on PSM installation 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.
- Reference all costs to LWDM with similar cost reduction paths, including volume and learning curves in 2~3 years time frame.

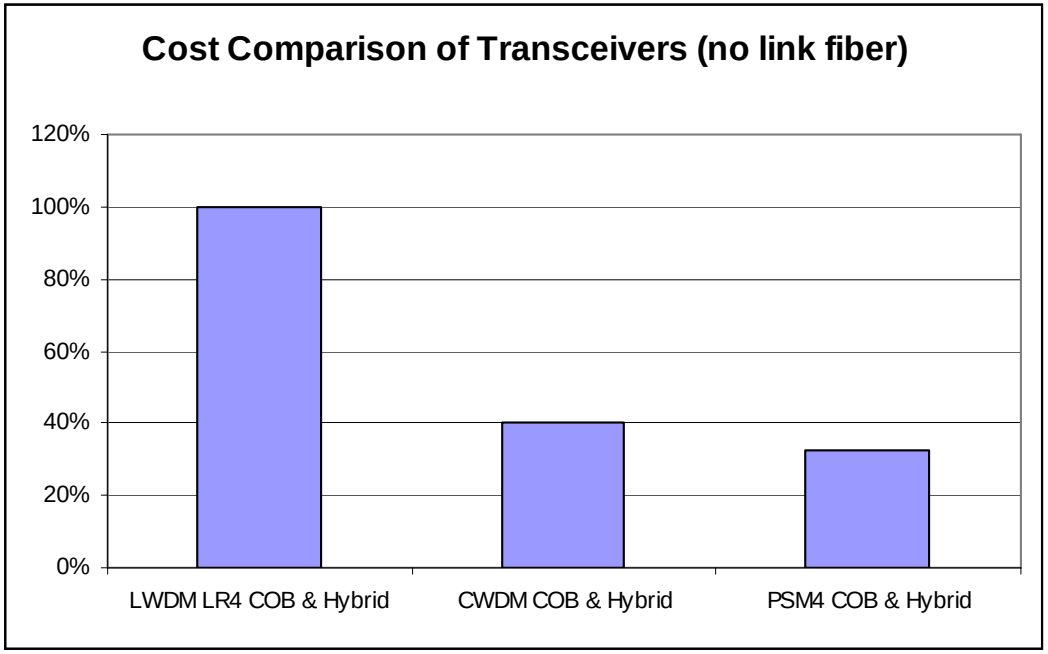
Relative Cost of LR4, CWDM and PSM4 Transceivers (No Link Cost)

In our transceiver cost analysis, we have applied long term (~3 years) volume and cost reduction plus COB and integration measures provide a cost reduction path for LR4. This cost reduced LR4 shall be used in our cost comparison that follows.

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

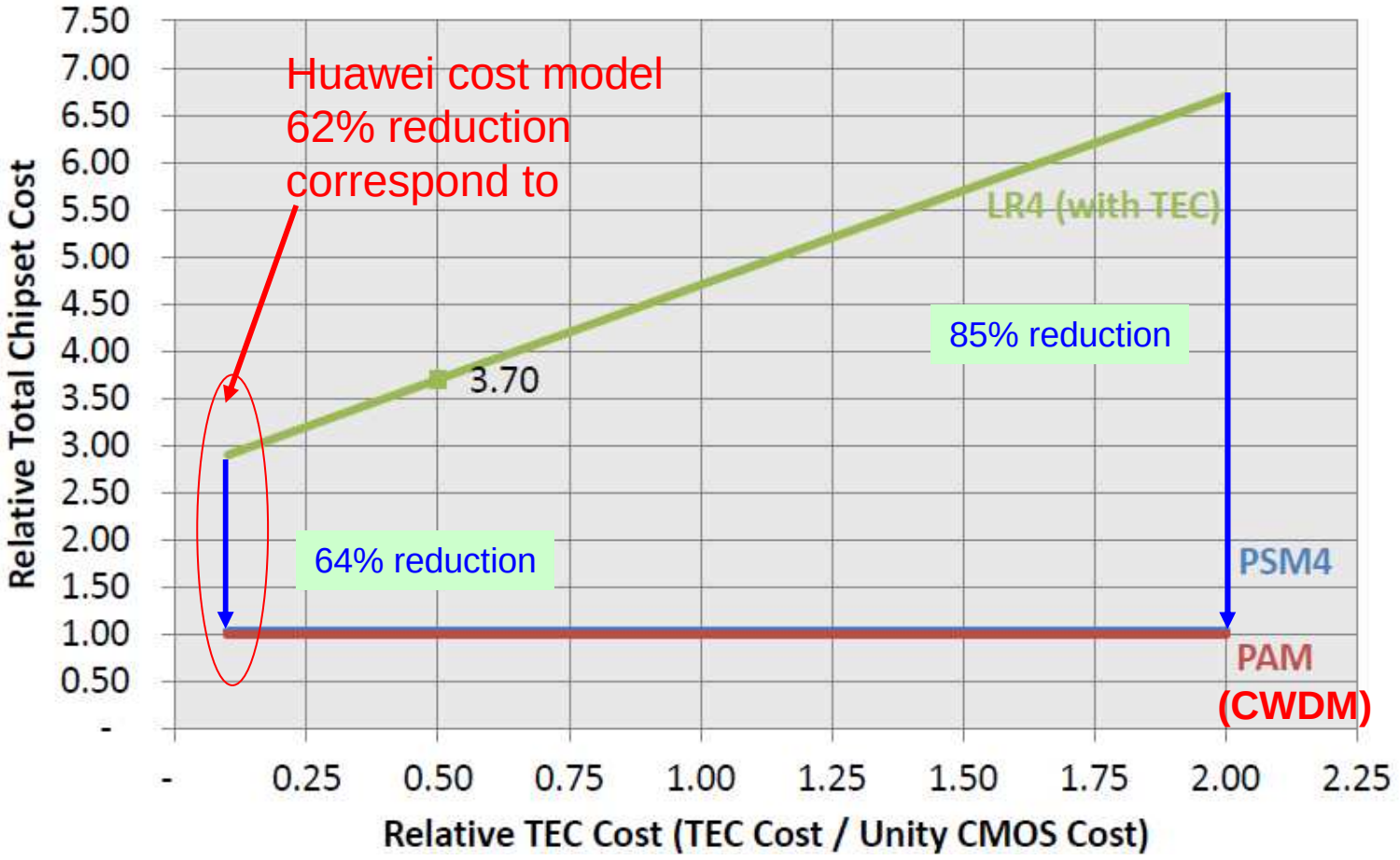
After applying all potential cost reduction measures:

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



Supporting Material of Cost Reduction
+ welch_01a_0113 Luxtera

Chipset BOM Comparison with TEC - Normalized



Supporting Material of Cost Reduction

Petrilla_03a_0113_optx Avago

Size, Power & Cost Estimates: 100G SR10, SR4, LR4 & PSM4

	100G SR10	100G SR4	100G LR4	100G PSM4	Comments
Lane Count	10	4	4	4	
Signal Rate/Lane	10.31 GBd	25.78 GBd	25.78 GBd	25.78 GBd	
XCVR Power Consumption	300 mW/lane	360 mW/lane	1200 mW/lane	640 mW/lane	For block diagram elements in SR10
Laser bias current	1x	1.2x	12x	8x	
CDR	Not Req'd	300 mW/lane	300 mW/lane	300 mW/lane	
TEC	Not Req'd	Not Req'd	250 mW/lane	Not Req'd	
XCVR/lane Total	300 mW/lane	660 mW/lane	1750 mW/lane	940 mW/lane	
XCVR 4 lane Total	na	2640 mW	7000 mW	3760 mW	
Density					
Form Factor	CXP	QSFP28		QSFP28	QSFP28 if power consumption < 3.5 W
		CFP4	CFP2	CFP4	CFP4 if power consumption < 6.0 W
Relative XCVR Cost	1x	1.1x	12x	4x	

- This analysis indicates that a 100G PSM4 based implementation in a CFP4 form factor supporting the 500 m SMF objective, can have 0.54x the power, 0.5x the size (2x density), for 0.33x the cost of the 100G LR4.
- With modest reduction of power consumption, the 100G PSM4 may be implemented in a QSFP28 form factor yielding additional density benefit.

Huawei cost model 62% reduction correspond to

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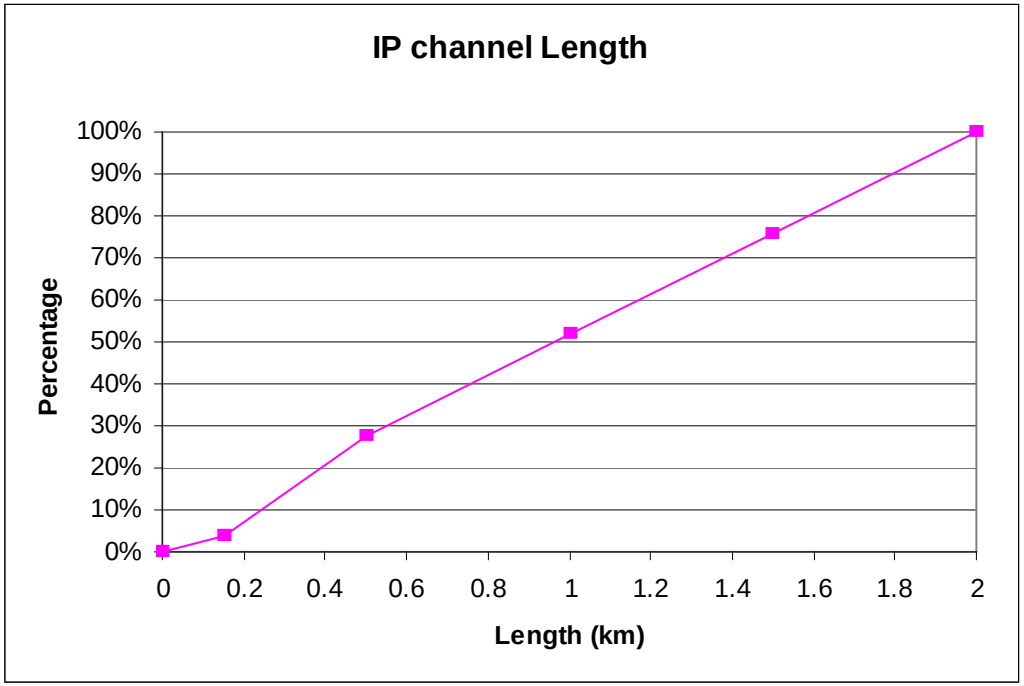
Cost Analysis of Double Link Cost

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 8-1 OS2 double-link channel = 7

+ kolesar_01a_0512

Carrier IP using relative cabling cost at CCL = 1km

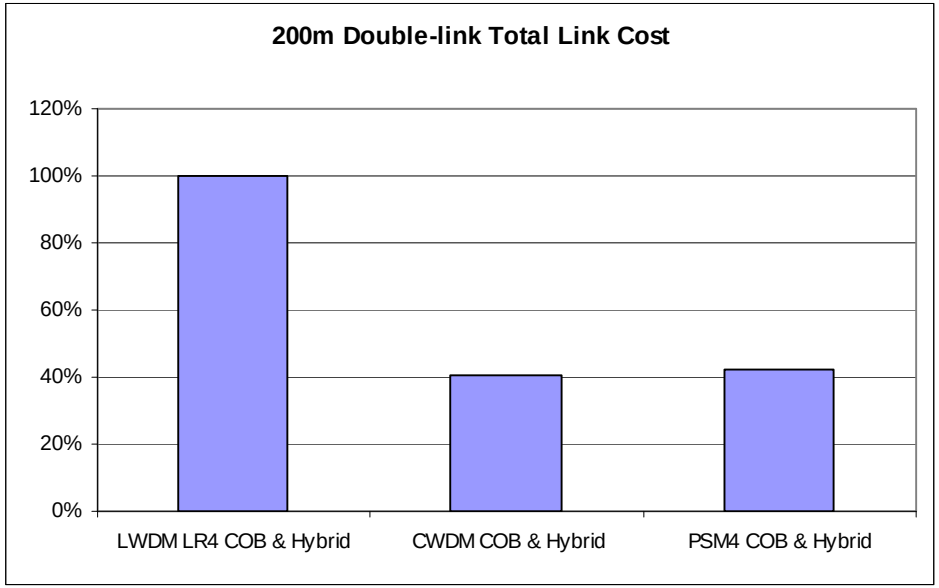
- 1km 2-f OS2 double-link channel = 6.5
- 1km 8-1 OS2 double-link channel = 26

802.3 using relative cabling cost at objective > 500m

- 500m 2-f OS2 double-link channel = 2.5
- 500m 8-1 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**



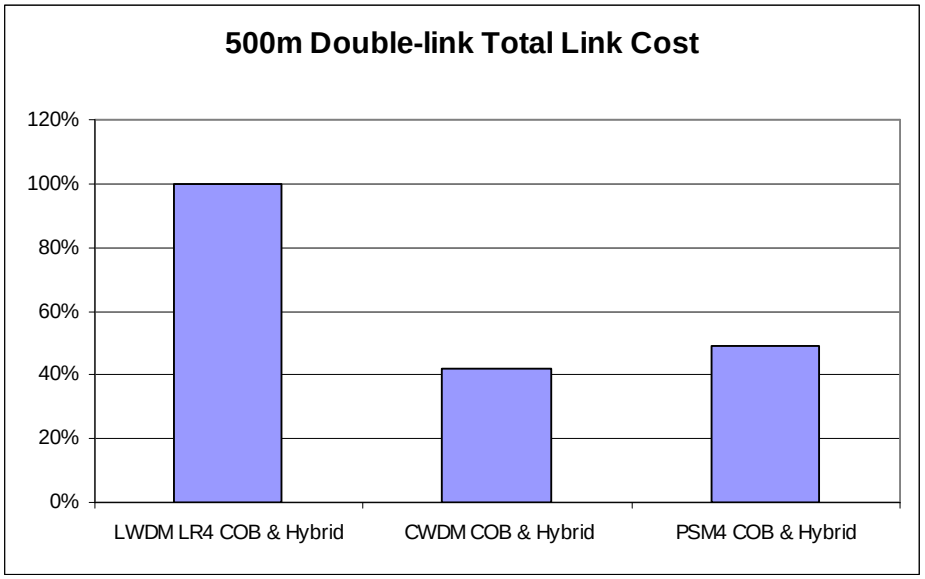
	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

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 8-1 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**



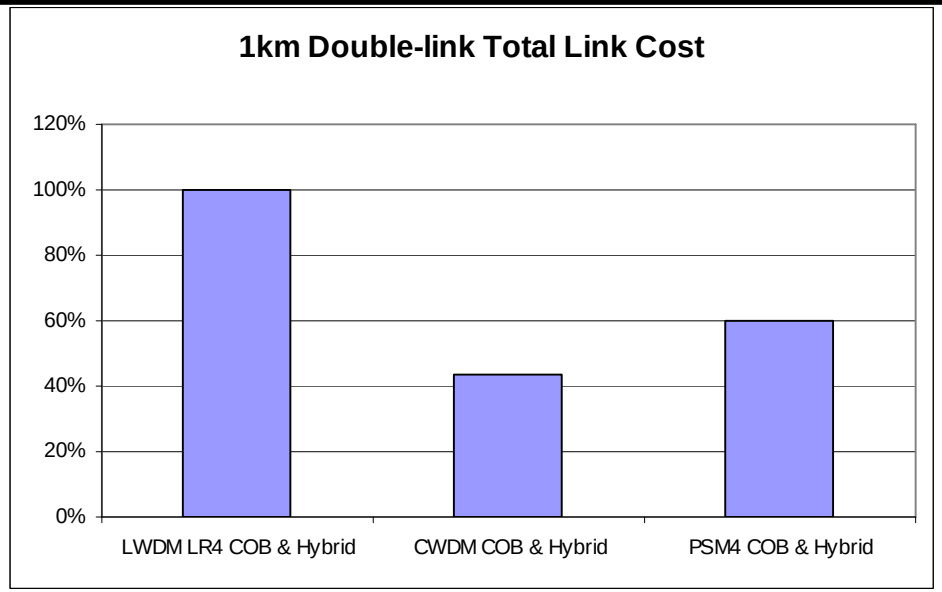
	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

802.3 using relative cabling cost at objective > 500m

- 500m 2-f OS2 double-link channel = 2.5
- 500m 8-1 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**

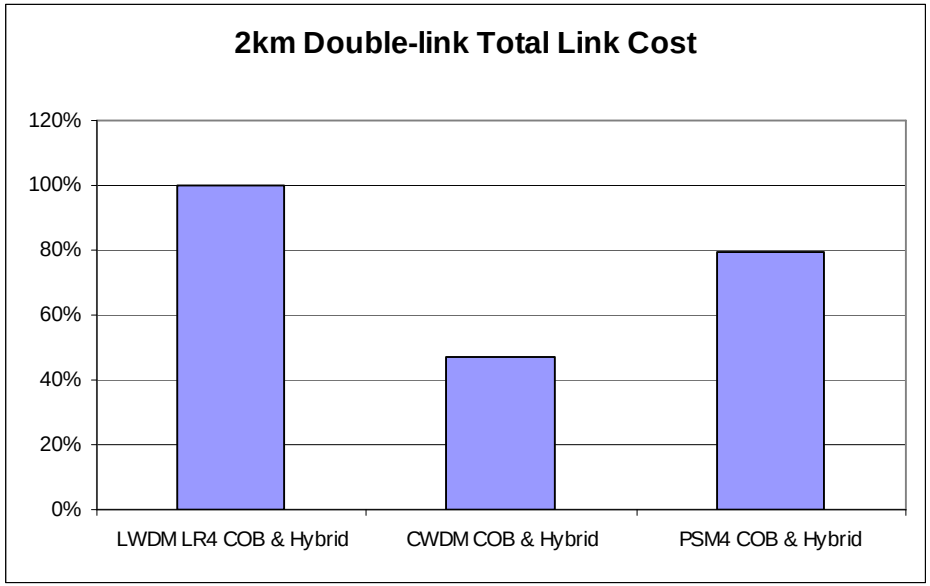


	Cost Reduced LR4	CWDM	PSM4
Transceivers cost	2.5	1	0.8

IP channel using relative cabling cost at CCL = 1km
1km 2-f OS2 double-link channel = 6.5
1km 8-1 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 8-1 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 >500m, including the Carrier IP market, CWDM has the lowest total link cost.**

Advantage of CWDM over PSM4

- CWDM link cost is lower than PSM4 for >=500m.
- CWDM solution use duplex fiber, which allows use of existing fiber in data centers and enterprises, where the fibers are already installed.
- CWDM solution using duplex fiber is a huge advantage for new applications such as campus applications where fiber is run between buildings and reach can be <500m, but underground. Pulling duplex fibers would be a much lower cost solution compare with pulling parallel fibers in those applications.
- CWDM solutions can extend to longer reach (>500m) in other markets such as carrier IP, enterprise, and campus markets with ease and practically no additional costs.
- No FEC in CWDM solution means no latency issue.

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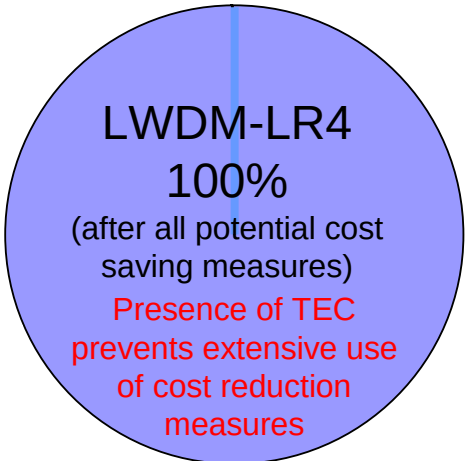
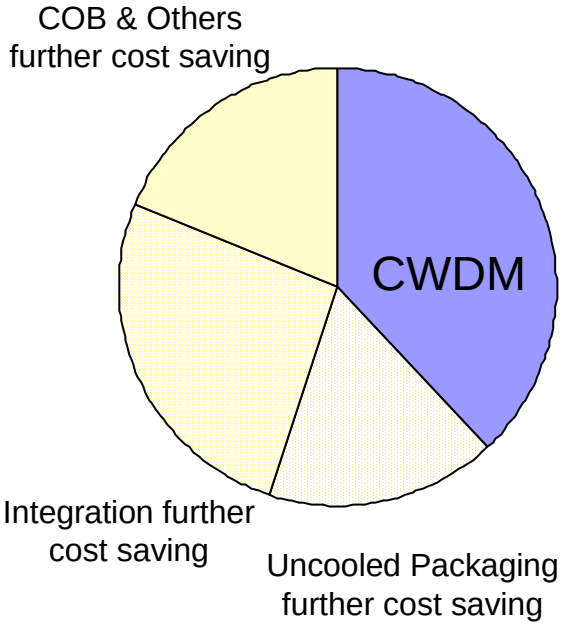
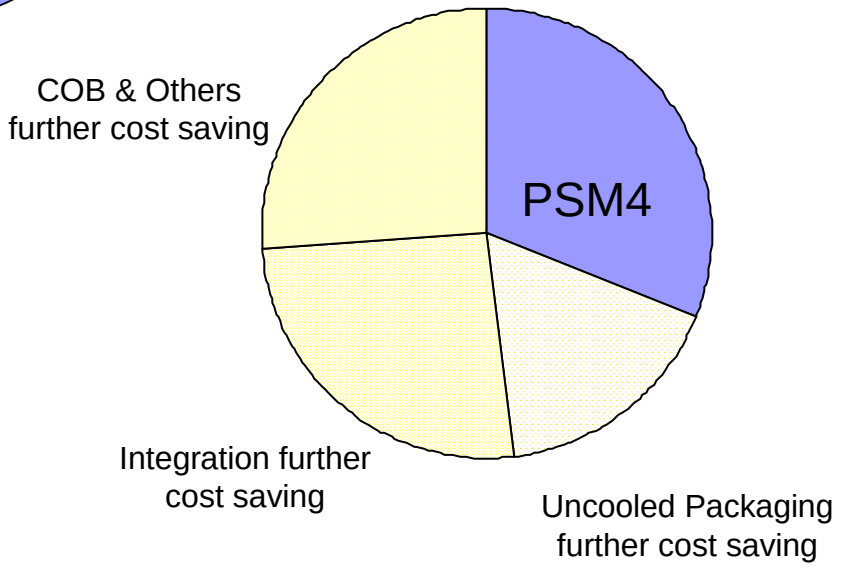
Further Cost Reduction in Transceivers in CWDM compared with Cost Reduced LR4



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**

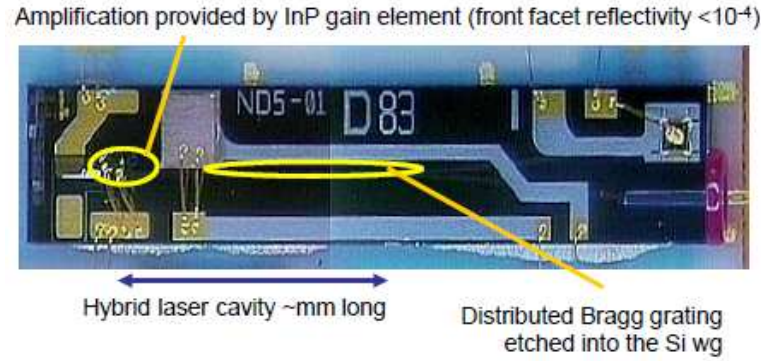
Cost Reduction Opportunities in CWDM compared with LR4 (2)

O/E Integration		
Cost reducing item	**LWDM**	**CWDM**
O/E integration	**Presence of TEC prevents extensive OEIC integration**	**OEIC integration possible due to without TEC**
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**
Golden Box	**Existing of high cost Golden Boxes, major contribution to overall cost**	**No Golden 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**

Supporting Material of Cost Reduction: COB AND Silicon Photonics + martin_02_0912 Kotura



IEEE P802.3bm 40G and 100G Task Force
September 2012 Interim

Reduction in Assembly Costs

1. Integration minimizes optical assembly
2. Wafer scale flip-chip bonding of 4-channel gain array
   - Automated, passive alignment
   - 40 seconds per array
3. Wafer scale testing
4. Die attach 4x25 CMOS driver array
5. Die attach TIAs on Rx
6. Connectorize TOSA-ROSA in QSFP/CFP4

Silicon photonics is one low-cost WDM PIC example

- CMOS chip fabrication
- Low-cost, flip-chip bonded Gig E style light source
- Full integration of laser grating, modulator, mux/demux and detectors
- CMOS drivers and TIAs
- Minimal piece parts
- Electronics style assembly
- Non hermetic packaging

Low Cost Checklist

√ Use CMOS where ever possible
√ No WDM specific lasers, no laser sub-assembly (no isolators, beam collimators, lens cap, etc.)
√ No hermetic packages
√ No active laser alignment
√ No detector sub assembly
√ No TEC
√ No WDM assembly
√ Use duplex connector instead of arrayed MPO

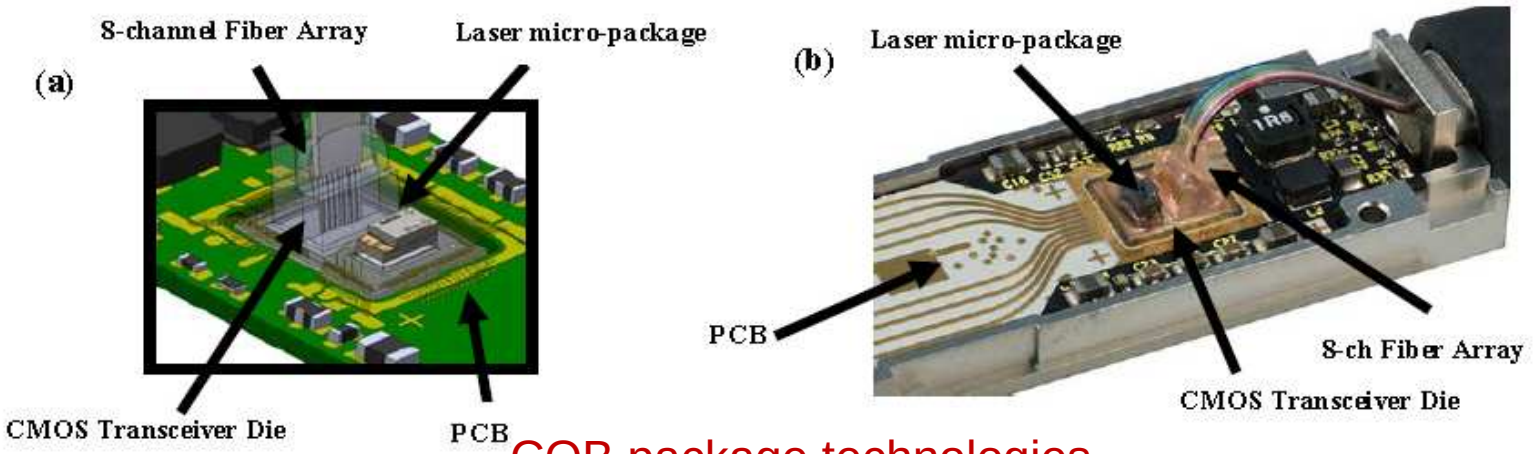
COB Technology Has Been Proved in in Luxtera / Molex 4*10G AOC

http://www.lightreading.com/comm-chips/luxtera-marks-10g-milestone/240140721?queryText=LUXTERA

CARLSBAD, Calif. -- Luxtera, the worldwide leader in Silicon CMOS Photonics, today announces that it has shipped its one-millionth 10Gbit channel. This important milestone validates the growing demand for Silicon Photonics in today's mission critical data centers and computer clusters as well as reinforces Luxtera's ability to meet high performance computing (HPC) needs on a larger scale. The announcement further signifies the emergence of Silicon Photonics as the next generation interconnect with 10 Petabits of transceiver bandwidth shipped.

Luxtera is the leading IP provider and supplier of Silicon CMOS Photonics and is the only known provider of Silicon Photonics shipping in significant commercial volume. The technology continues to be a driving force that supports growing bandwidth demands of equipment in HPC, next generation datacenters and cloud computing. Silicon Photonics offers a reliable, low cost yet high performance solution as opposed to traditional technologies such as vertical cavity surface emitting lasers (VCSELs). Recognizing its benefits, Silicon Photonics continues to be the focus of many research labs and universities, most notably IBM and Intel. The technology has made news recently as the enabling building block in the race for building computers at an exascale (1018 byte) level, to learn more visit www.luxtera.com.

http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5465371



COB package technologies

Non-hermetic COB product and reliability data

Molex's 4x10G Active Optical Cables (AOCs) have accumulated in excess of 800 million device hours with no in-module field failures, giving a predicted FIT rate of <1.2.^

^From Molex AOC Reliability Report.

Conclusions

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 40 ports in 10U front panel（CFP4 or QSFP）;**
- **No FEC means no concern of latency issue;**
- **Reach is at least 500m;**
- **Wide potential market: Data Center and Carrier IP, can extend into Enterprise and Campus 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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