Optics Technology Advances

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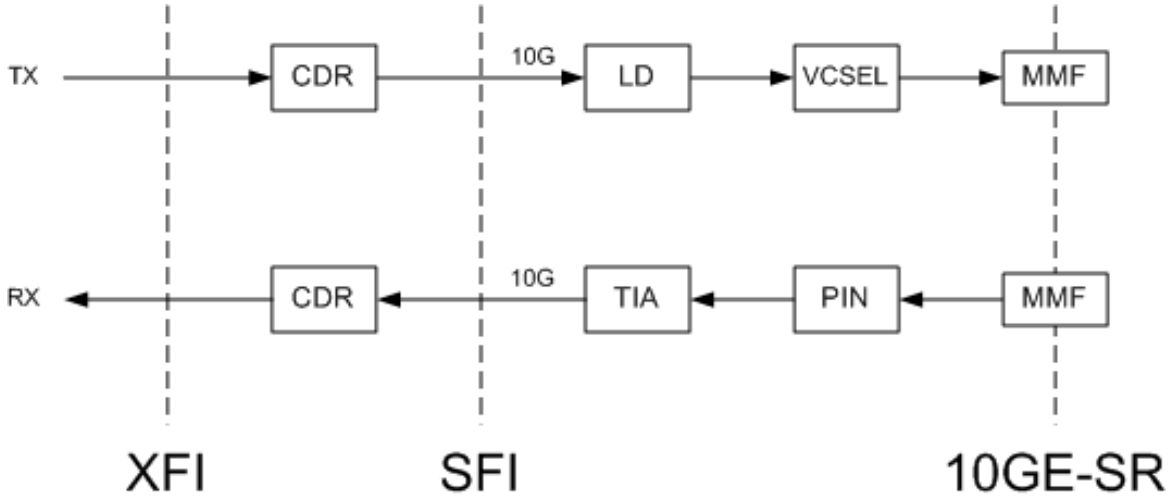
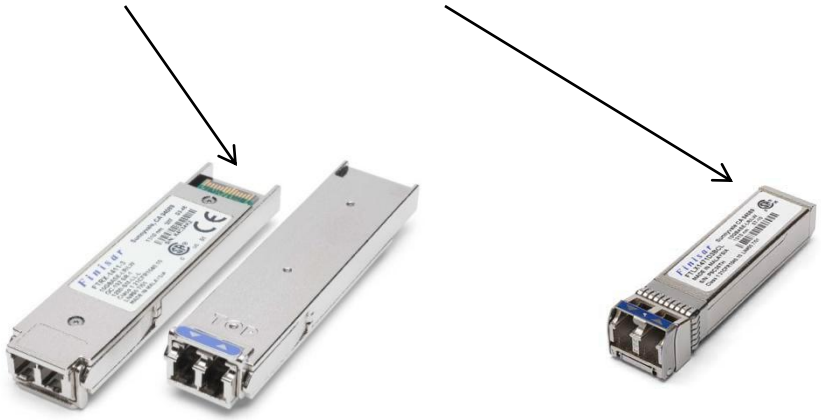
Outline

- 10G
- Optics Specifications
- Pluggable Modules
- 40G
- Multi-link Modules
- 100G
- Board Mounted Optical Engines
- 400G
- Summary

Mainstream 10G MMF: SR NRZ XFP/SFP+





Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
1	10	1	1	10
10		10		

Mainstream 10G SMF (LR) also uses duplex LC connector & fiber cable

Optics Specifications

- Engineering View: Link Budget in dB
  - Link Budget = Penalties + Loss
    - Penalties: Fiber Chromatic Dispersion, PMD, others
    - Loss : Fiber attenuation, connector loss, others
- Operator View: Reach in meters or kilometers
- Reach as only spec is fine for MMF optics
  - Link budget is mainly Penalties over specified reach
  - Reach is synonymous with Penalties
- Reach as only spec is not OK for SMF datacenter optics
  - Link budget is mainly Loss over max. reach
  - SMF optics are rarely used over max. reach
  - Loss is what operators really care about
  - Reach is often not synonymous with Loss

Optics Specification Example

Client optics specification	High density data center duplex or parallel MMF	Structured data center duplex or parallel SMF	Data center & central office duplex SMF	General data center duplex SMF
reach (determines min. penalty)	300m	500m	2km	10km
minimum loss budget	2dB	3dB	4dB	6dB
10G standard	10GbE-SR	none	OC-192 SR-1 G.693 10G	10GbE-LR

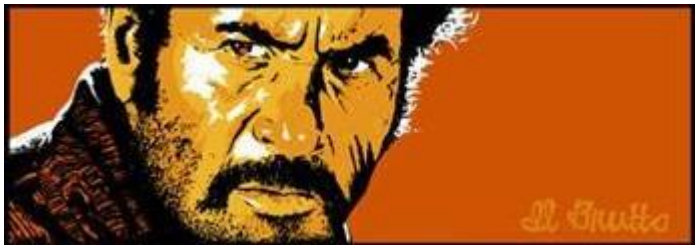
- 300m (or 100m) for MMF interface is sufficient
- 500m, or 2km or 10km for SMF optics is insufficient
- Ask for 500m/3dB, or 2km/4dB, or 10km/6dB min. for SMF
- Sufficient loss gives plug and play: no link engineering!

Pluggable Module Characteristics

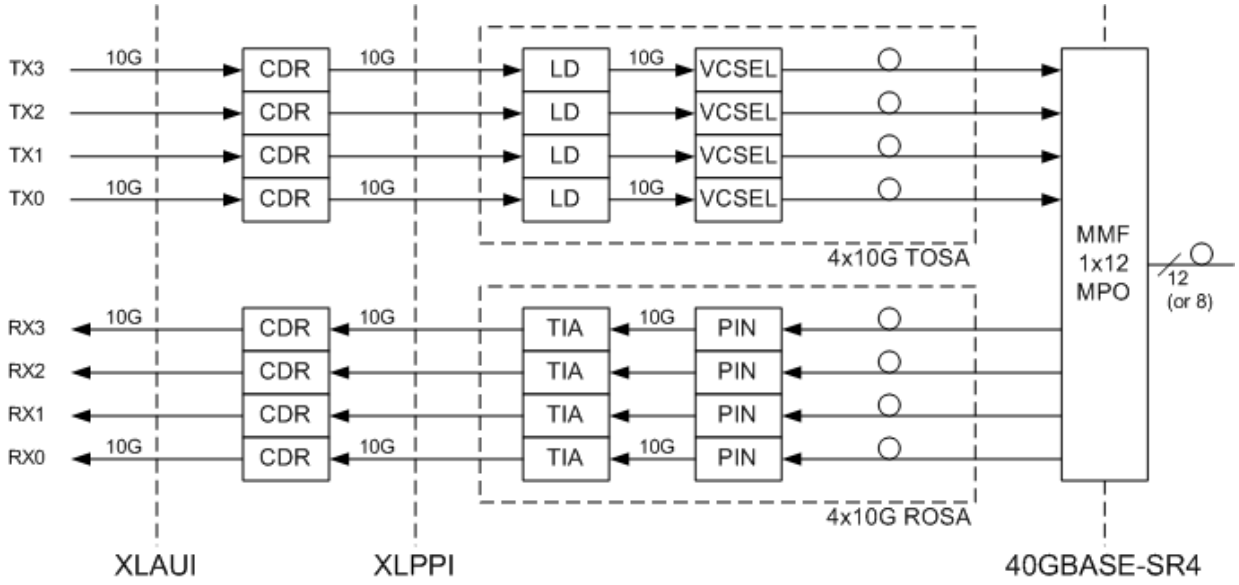
- the good (il buono)
  - multiple applications supported
  - pay as you go
  - confined, replaceable failures
  - common market
  - specialized R&D & production

- the bad (il cattivo)
  - increased component count
  - SI complicated by I/O connector
  - power increased by I/O SerDes
  - density limited by SFP+ size

- & the ugly (il brutto)
  - poor thermal interface
  - heat localized at host front



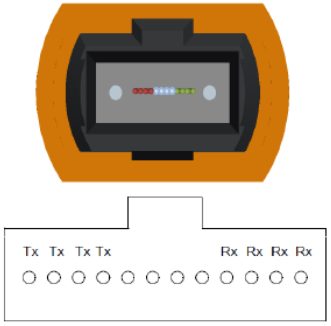
Mainstream 40G MMF: SR4 Parallel QSFP+



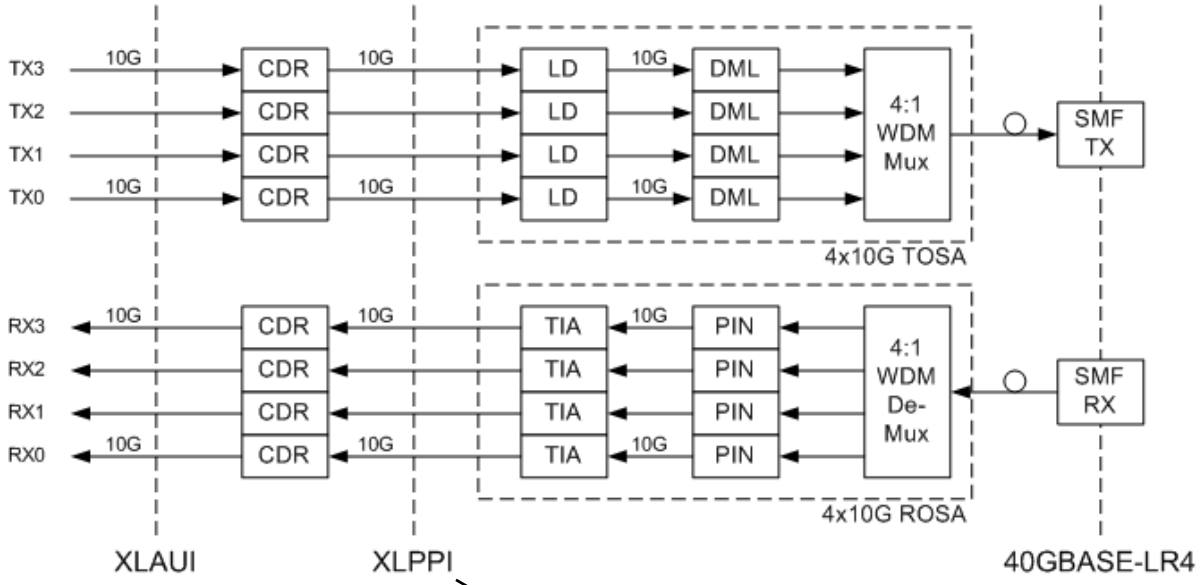
Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
	10		1	10
4		4		
40		40		

1x12 MPO parallel connector & MMF cable differs from 10GE-SR

MPO connector

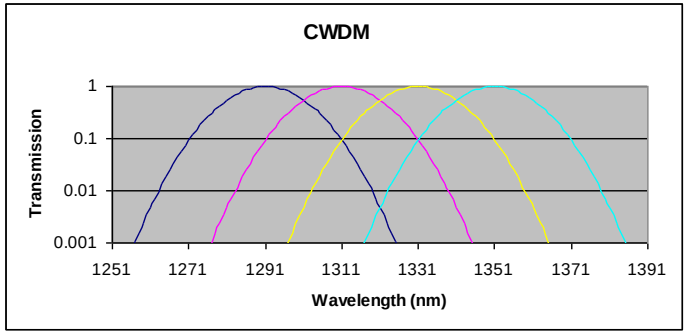


Mainstream 40G SMF: LR4 WDM QSFP+



Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
	10	1		10
4			4	
40		40		

duplex LC connector & SMF cable is same as 10GE-LR

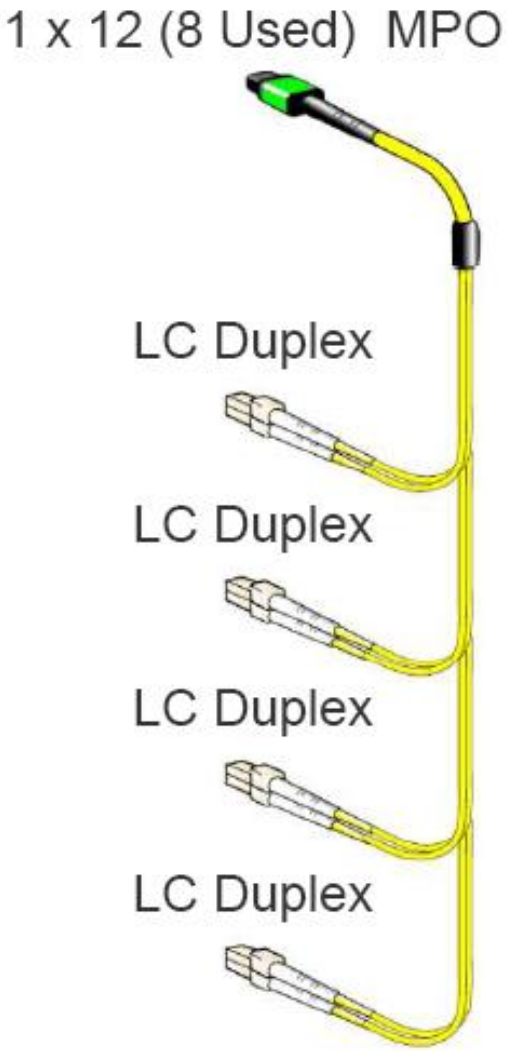


High Density 10G SMF: LR Parallel QSFP+

Octopus break-out cable connects

QSFP+ ⇔ 4x SFP+

(same for high density 10G MMF: SR parallel QSFP+)



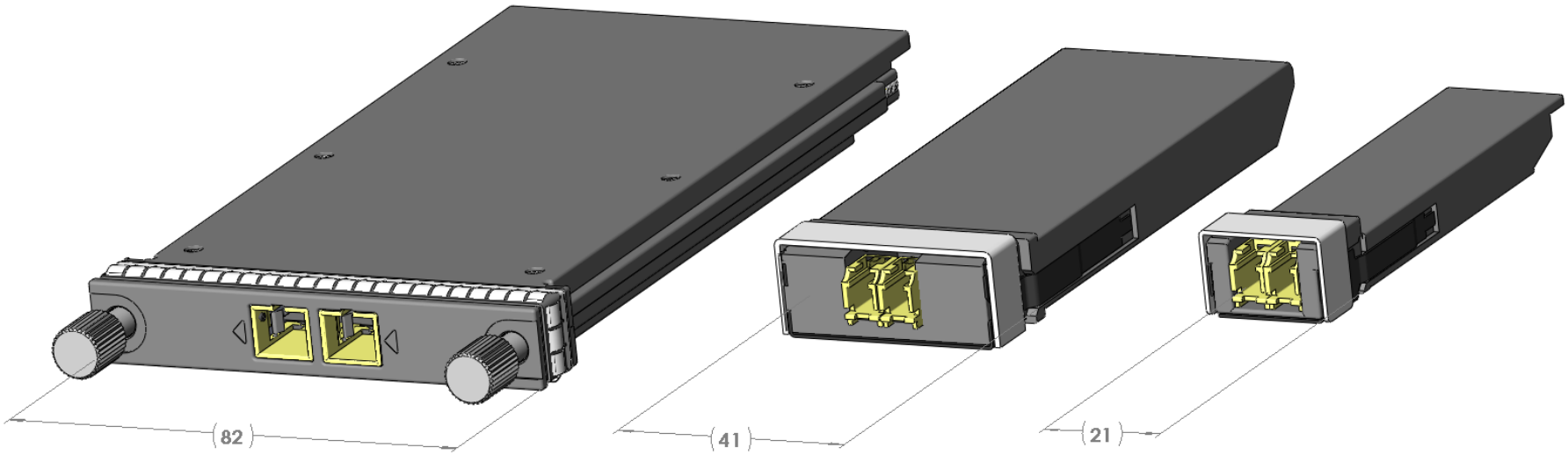
Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
	10		1	10
4		4		
4x10		4x10		

Multi-Link Example: 1UI Line Card Density

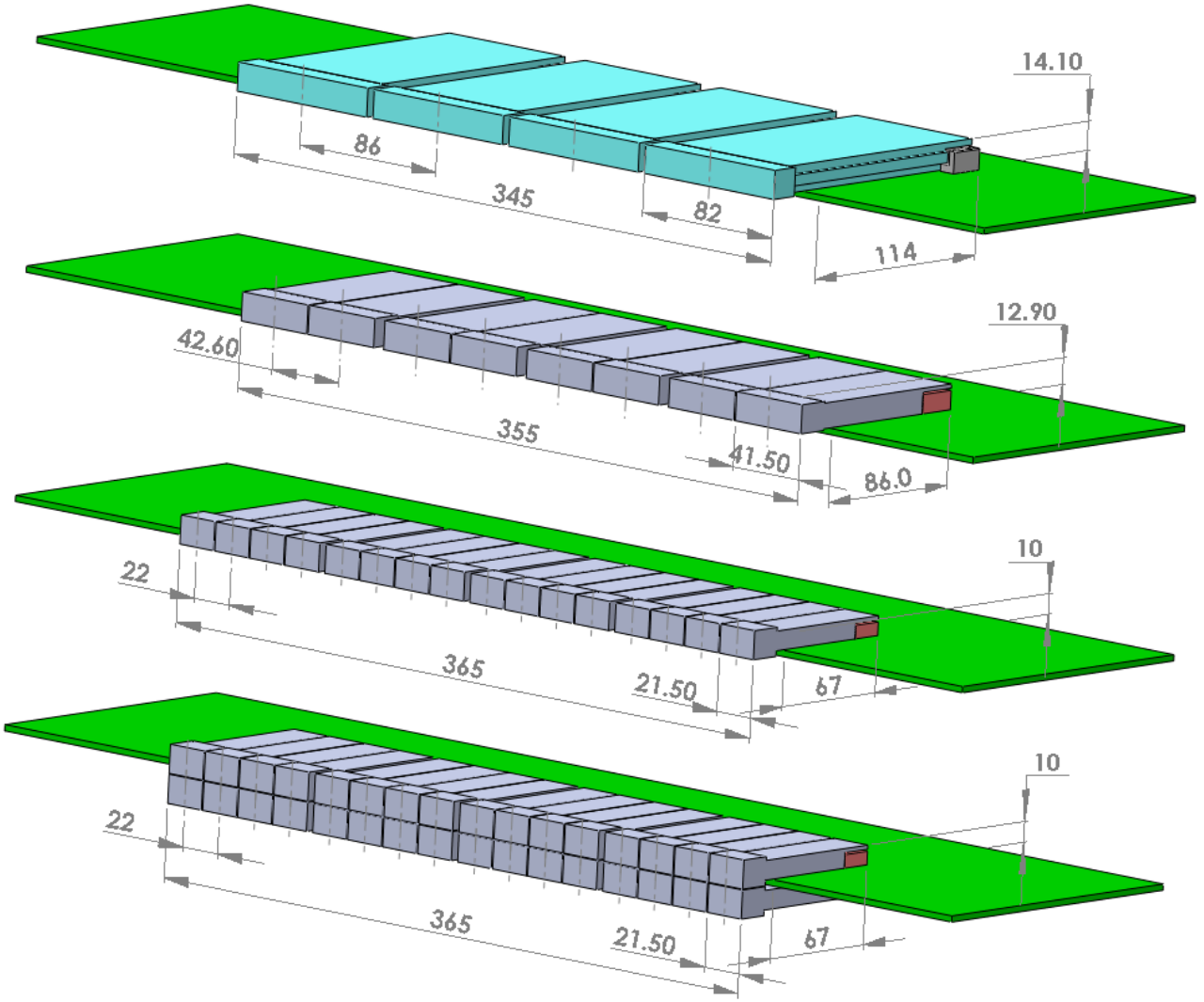
Form Factor	Electrical I/O	Rows	10GE Ports	40GE Ports	Power
SFP+	1x10G	Double	48	N.A.	~40W
QSFP+	4x10G	Double	176	44	~80W
CFP4 MLG	4x25G	Double	360	72	~120W

- Integer multiple density increase
- Thermal load increase
- Single channel failure requires bringing down multiple links to replace

100G Modules: CFP / CFP2 / CFP4



CFP / CFP2 / CFP4 Module 1UI Card Density



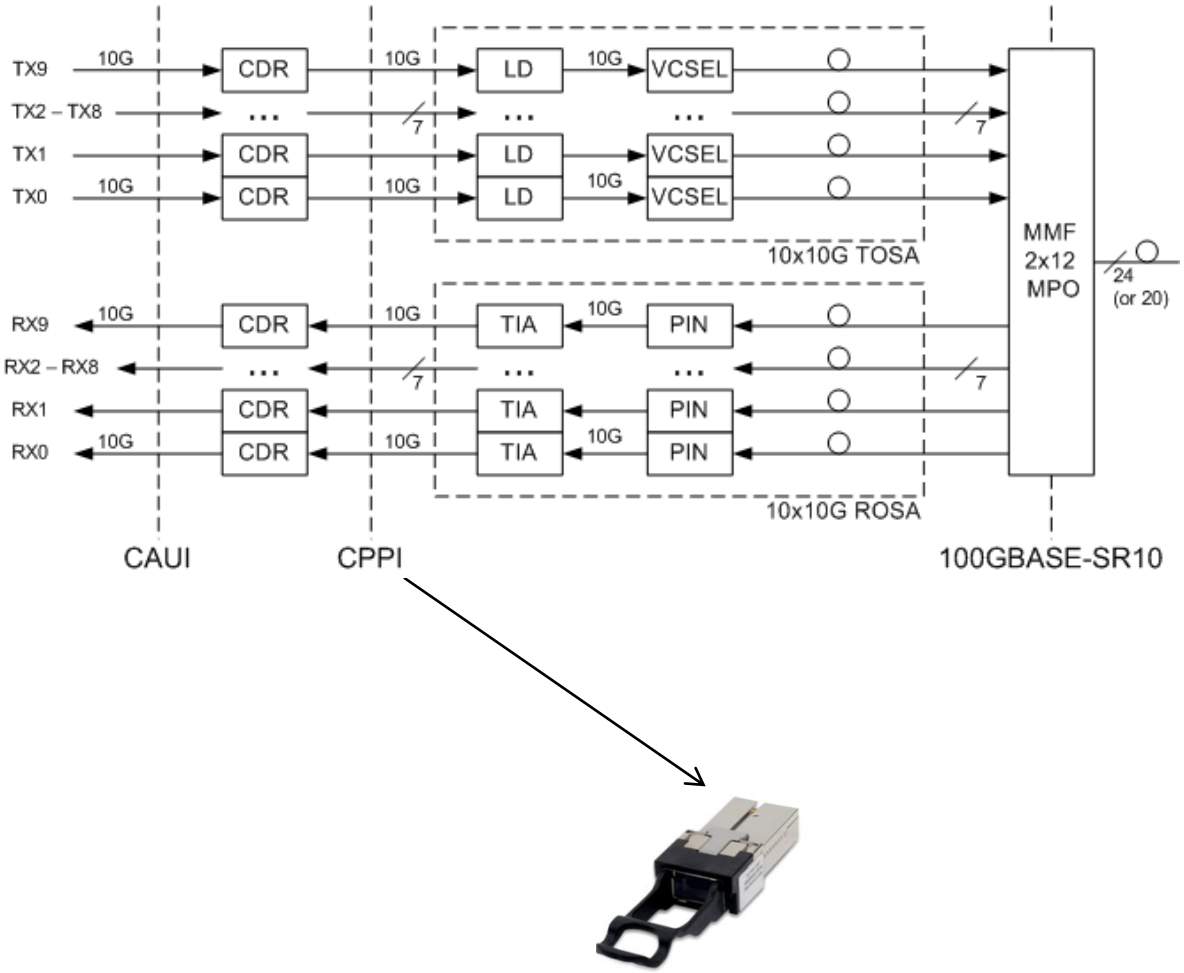
4x CFP
(or 5x)

8x CFP2
(or 10x)

16x CFP4
(or 20x)

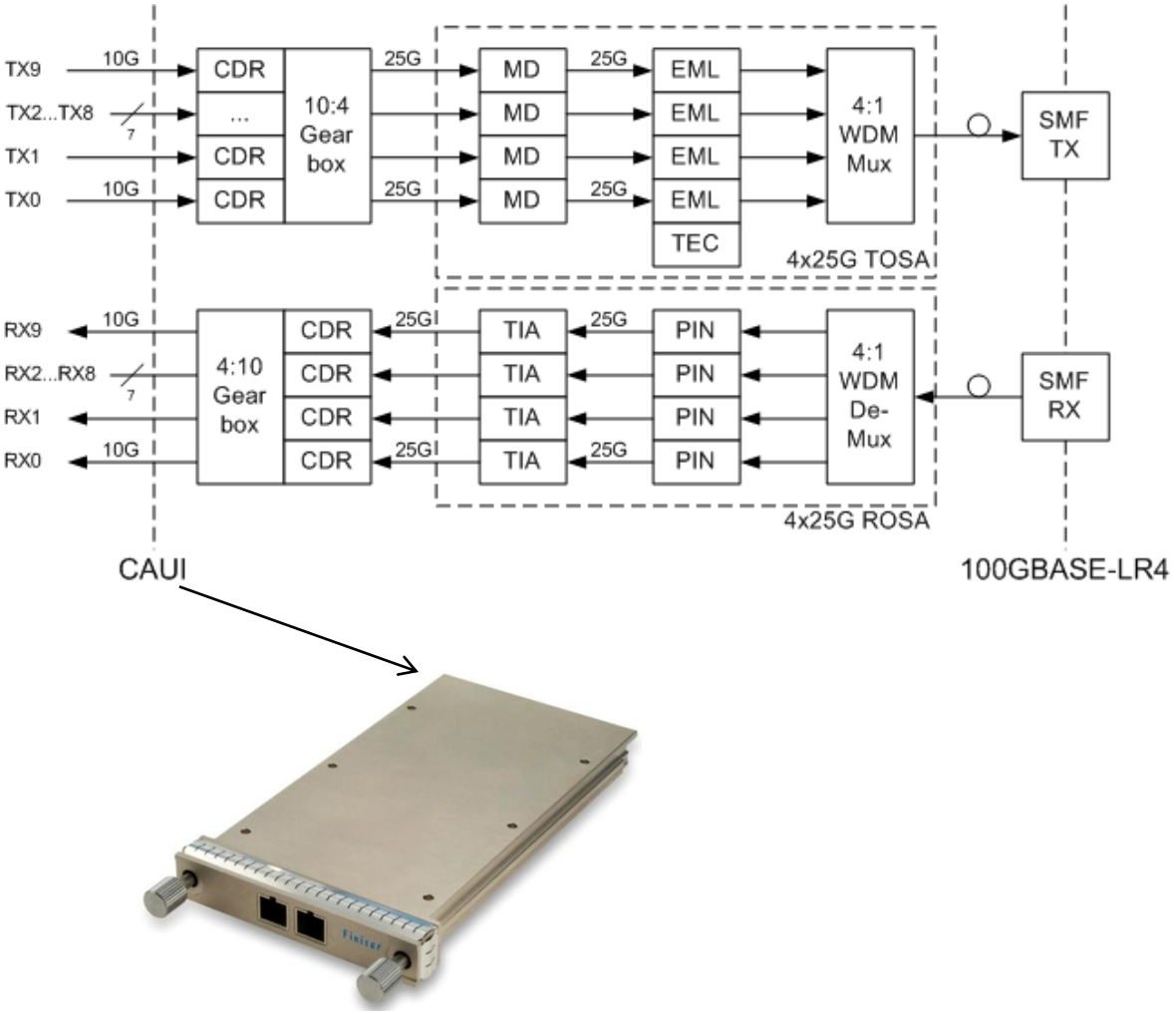
32x CFP4
(belly-to-belly)
(or 36x)

Gen1 100G MMF: SR10 CFP / CFP2 / CXP



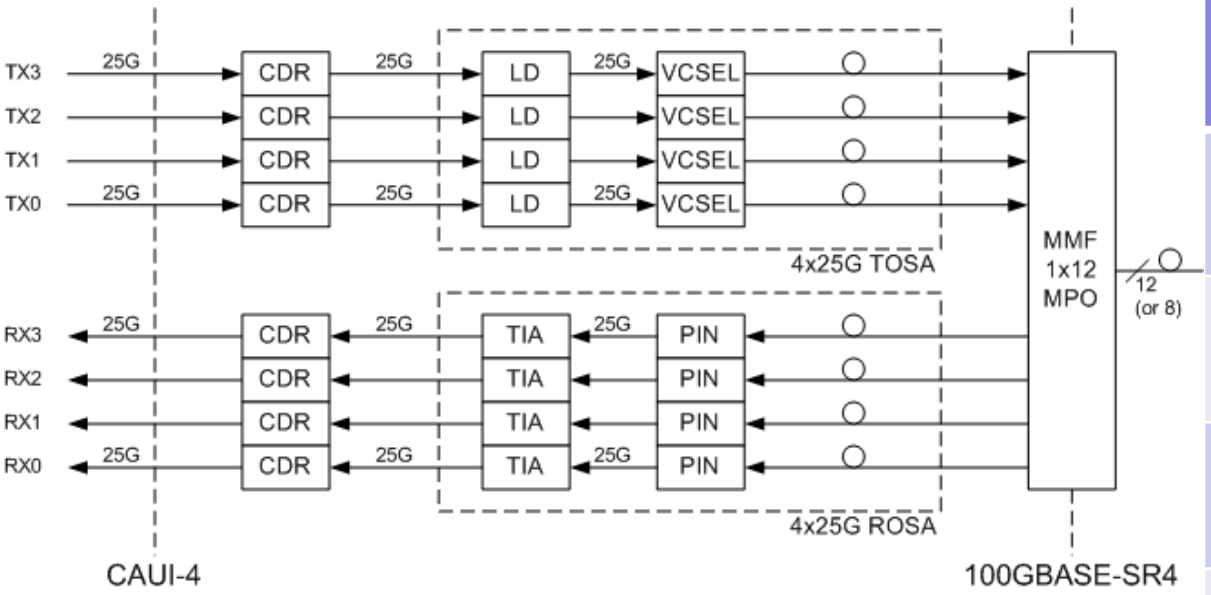
Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
	10		1	10
10		10		
100		100		

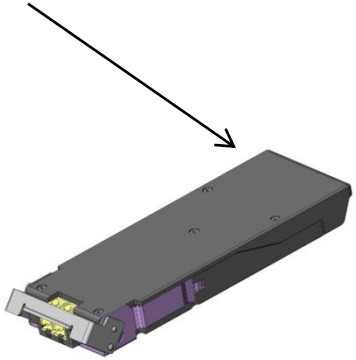
Gen1 100G SMF: LR4 CFP



Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
	10	1		
			4	
10				25
100		100		

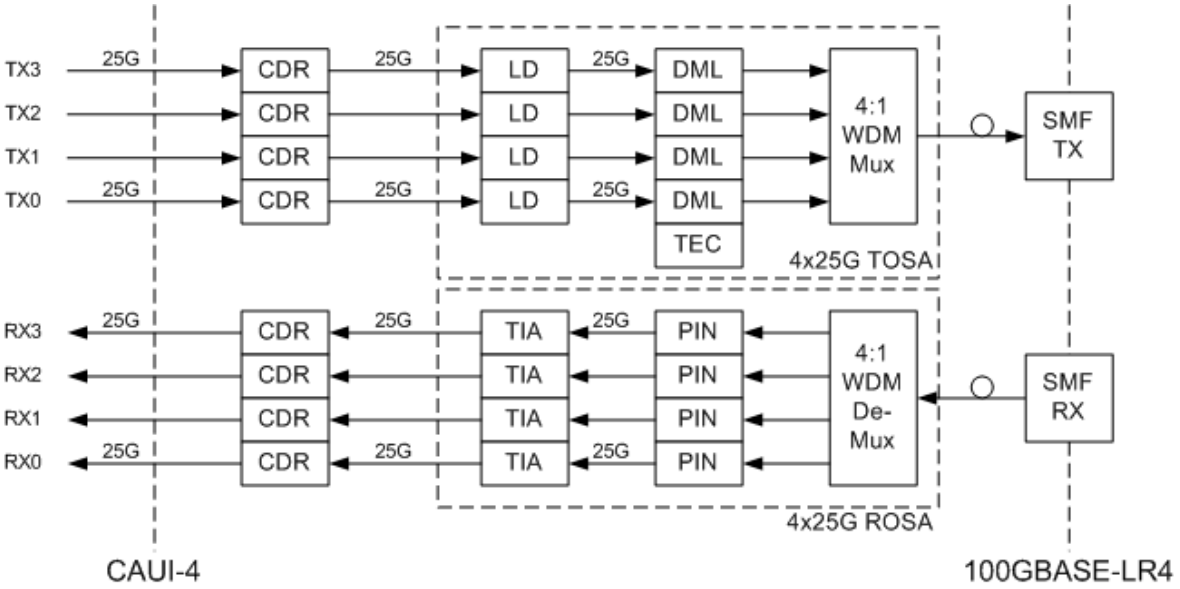
Gen2 MMF: SR4 CFP2 / CFP4 / QSFP28

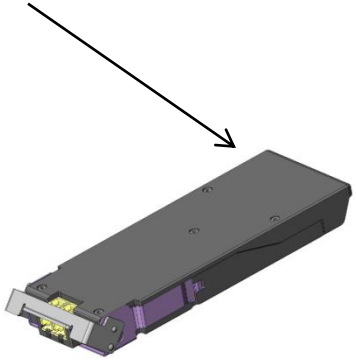




Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
			1	
4		4		
	25			25
100		100		

Gen2 SMF: LR4 CFP2 / CFP4 / QSFP28



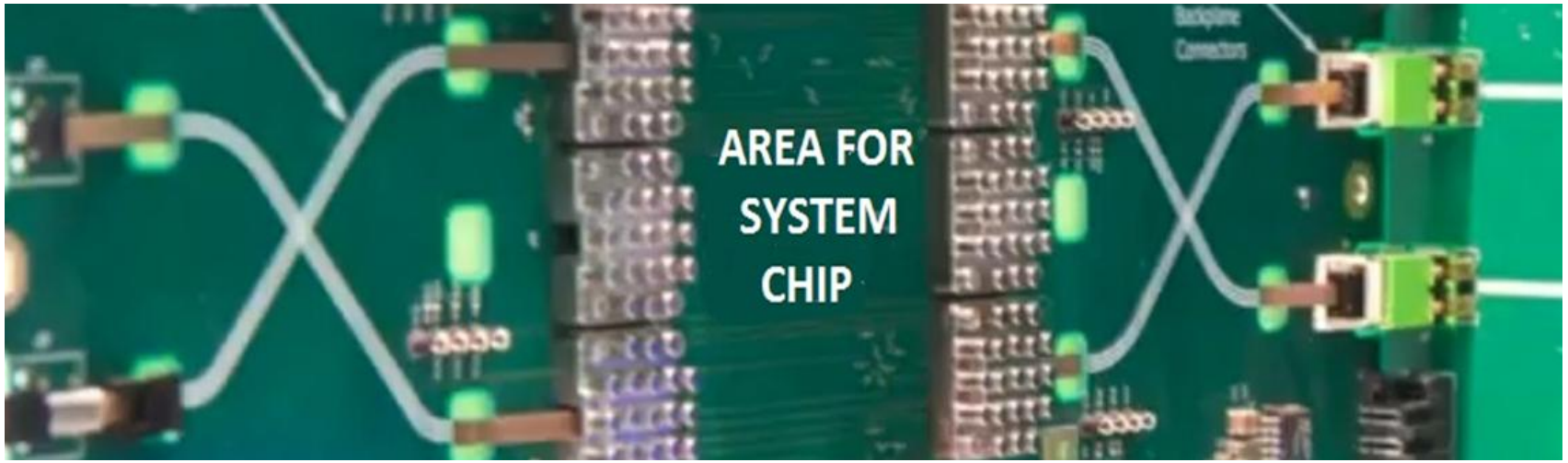


Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
		1		
4			4	
	25			25
100		100		

Future 40G & 100G Technologies

- 40Gb/s per lane (Serial)
  - 1x40G architecture
  - Candidate to replace Copper wires for servers
- 50Gb/s per lanes
  - 2x50G architecture
  - 2x density improvement
- Parallel SMF
  - Similar to SR4 but for SMF instead of MMF
  - Ongoing industry debate about broad market potential for longer reach datacenter links
- Board Mounted Optical Engines
- Higher Order Modulation

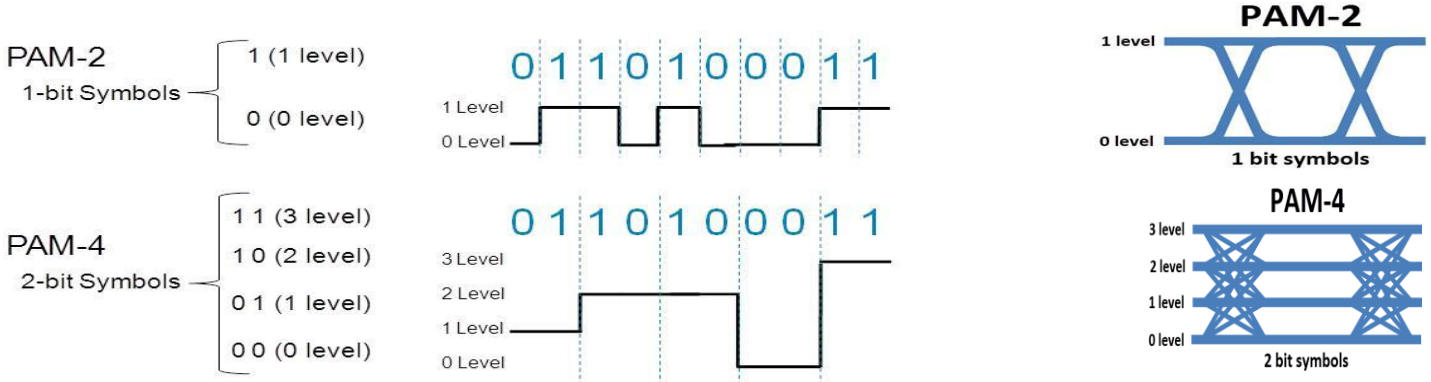
Board Mounted Optical Engine



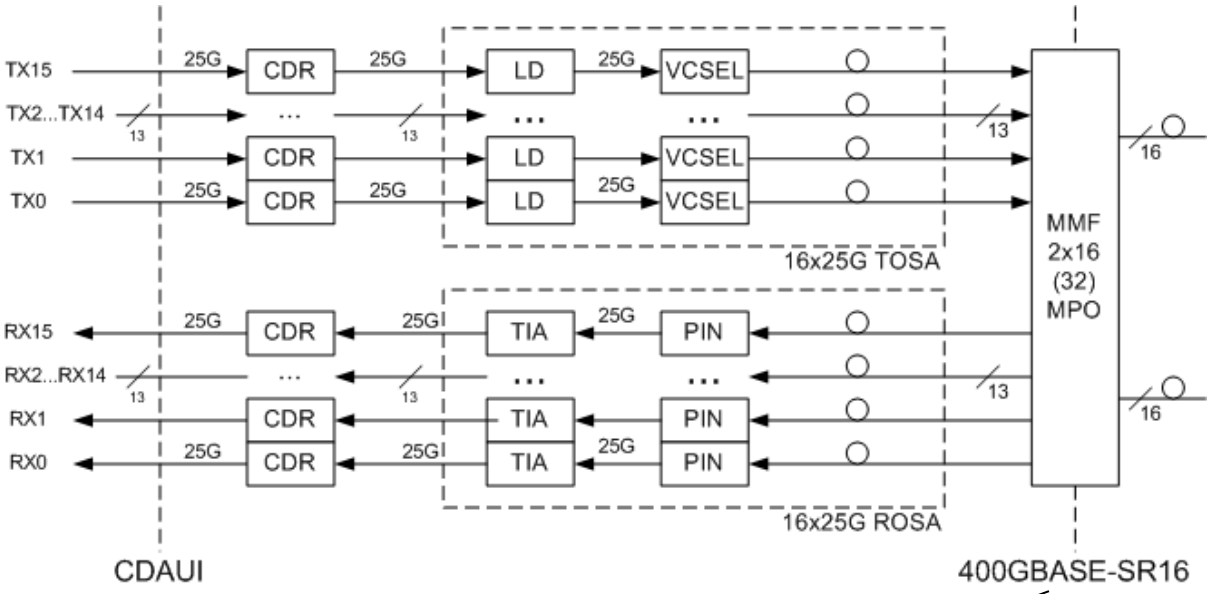
Board Mounted Optical Engine Card Example

Higher Order Modulation

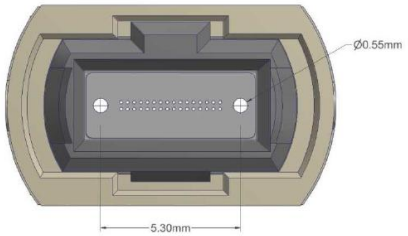
- Four basic parameters determine link rate:
  - Symbol rate (Baud)
  - Number of fibers (Parallel)
  - Number of wavelengths (WDM)
  - Number of bits/symbol (modulation order)
- Higher Order Modulation (>1bit/symbol) example
  - PAM-4 instead of NRZ (PAM-2) reduces by 2x the Baud, or number of fibers, or number of wavelengths

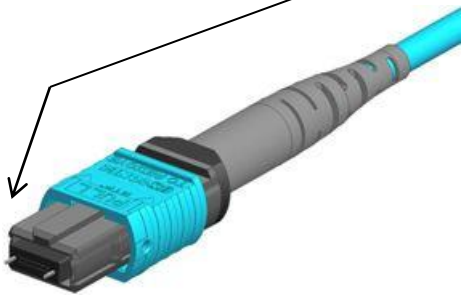


Gen 1 400G MMF: SR16



2 x 16 MMF MT ferrule



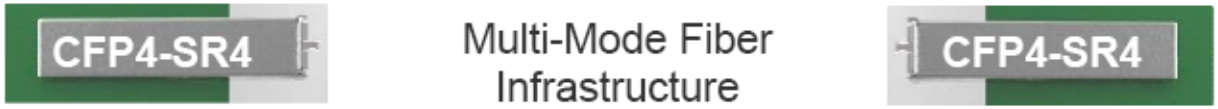


Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
			1	
	25			25
16		16		
400		400		

Gen 1 400G MMF: SR16

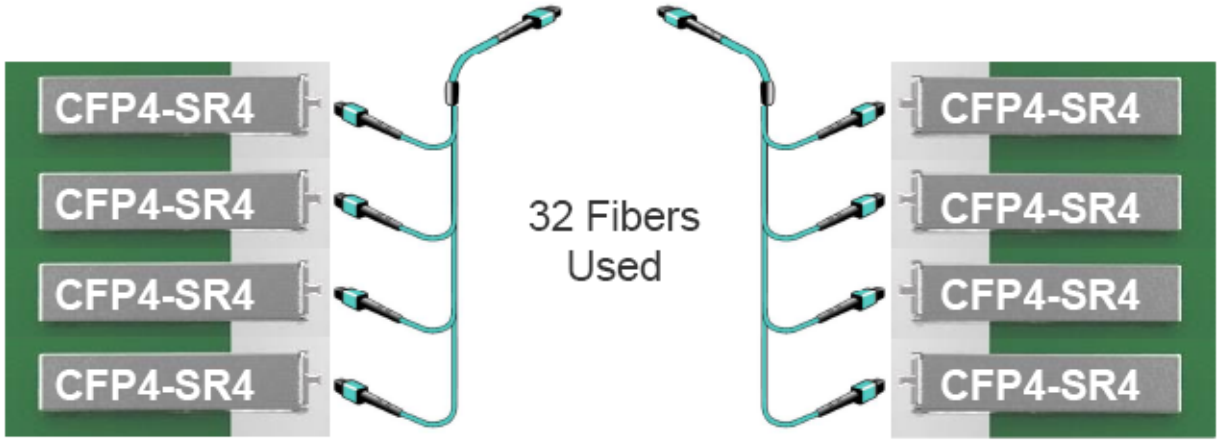
400GE over MMF by using the 100GBASE-SR4 PMD

100G Ethernet up to 100 m on OM4

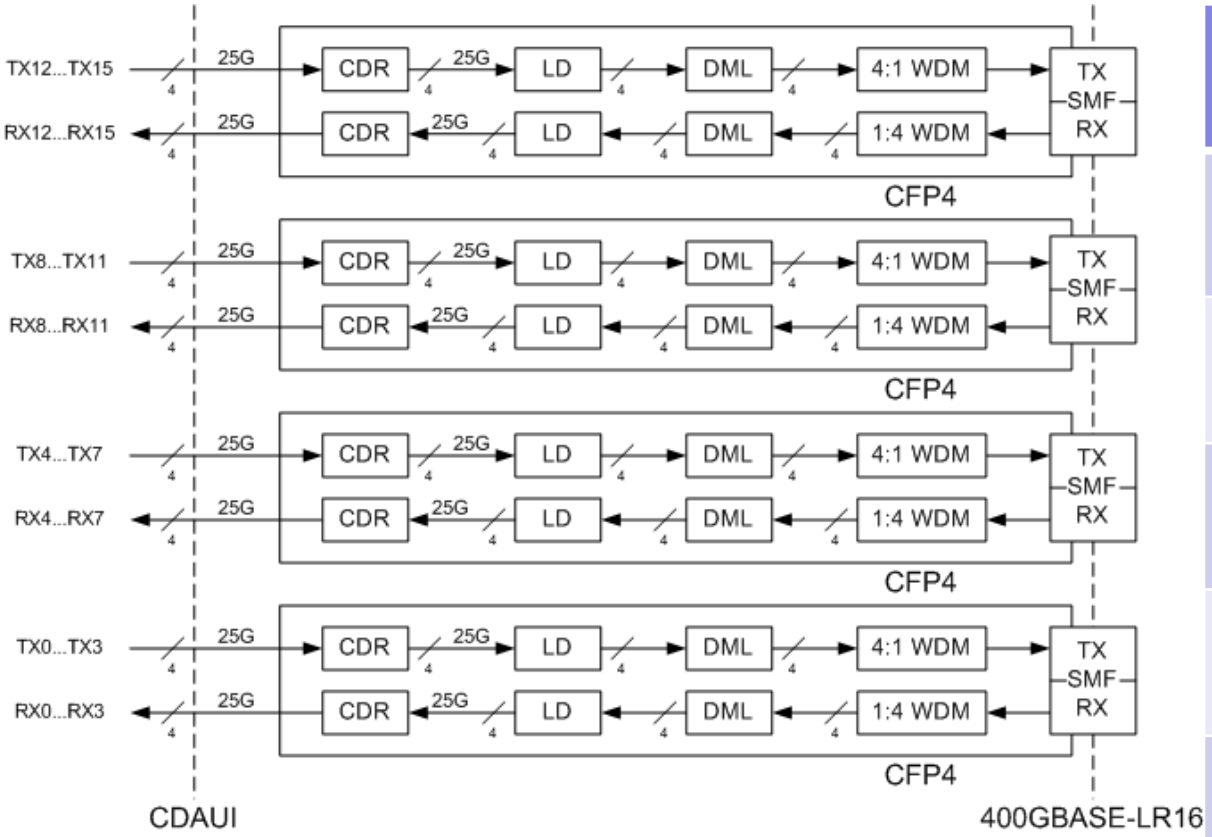


400G Ethernet up to 100 m on OM4

Parallel Multi-Mode Fiber Infrastructure

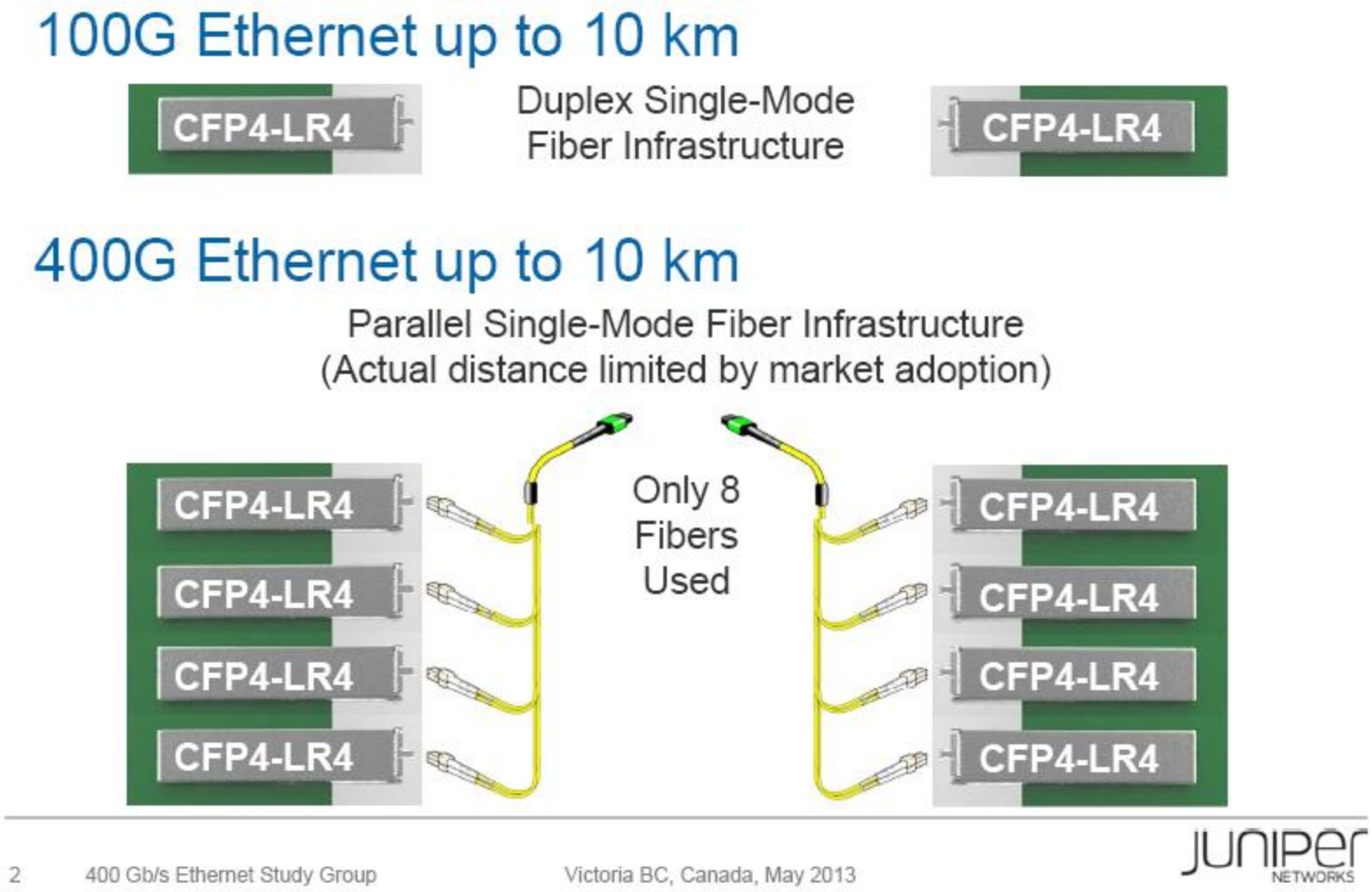


Gen1 400G SMF: LR4x4 4x CFP4

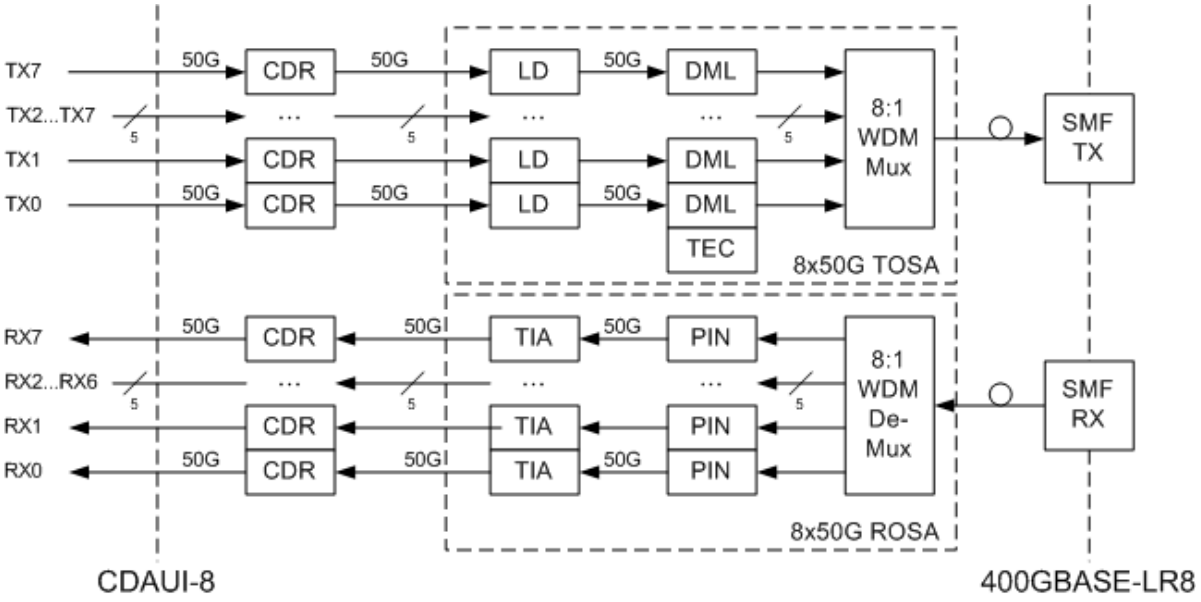


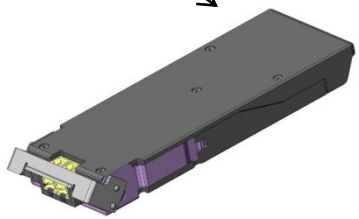
Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
		4	4	
	25			25
16				
400		400		

Gen1 400G SMF: LR4x4 4x CFP4



Gen2 400G SMF: LR8 CFP2





LR4 Alternative:

4:1 WDM with Higher Order Modulation

Electric I/O		Optical I/O		
pin pair	Gb/s	fiber pair	λ	Gb/s
		1		
			8	
8				
	50			50
400		400		

What's After 400G?

- 1Tb/s Ethernet
  - Has been extensively discussed
  - Vestige of 10x historical Ethernet speed jumps
  - Will require huge R&D investment
  - 2.5x speed increase from 400G is not compelling
- 1.6Tb/s Ethernet
  - 4x speed increase reasonable return on R&D $
  - More likely future speed jumps
  - Similar to historical Transport speed jumps
  - Gen1 can use 4x 400G architecture

Summary

- 10G
  - Duplex LC NRZ MMF and SMF
  - Pluggable Transceivers
- 40G and 100G
  - Parallel MPO MMF
  - Duplex LC WDM SMF
  - Multi-link modules with break-out cables
  - Board Mounted Optics
- Future 40G, 100G, 400G and 1.6T
  - Faster lane rates
  - Parallel MPO SMF
  - Higher Order Modulation (w/ WDM)

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