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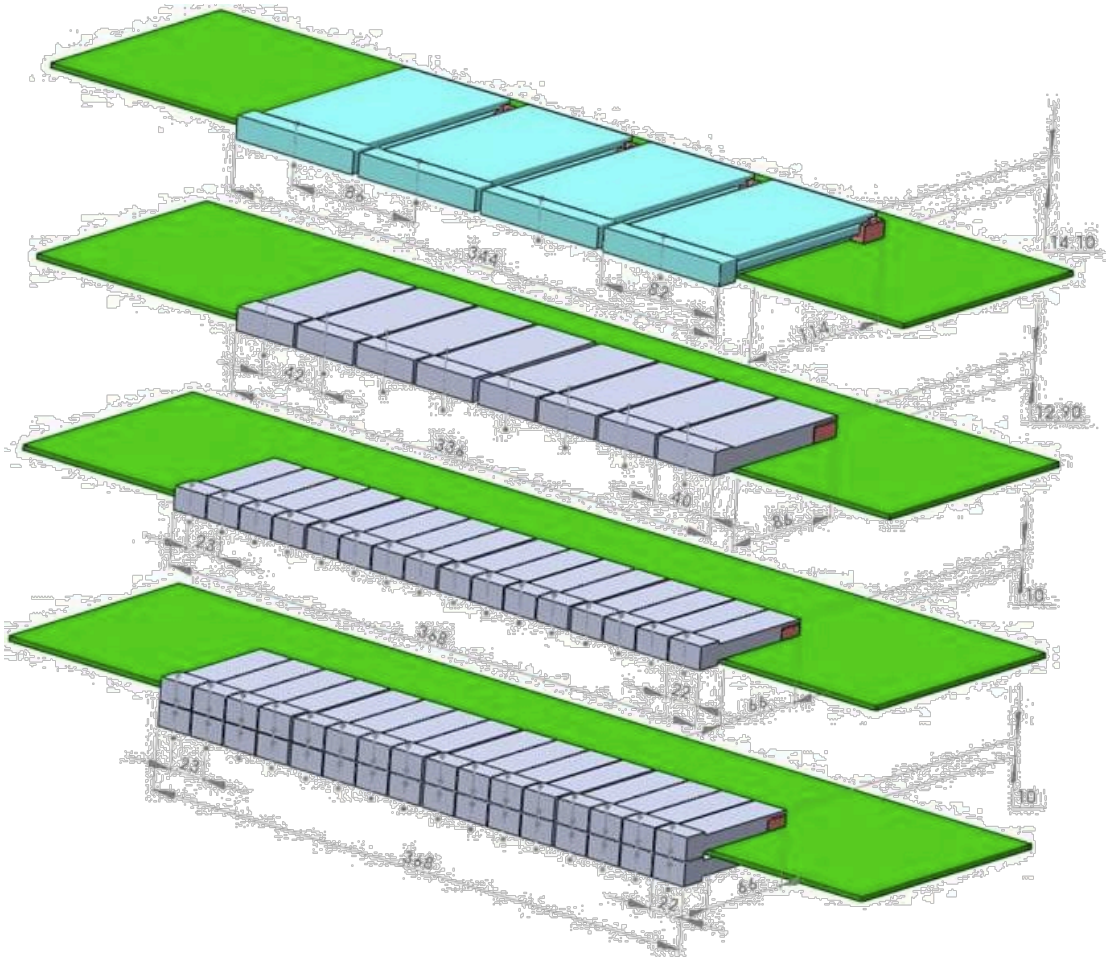


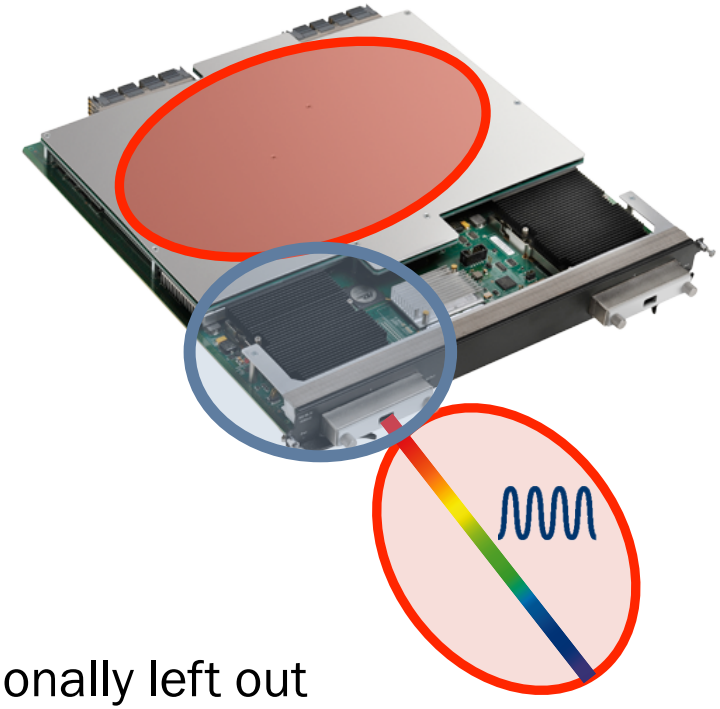
100 GBE AND BEYOND

Greg Hankins <ghankins@brocade.com>

NANOG52

Diagram courtesy of the CFP MSA.

Agenda and What's Covered in This Presentation



- Ethernet interface technology
  - Overview
  - 28 Gbps Common Electrical Interfaces (CEI)
  - New 100 Gbps Media Modules
  - 100 GbE Developments
  - Beyond 100 GbE…
- Optical technology developments are intentionally left out
  - Go see Drew Perkins' talk tomorrow morning:

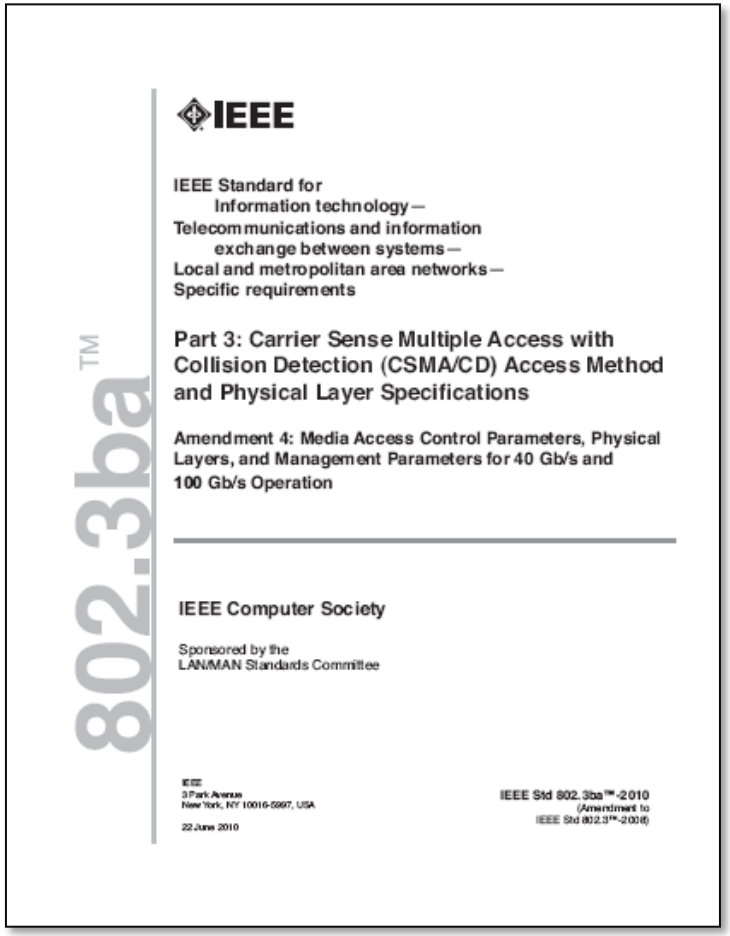
  "Dawn of the Terabit Age: Scaling Optical Capacity to Meet Internet Demand"
- Skipping router packet processing, lookup capabilities and memory architectures
  - Wire-speed 100 GbE is ~149 Mpps, or one packet every 6.7 ns at 64 byte frames
  - Maybe a topic for the next NANOG?

Standards Organizations and You, Revisited

Name	Primary Role (in Context of this Presentation)	Primary Players
Customers	Buy Your Services	
You	*Run Networks*	
Hardware Vendors	Make Equipment	
MEF METRO ETHERNET FORUM	Ethernet Service Definitions, Standards and Certification	Hardware Vendors, Network Operators
IETF	Higher Layer Protocol Standards	Hardware Vendors, Network Operators
IEEE	Ethernet Standards (802.1, 802.3)	Component and Hardware Vendors
incits	Fibre Channel Standards (T11)	
ITU International Telecommunication Union	Telecom Standards (SG15)	
10X10 MSA	Optical Module Standards	Component and Hardware Vendors, Network Operators
CFP SFF Committee	Media Module Standards	Component and Hardware Vendors
OIF OPTICAL INTERNETWORKING FORUM	Component Interface Standards	Component and Hardware Vendors

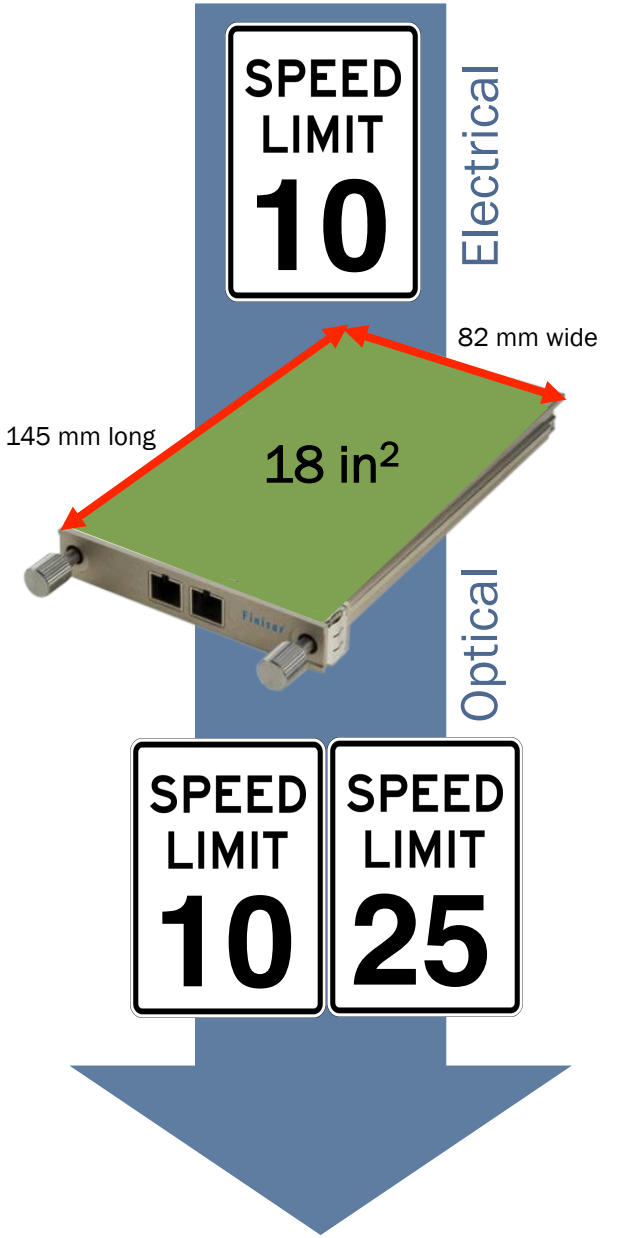
Current State of the Industry

- There is already demand for other interfaces beyond the scope of IEEE 802.3ba (June 2010)
- Standard defines a flexible architecture that enables many implementations as technology changes
- New 40 GbE and 100 GbE standards are in progress
  - IEEE 802.3bg defined a 40 GbE serial interface to OTU3/STM-256/OC-768
  - The 2nd generation of 100 GbE will use 4 x 25 Gbps electrical and optical signaling



Current State of the Industry

- Fundamental 1st generation technology constraints limits higher 100 GbE density and lower cost
- Electrical signaling inside the box
  - 100 Gbps Attachment Unit Interface (CAUI) uses 10 x 10 Gbps
- Optical signaling outside the box
  - 10x10 MSA: 10 x 10 Gbps
  - 100GBASE-LR4 and 100GBASE-ER4: 4 x 25 Gbps
- CFP module size and power consumption

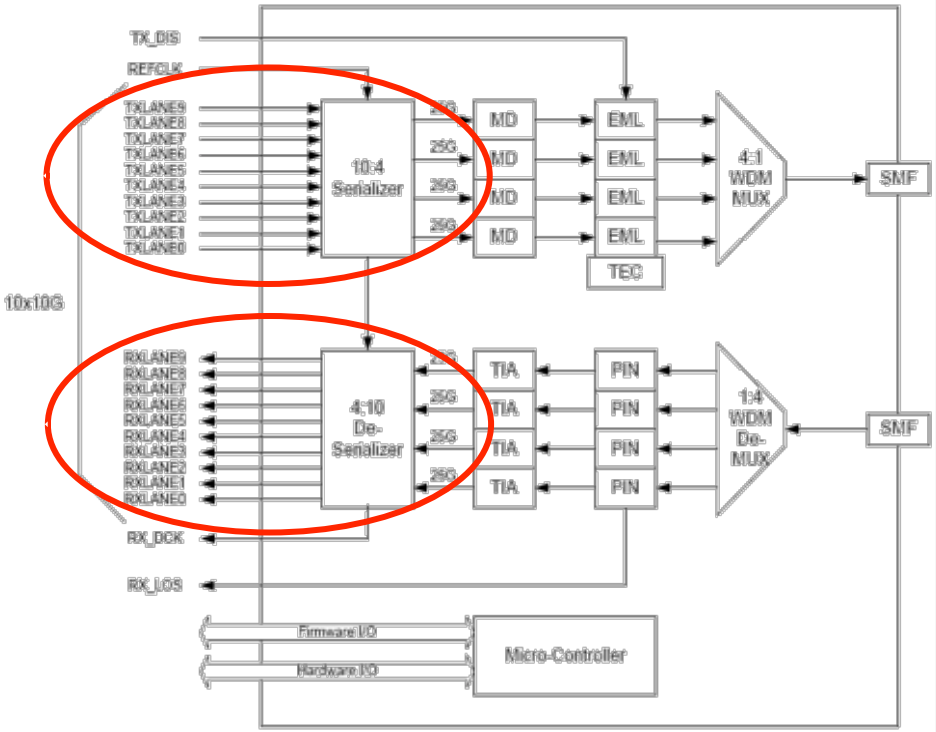


CFP image courtesy of Finisar.

1st Generation vs 2nd Generation 100 GbE

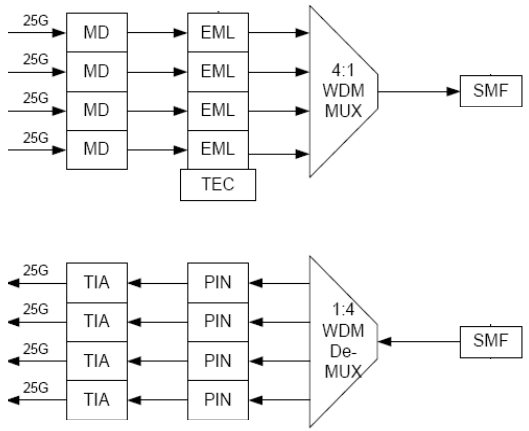
2nd Generation 100 GbE Needs Faster Electrical Signaling

1st Generation 10 x 10 Gbps



10 Gbps Electrical Signaling and 10:4 Gearbox Adds Complexity, Cost, Space, Power…

2nd Generation 4 x 25 Gbps

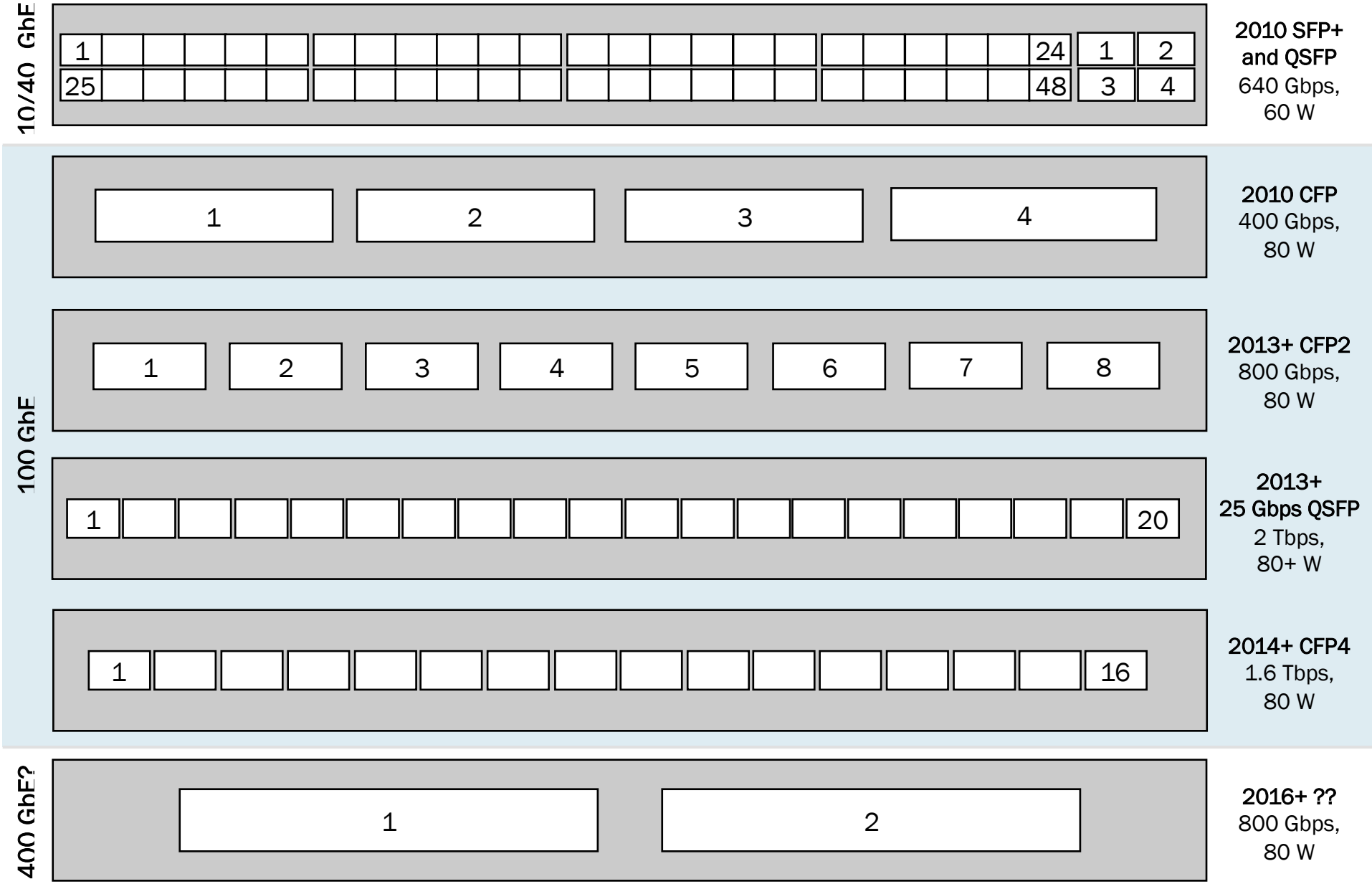


25 Gbps Electrical and Optical Signaling

Source: http://grouper.ieee.org/groups/802/3/ba/public/jul08/cole_03_0708.pdf

Front Panel Interface Density Trends

Module Form Factor, Throughput and Power



Key Industry Initiatives in 2011

Developing Technology for 2nd Generation 100 GbE

IEEE	100 Gbps Backplane and Copper Study Group
	100 Gbps Interfaces Using 4 x 25 Gbps Electrical Signaling
	Ethernet Bandwidth Assessment Ad Hoc
10X10 MSA	Lower Cost 10 x 10 Gbps Optical Modules
CFP **SFF Committee**	Next Generation Pluggable Media Module Form Factors
OIF OPTICAL INTERNETWORKING FORUM	28 Gbps Electrical Interfaces

Agenda

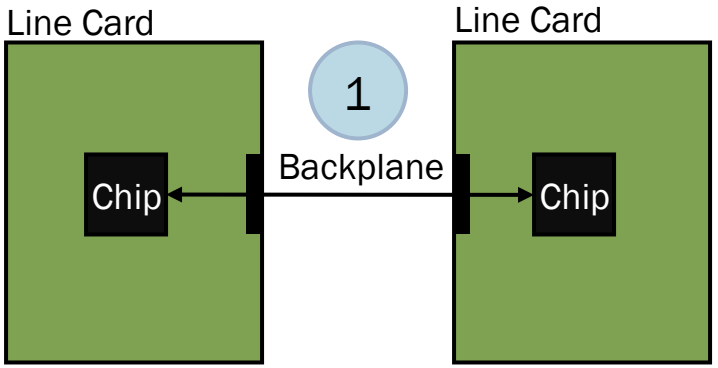
- Overview
- 28 Gbps Common Electrical Interfaces (CEI)
- New 100 Gbps Media Modules
- 100 GbE Developments
- Beyond 100 GbE…

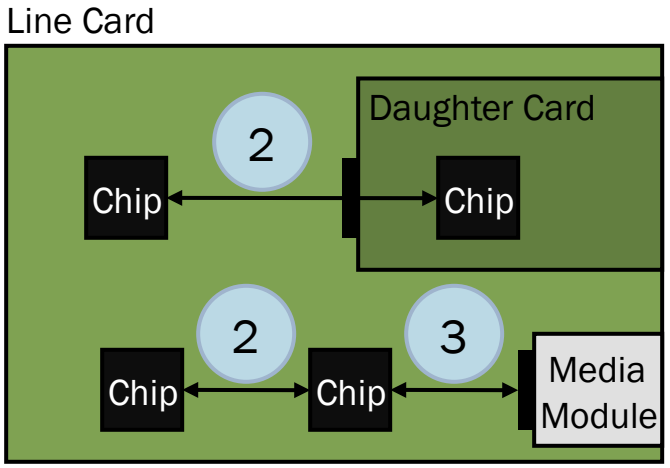
28 Gbps Common Electrical Interfaces (CEI)

- OIF is doing fundamental work on 28 Gbps electrical signaling which will make newer interfaces and pluggable media modules possible
- Lower power, Very Short Reach (VSR) 4" interfaces are being defined for several new applications
  - 1 lane for 32 Gbps Fibre Channel at 28.05 Gbps
  - 4 lanes for 100 GbE at 25.78125 Gbps
  - 16 lanes for 400 GbE at 25.78125 Gbps?
- CEI-28G-VSR is approaching technical stability, and is expected to be finished in January 2012

25 Gbps and 28 Gbps Common Electrical Interfaces (CEI)

1. Backplane: CEI-25G-LR – 30”
2. Chip to chip: CEI-28G-SR – 12”
3. Chip to module: CEI-28G-VSR – 4”
   (used by 2nd generation 100 GbE media modules)





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10 Gbps Module Review – 3 Generations of 10 GbE Over 7 Years

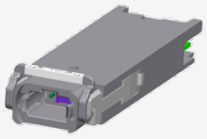
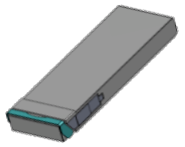
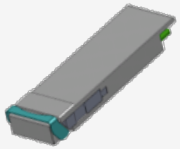
Each Module Increased Density, While Reducing Cost and Power

	1st Generation	2nd Generation			3rd Generation	
Module Name (Images not to Scale)	 300PIN MSA	 XENPAK	 XPAK	 X2	 XFP	 SFP+
Approximate Module Dimensions (Length x Width to Scale)						
Front Panel Density	1	4	8	8	16	48
Electrical Interface	XSBI	XAUI	XAUI	XAUI	XFI	SFI
Electrical Signaling	16 x 644 Mbps	4 x 3.125 Gbps	4 x 3.125 Gbps	4 x 3.125 Gbps	1 x 10.3125 Gbps	1 x 10.3125 Gbps
Release Year	2002	2003	2004	2004	2006	2009

Module images courtesy of Finisar.

100 Gbps Module Evolution

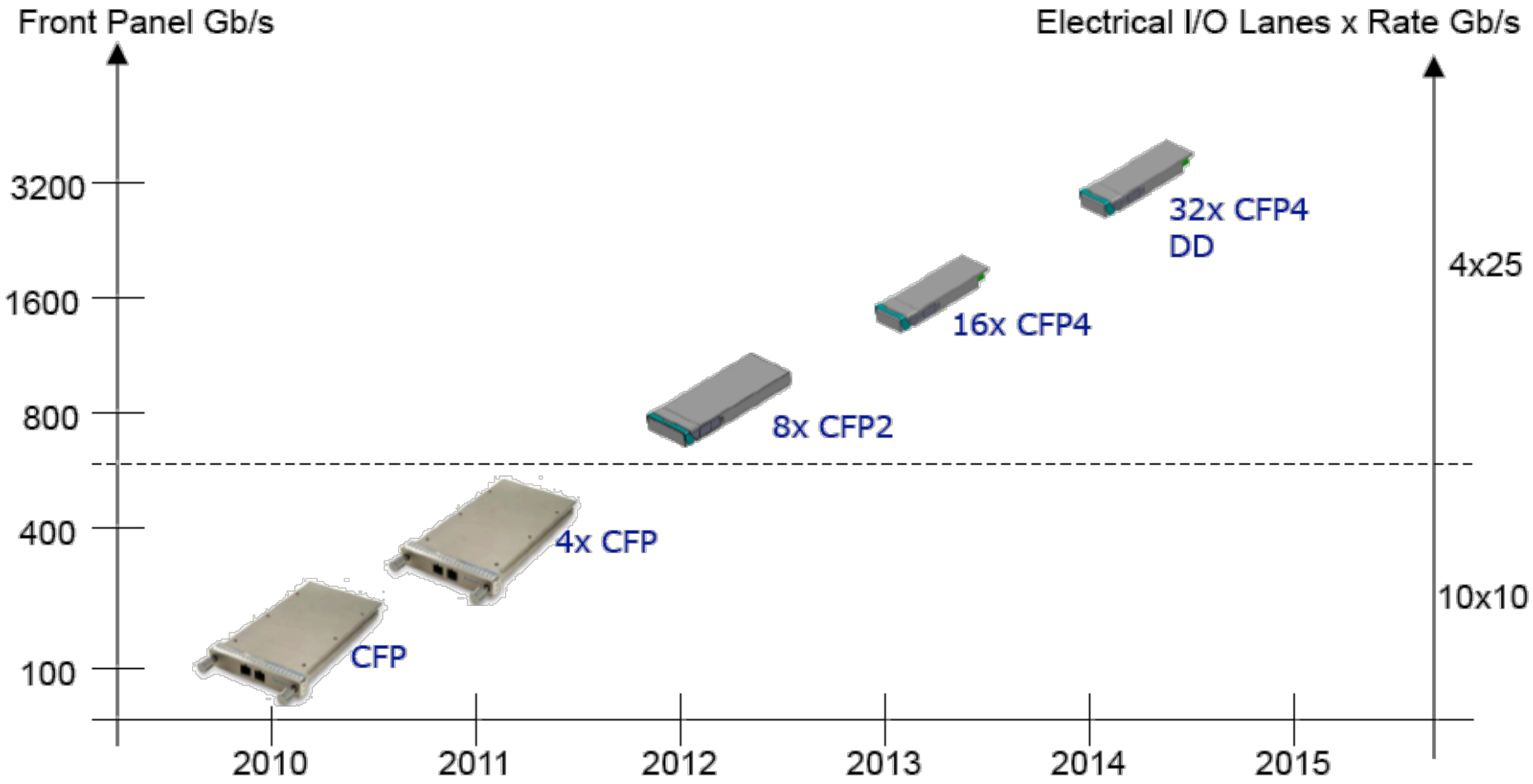
Two Generations of 100 GbE Expected to Take 5 Years

	1st Generation		2nd Generation		
Module Name (Images not to Scale)	 CFP	 CXP	 25 Gbps QSFP	 CFP2	 CFP4
Approximate Module Dimensions (Length x Width to Scale)					
Front Panel Density	4	16	22 - 44	8	16 - 32
Electrical Interface	CAUI	CPPI	CPPI-4	CAUI-4	CPPI-4
Electrical Signaling (Gbps)	10 x 10	10 x 10	4 x 25	4 x 25	4 x 25
Media Type	SMF	Twinax, MMF	MMF/SMF?	SMF	SMF
Advantages	Long Reach, High Power Dissipation	Small Size, Designed for Passive Cabling	Highest Density, Established Form Factor	Long Reach, Higher Density	Highest Density, Smaller Size,
Disadvantages	Too Big	Short Reach, Too Small	Limited Power Dissipation and Reach	Bigger Size	Unproven Form Factor (vs. QSFP)
Availability *(Subject to Change)*	2010	2010	2011 (InfiniBand) 2013+ (Ethernet)	2013+	2014+

CFP and CXP images courtesy of Finisar, QSFP image courtesy of the SFF Committee, SFP2 and SFP4 images courtesy of the CFP MSA.

100 Gbps CFP Module Evolution

Module Form Factor vs. Front Panel Density



Source: http://www.cfp-msa.org/Documents/CFP_MSA_baseline_specifications.pdf

100 Gbps Module Evolution

Graphical View of Module Form Factors

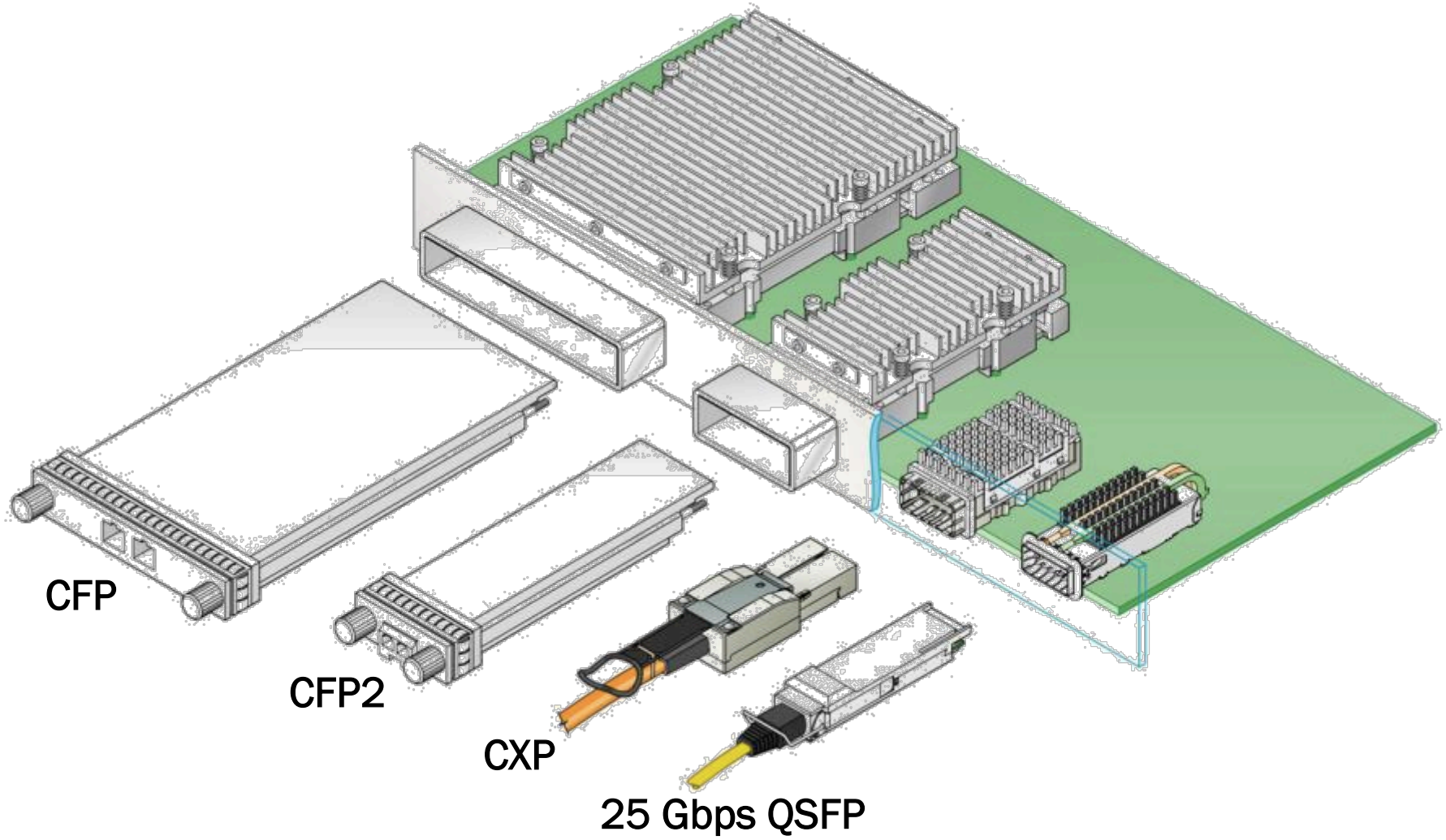
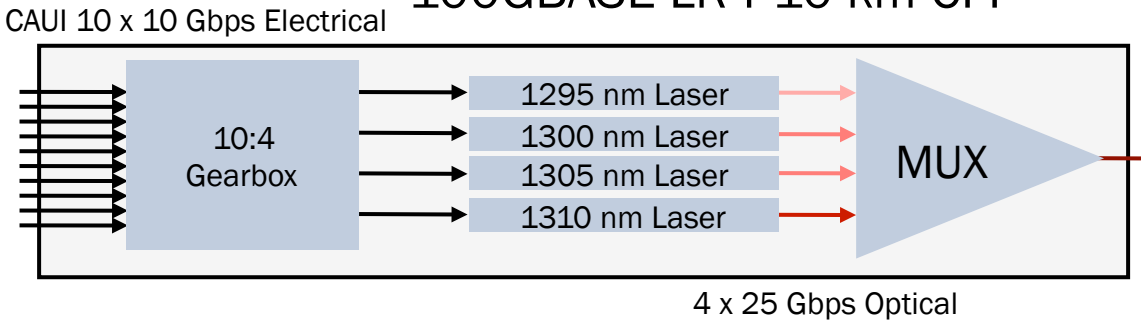


Diagram courtesy of Molex.

100 GbE Module Technologies Compared

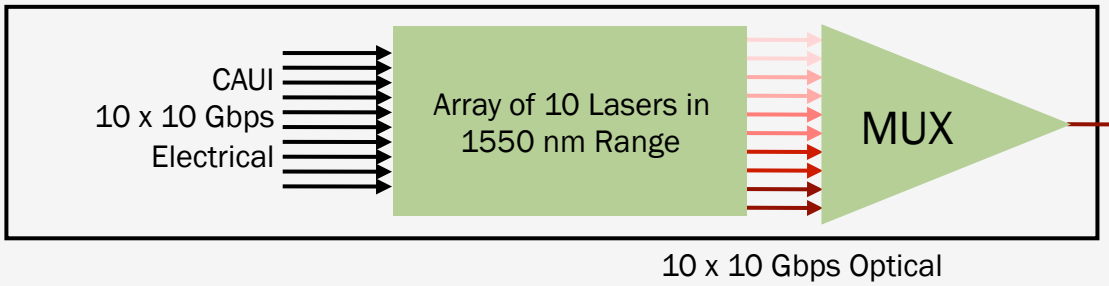
Transmit Side of Module

100GBASE-LR4 10 km CFP



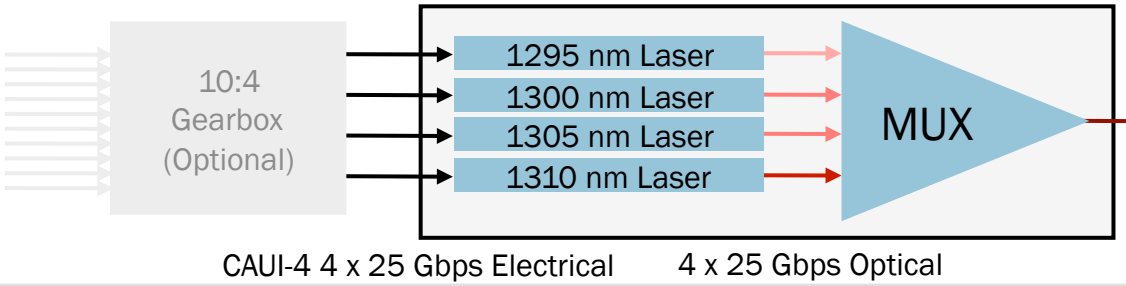
- Most expensive, complex and uses the most power
- Gearbox converts 10 x10 Gbps electrical signaling into 4 x 25 Gbps signaling

10x10 MSA 2 km, 10 km, 40 km CFP



- Less cost, complexity and power consumption
- Uses 10 x 10 Gbps electrical and optical signaling
- Doesn't need the gearbox

100GBASE-LR4 10 km CFP2



- Lower cost, complexity and power consumption
- Uses 25 Gbps electrical and optical signaling
- Doesn't need the gearbox

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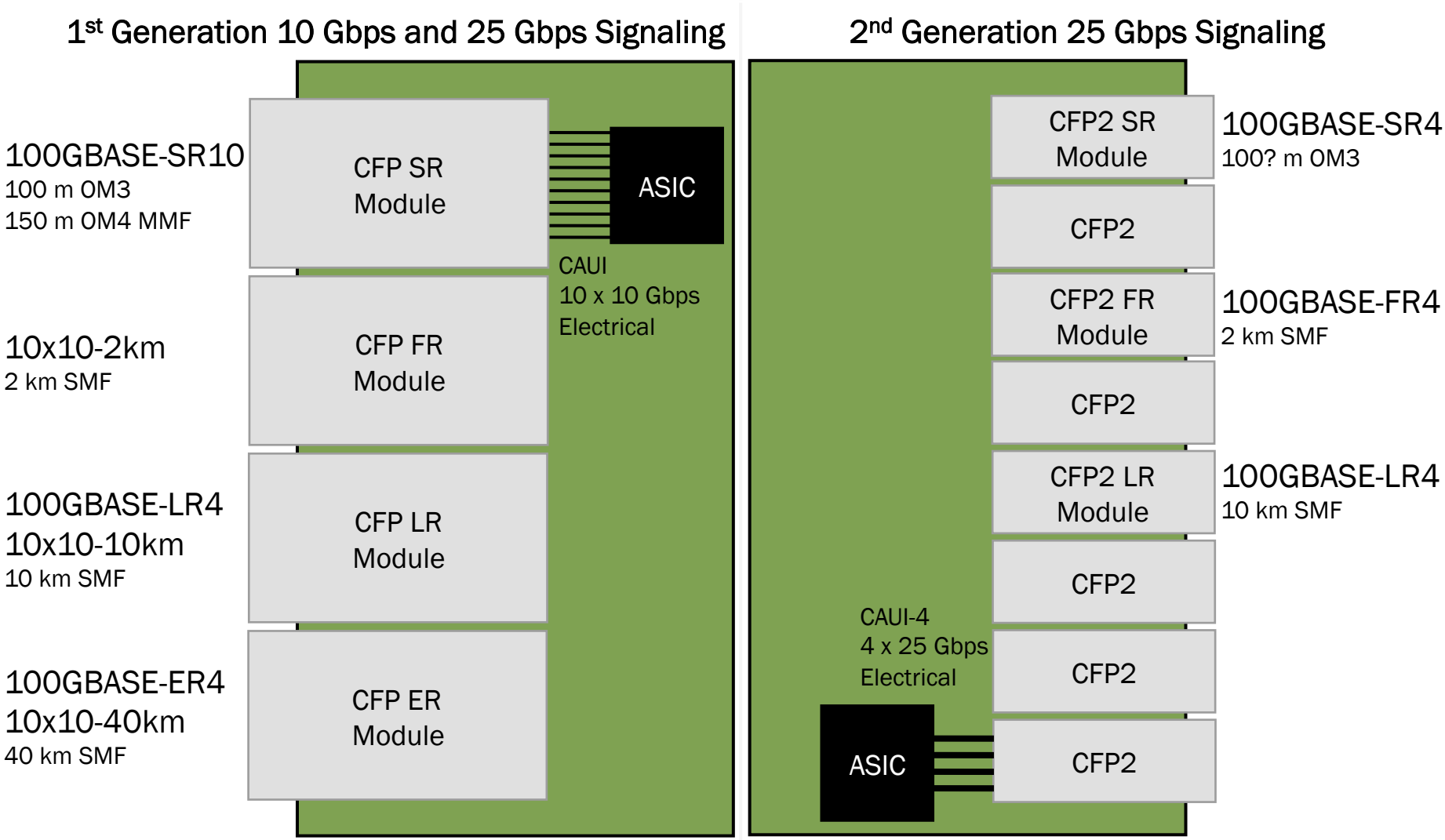
Recent 100 GbE Developments

- 2nd generation projects based on 4 x 25 Gbps electrical signaling have started
- New IEEE Copper Study Group was approved in November, 2010
  - 100GBASE-KR4: 4 x 25 Gbps over backplane
  - 100GBASE-CR4: 4 x 25 Gbps over copper cable
  - http://www.ieee802.org/3/100GCU/index.html

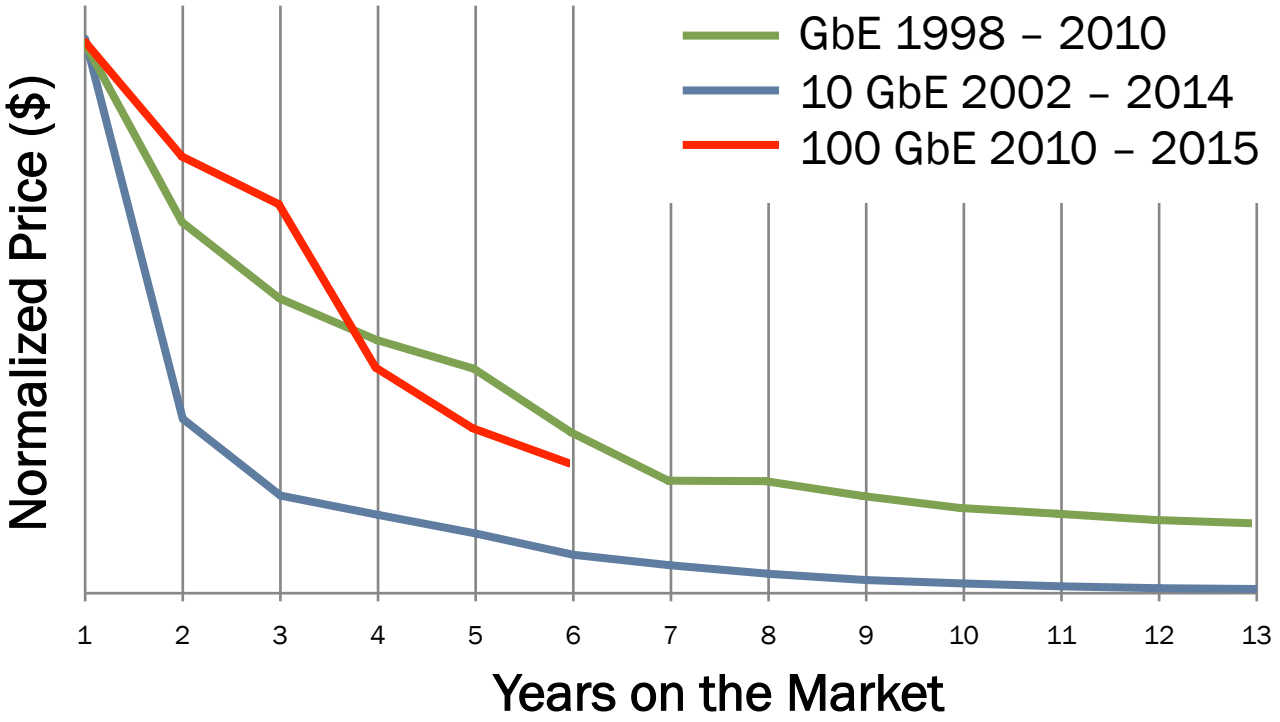
Recent 100 GbE Developments

- 10x10 MSA is growing and working on several projects
  - Up to 25 members including AMS-IX, Facebook and Google
  - Finishing 10x10-10km and 10x10-40km standards, expected to be approved in July, 2011
  - Investigating muxing 8 bands of 40 km links to carry 8 x 100 Gbps over a single fiber pair
- IEEE is expected to start work in July, 2011 to define new interfaces that are expected to be available in 2013+
  - 100GBASE-SR4: 4 x 25 Gbps over OM3 MMF
  - 100GBASE-FR4: 4 x 25 Gbps over SMF for 500 m – 2 km
  - CAUI-4: electrical signaling to the CFP2
  - CPPI-4: electrical signaling to the 25 Gbps QSFP and CFP4
  - 25 Gbps QSFP and CFP2/4 will be competing for the highest front panel density

Putting it All Together – 100 GbE Line Card Architectures



Ethernet Average Selling Price (ASP) Trends



- Prices of previous Ethernet generations fell significantly during the first few years on the market
- Already seeing a similar trend as 1st generation 100 GbE volume increases, expect 2nd generation 100 GbE to deliver significantly lower prices

Data sources: Dell'Oro and Infonetics

100 GbE Technology Summary

1st Generation IEEE
1st Generation 10x10 MSA
2nd Generation IEEE

Physical Layer Reach	*1?* m Back-plane	*5+?* m Copper Cable	7 m Copper Cable	*100?* m OM3 MMF	100 m OM3, 150 m OM4 MMF	2 km SMF		10 km SMF		40 km SMF	
Name	100GBASE -KR4	100GBASE -CR4	100GBASE -CR10	100GBASE -SR4	100GBASE -SR10	10x10-2km	100GBASE -FR4	10x10-10k m	100GBASE -LR4	10x10-40k m	100GBASE -ER4
Standard Status	Possible Future IEEE	Possible Future IEEE	2010 IEEE 802.3ba	Possible Future IEEE	2010 IEEE 802.3ba	2011 10x10 MSA	Possible Future IEEE	Future 10x10 MSA	2010 IEEE 802.3ba	Future 10x10 MSA	2010 IEEE 802.3ba
Generation	2nd	2nd	1st	2nd	1st	1st	2nd	1st	1st	1st	1st
Electrical Signaling (Gbps)	4 x 25	4 x 25	10 x 10	4 x 25	10 x 10	10 x 10	4 x 25	10 x 10	10 x 10	10 x 10	10 x 10
Media Signaling (Gbps)	4 x 25	4 x 25	10 x 10	4 x 25	10 x 10	10 x 10	4 x 25	10 x 10	4 x 25	10 x 10	4 x 25
Media Type	Backplane	Twinax	Twinax	MPO MMF	MPO MMF	Duplex SMF	Duplex SMF	Duplex SMF	Duplex SMF	Duplex SMF	Duplex SMF
Media Module	Backplane	25 Gbps QSFP, CFP2, CFP4	CXP	25 Gbps QSFP, CFP2, CFP4	CXP, CFP	CFP	25 Gbps QSFP, CFP2, CFP4	CFP	CFP	CFP	CFP
Availability	2013+	2013+	2010	2013+	2010	Q1 2011	2013+	Q3 2011	2010 (CFP2 in 2013+)	Q3 2011	2012

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Bandwidth Requirements Projection

All Solutions are Good, Fast, or Cheap – Pick Any Two

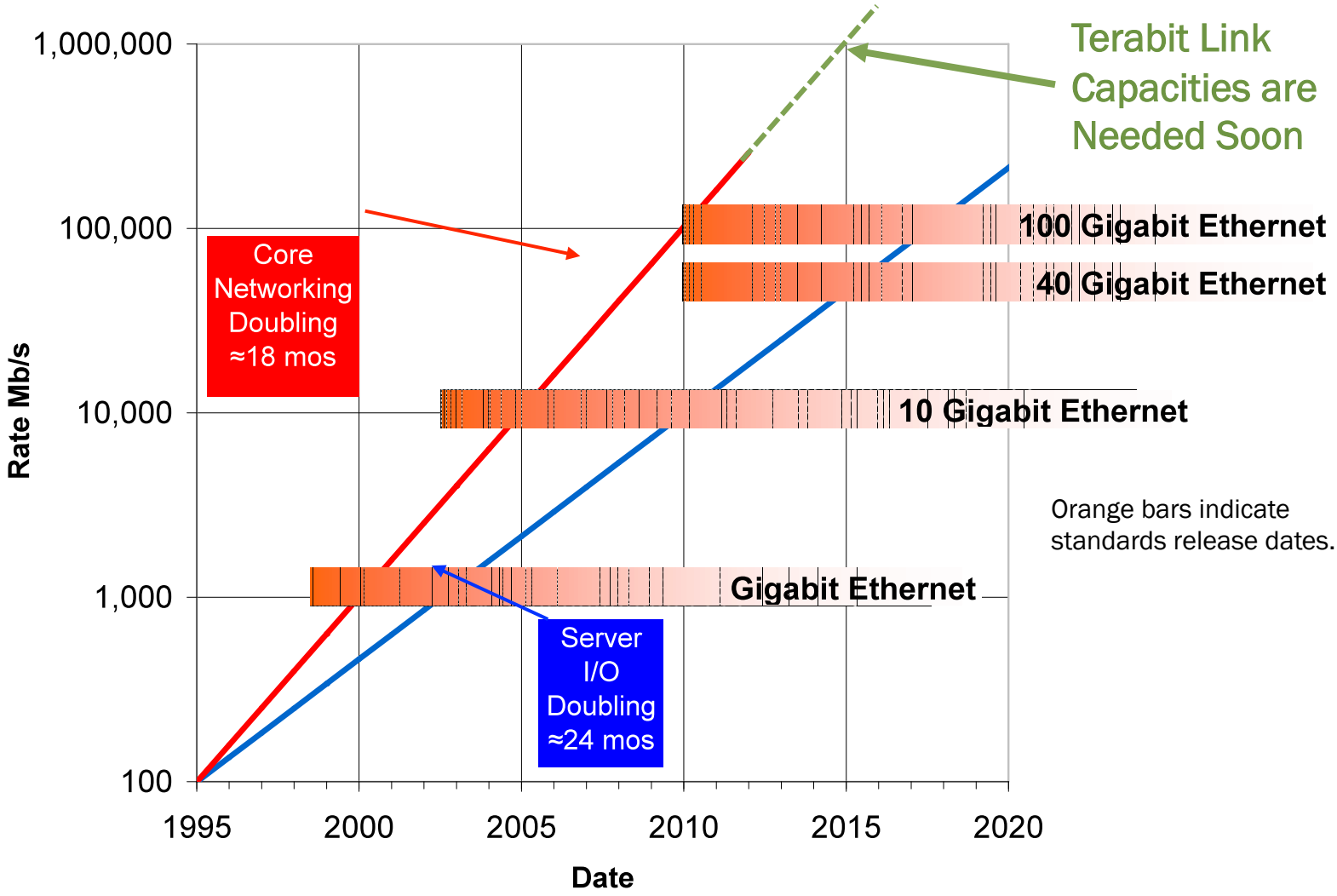
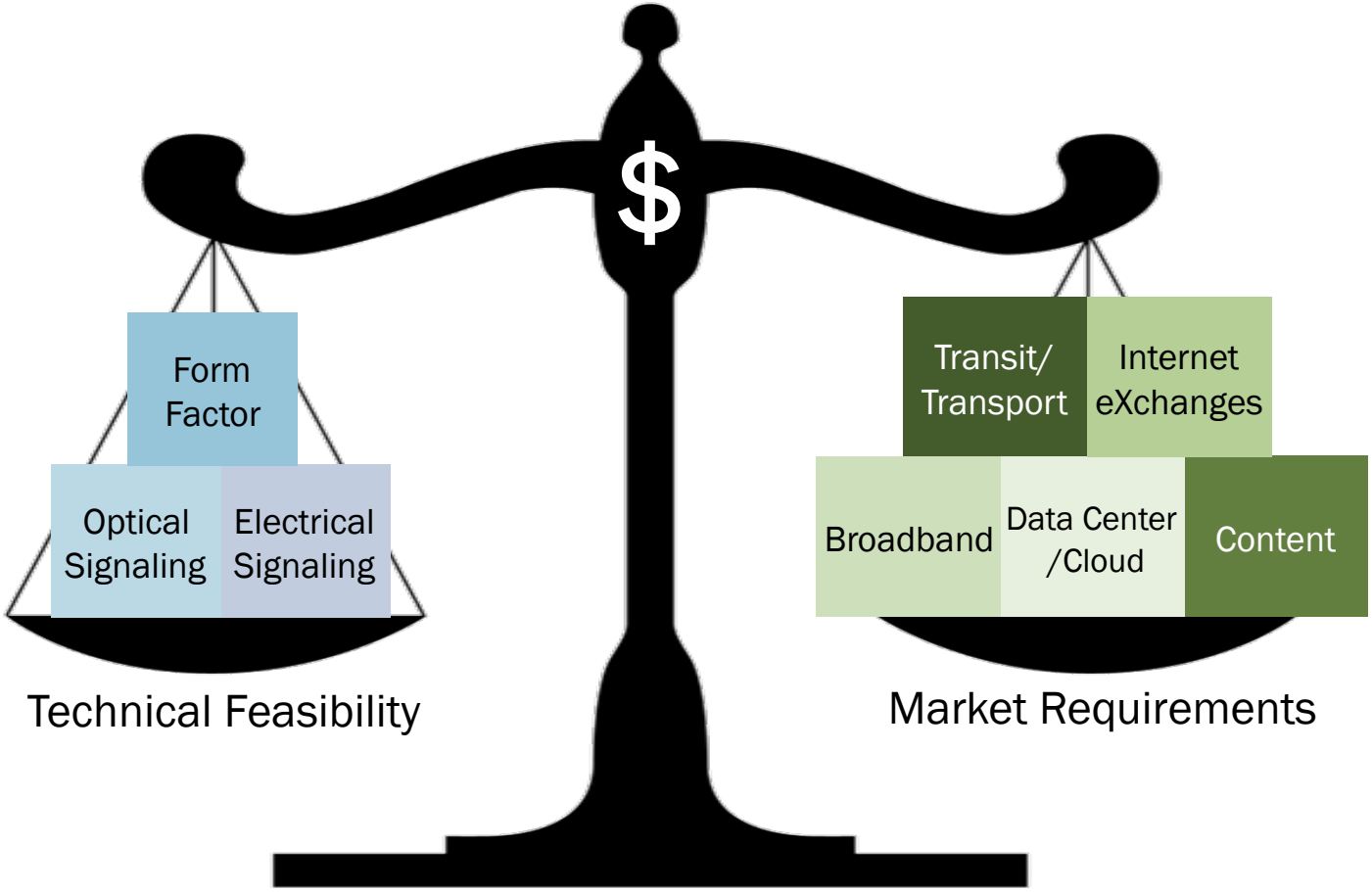


Diagram source: http://www.ieee802.org/3/hssg/public/nov07/HSSG_Tutorial_1107.zip

Beyond 100 GbE: Industry Challenges

2nd Generation 100 GbE and Higher Speeds



Economics Dictate the Solution

IEEE Provides an Open Industry Forum to Make Decisions

IEEE Ethernet Standards Timelines

- 8 years between 10 GbE and 100 GbE standards
- We need to start immediately in order to finish a new Ethernet speed standard by 2016

Diagram source: http://www.euro-ix.net/download/48/948

IEEE Ethernet Bandwidth Assessment Ad Hoc

- Laying groundwork and investigating industry interest for the next Ethernet speed
  - Evaluate Ethernet wireline bandwidth requirements
  - Provide data and reference material to the IEEE
  - Gather information only, will not make a recommendation
- Web page:

  http://www.ieee802.org/3/ad_hoc/bwa/index.html
- Mailing list:

  http://www.ieee802.org/3/ad_hoc/bwa/reflector.html

IEEE Ethernet Bandwidth Assessment Ad Hoc

- Network operator input is needed on future requirements
  - Speed, density, distance, cost, topology, anything really
- Presentations can be given on conference calls or at meetings, schedule is opportunistic
- Please get involved… this means ***you***!!
- Request for data :

  http://www.ieee802.org/3/ad_hoc/bwa/public/anslow_01a_0411.pdf
- Ad Hoc Chair contact:

  John D'Ambrosia, <jdambrosia@ieee.org>

Future 100 GbE Projects

- In the short term, 4 x 25 Gbps electrical and optical interfaces will keep the IEEE 802.3 Working Group busy for 2+ years
- 100 GbE serial is still not feasible in the near future
  - 25 Gbps signaling is challenging
  - We'll get a better idea of what is possible as 25 Gbps technology matures
- 3rd generation 100 GbE is likely to be developed several years from now

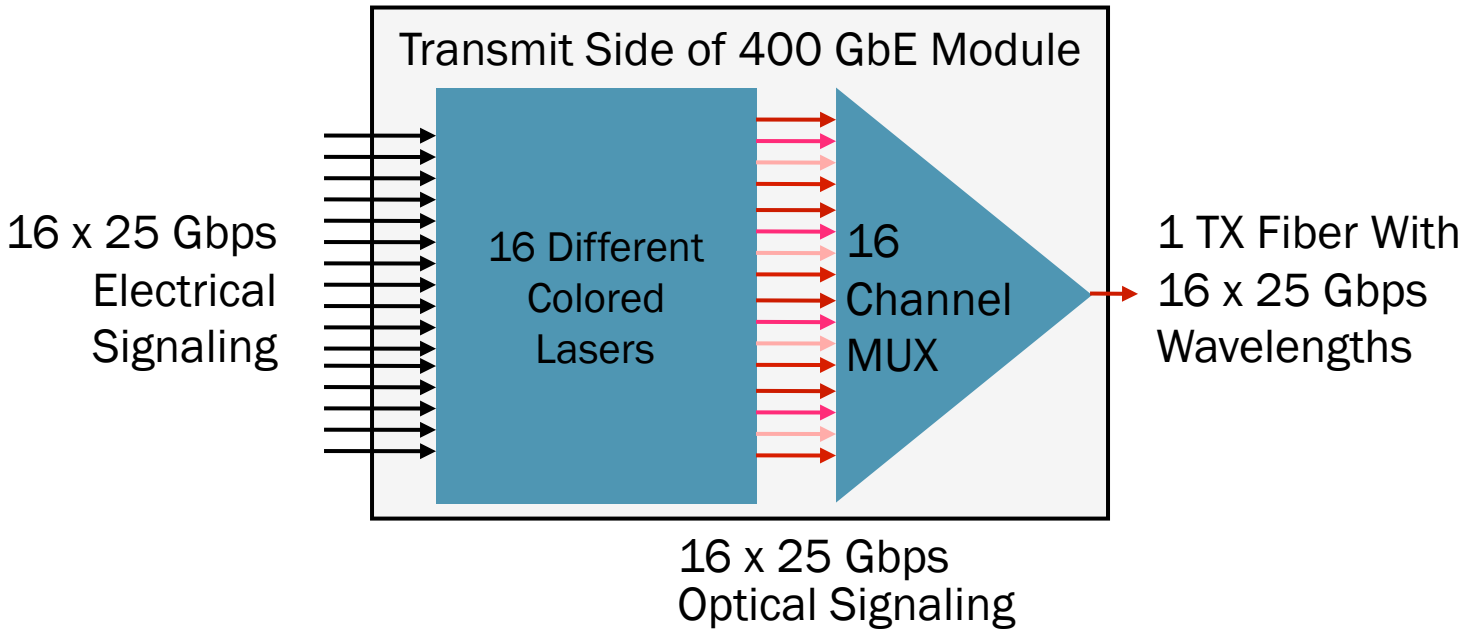
Next Higher Speed Ethernet

250 GbE, 300 GbE, 400 GbE, or TbE?

- Using 10 x 25 Gbps signaling the next speed could be 250 GbE
  - The industry wants a larger jump
- 12 x 25 Gbps signaling matches the number of fibers in a high density MMF cable for 300 GbE
  - Unpopular too
- The likely candidate for the next speed is 400 GbE using 16 x 25 Gbps signaling
  - 16 x 25 Gbps wavelengths can be easily muxed/demuxed onto one SMF
  - MMF solutions would need 32 fibers in a high density cable MPO/MTP assembly
  - Evolution to 10 x 40 Gbps signaling
- TbE is simply impractical in the near future
  - 40 x 25 Gbps lanes in and 40 x 25 Gbps lanes out would make a gigantic media module
  - 40 Gbps serial lanes aren't expected to be economical until after 2016, and will take considerable work as electrical losses grow exponentially with super high frequency signaling

400 GbE Module

- The 400 GbE module could be 16 channels wide and would be larger than the current 100 GbE CFP



Summary

- The 1st generation of 100 GbE uses 10x10 Gbps electrical lanes and large CFP media modules
- The 2nd generation of 100 GbE will use 4x25 Gbps electrical lanes and smaller CFP2/CFP4/25 Gbps QSFP modules
- Industry is working on 2nd generation 100 GbE for the next few years
- 400 GbE work may start in 2013+ and could finish by 2016+
- TbE is currently technically and economically unfeasible until 40 Gbps electrical lanes are defined after 2013 with a possible standard following many years later

BROCADE

Questions?