100 Gbps/λ vs. 50 Gbps/λ : Cost and Power Comparisons in Silicon Photonics

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Caveats and Disclaimers

- **This presentations is** a comparison of cost for different 400 Gbps proposed solutions.
- **This presentation assumes** as solutions ship at the same (high) volumes
- **This presentation assumes** a silicon photonics technology is used
- **This presentation does not** assume development costs are heavily amortized into per unit costs

Comparisons

- Investigates silicon photonics solutions for the different 500m and 2km objective proposals

  - 400G-PSM4 @ 1λx4x50GBD-PAM4
  - 400G-PSM4 @ 2λx8x25GBD-PAM4
  - 400G-PSM4 @ 2λx8x50GBD-NRZ
  - 400G-FR4 @ 4λx4x100GBD-PAM4
  - 400G-FR8 @ 8λx8x25GBD-PAM4
  - 400G-FR8 @ 8λx8x50GBD-NRZ

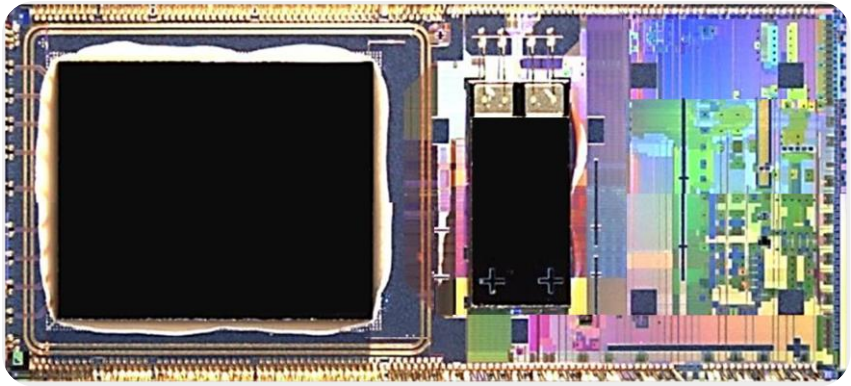
Cost Modeling

Methodology

- Employs the transceiver cost modeling methodology first employed in welch_01b_0113_optx.pdf
  - COGS build up from silicon photonics chipset
- Solutions compared to 100G-PSM4
- Assuming a CDAUI-8 electrical interface for all solutions
- Parametric yield effects not considered

Baseline – 100G-PSM4

Chipset



Photonics IC	68 mm^2
Electronics IC	17 mm^2
Light Source(s)	1
Chipset COGS	1

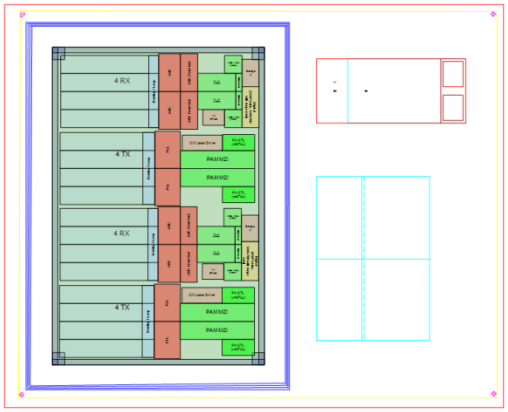
Module

Chipset COGS	1
Optical Attaches	2
Yield per Attach	95%
Net Yield	90%
Module COGS†	1

† Renormalized with packaging and transformation costs applied

400G-PSM4: 1λx4x50GBD-PAM4

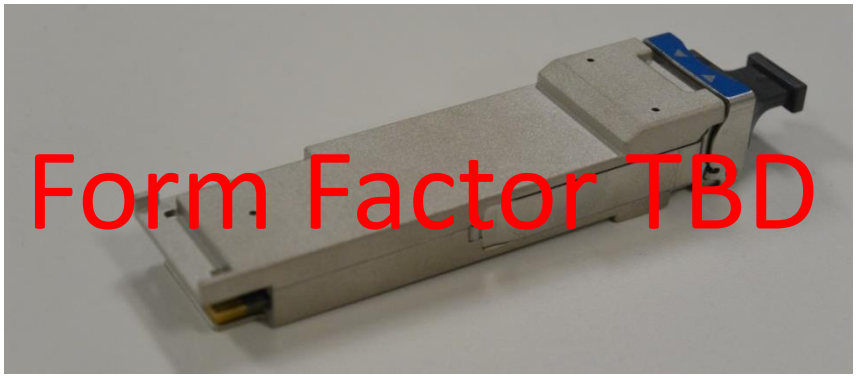
Chipset



Photonics IC	102 mm^2
Electronics IC	34 mm^2
Light Source(s)	1
Chipset COGS	1.5 - 1.7‡

‡ Range reflects potential for increased light source cost due to more stringent TX specifications

Module

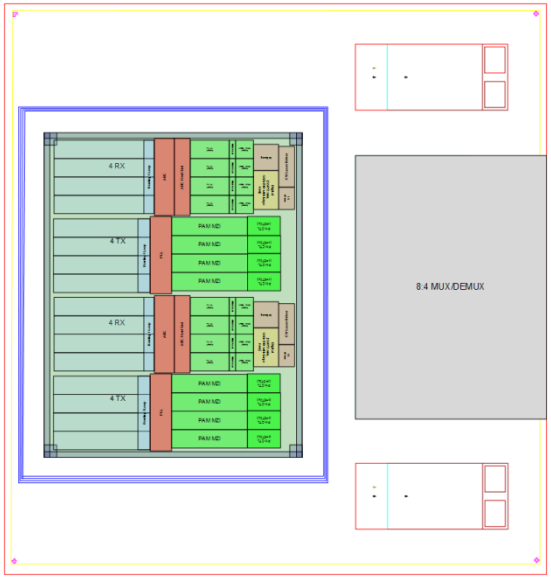


Chipset COGS	1.5-1.7
Optical Attaches	2
Yield per Attach	95%
Net Yield	90%
Module COGS†	1.3 – 1.6‡

† Renormalized with packaging and transformation costs applied

400G-PSM4: 2λx8x25GBD-PAM4

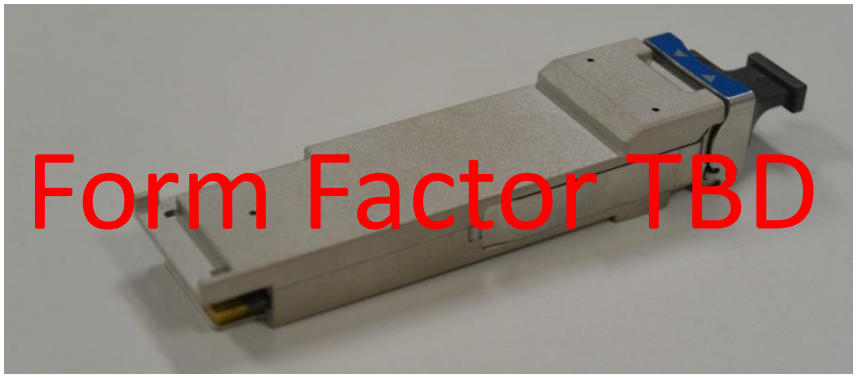
Chipset



Photonics IC	148 mm^2
Electronics IC	40 mm^2
Light Source(s)	2
8:4 WDM MUX/Demux	1
Chipset COGS	2.9-3.4‡

‡ Range reflects potential for increased light source cost due to more stringent TX specifications

Module

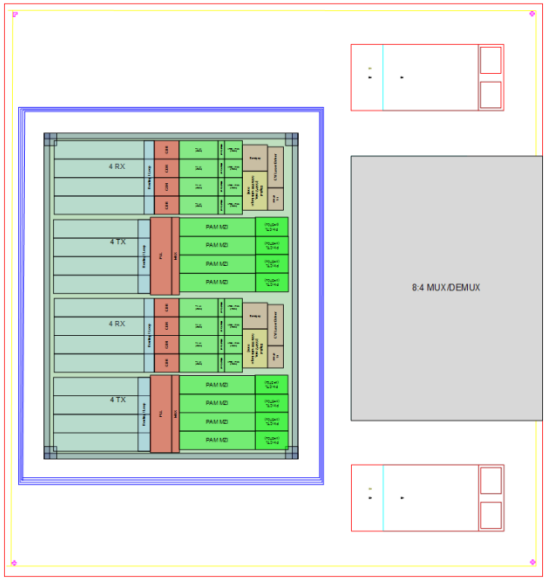


Chipset COGS	2.9-3.4
Optical Attaches	3
Yield per Attach	95%
Net Yield	86%
Module COGS†	3 – 3.6‡

† Renormalized with packaging and transformation costs applied

400G-PSM4: 2λx8x50GBD-NRZ

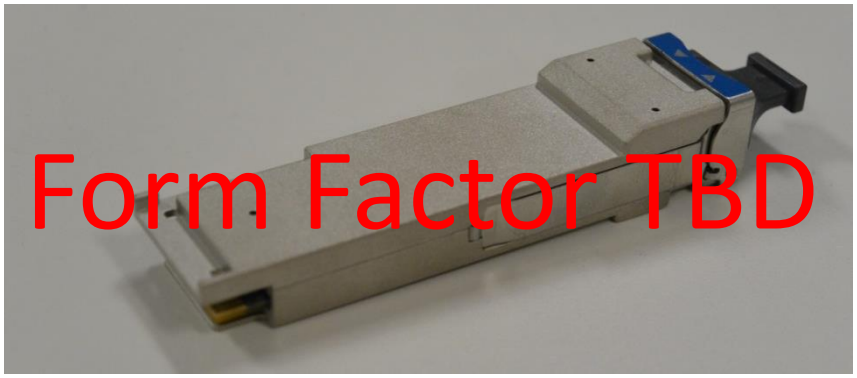
Chipset



Photonics IC	148 mm^2
Electronics IC	40 mm^2
Light Source(s)	2
8:4 WDM MUX/Demux	1
Chipset COGS	2.9-3.4‡

‡ Range reflects potential for increased light source cost due to more stringent TX specifications

Module

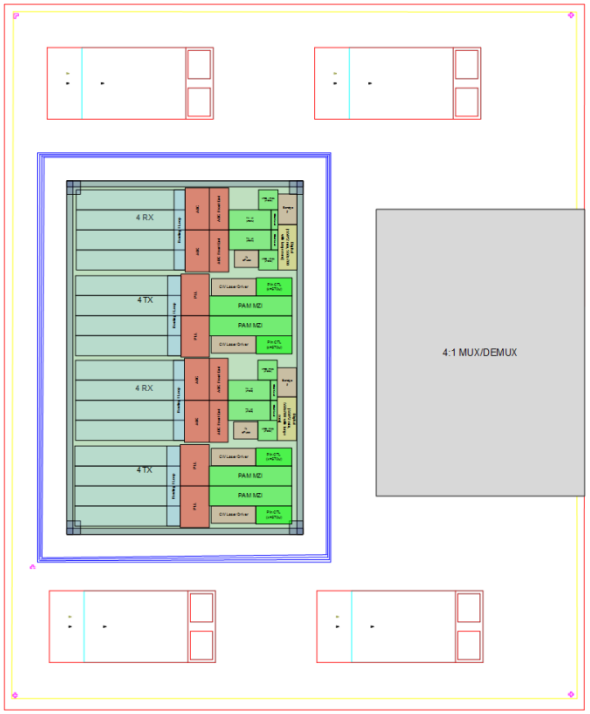


Chipset COGS	2.9-3.4
Optical Attaches	3
Yield per Attach	95%
Net Yield	86%
Module COGS†	3 – 3.6‡

† Renormalized with packaging and transformation costs applied

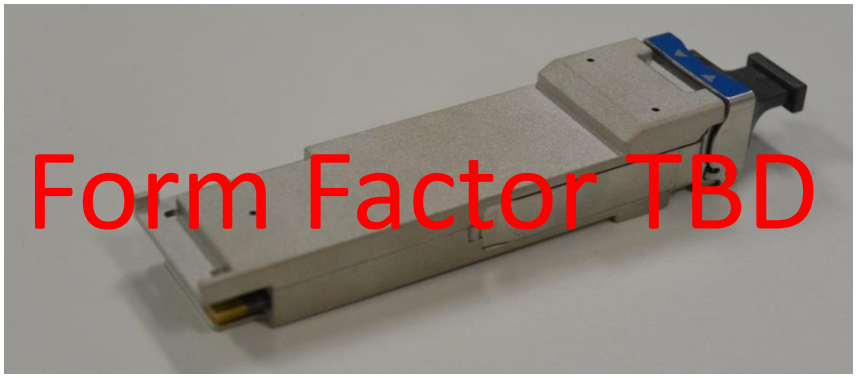
400G-FR4: 4λx4x50GBD-PAM4

Chipset



Photonics IC	167 mm^2
Electronics IC	34 mm^2
Light Source(s)	4
4:1 WDM MUX/Demux	1
Chipset COGS	3.9-4.9‡

Module



Chipset COGS	3.9 – 4.9
Optical Attaches	5
Yield per Attach	95%
Net Yield	77%
Module COGS†	4.6 – 5.7‡

† Renormalized with packaging and transformation costs applied

400G-FR8: 8λx4x25GBD-PAM4

Chipset

Chipset	
Photonics IC	218 mm^2
Electronics IC	40 mm^2
Light Source(s)	8
8:1 WDM MUX/Demux	1
Chipset COGS	7-9‡

Module	
Chipset COGS	3.9 – 4.9
Optical Attaches	9
Yield per Attach	95%
Net Yield	63%
Module COGS†	10 – 12.9‡

† Renormalized with packaging and transformation costs applied

400G-FR8: 8λx4x50GBD-NRZ

Chipset

Chipset	
Photonics IC	218 mm^2
Electronics IC	40 mm^2
Light Source(s)	8
8:1 WDM MUX/Demux	1
Chipset COGS	7-9‡

Module	
Chipset COGS	3.9 – 4.9
Optical Attaches	9
Yield per Attach	95%
Net Yield	63%
Module COGS†	10 – 12.9‡

† Renormalized with packaging and transformation costs applied

Cost Comparison

	Module Cost	Cost/Gbps (Normalized)
100G-PSM4: 1λx4x25GBD-NRZ	1	1
400G-PSM4: 1λx4x50GBD-PAM4	1.3 – 1.6	0.3 - 0.4
400G-PSM4: 2λx8x25GBD-PAM4	3 – 3.6	0.8 – 0.9
400G-PSM4: 2λx8x50GBD-NRZ	3 – 3.6	0.8 – 0.9
400G-FR4: 4λx4x50GBD-PAM4	4.6 – 5.7	1.1 – 1.4
400G-FR8: 8λx8x25GBD-PAM4	10 - 12.9	2.5 – 3.2
400G-FR8: 8λx8x50GBD-NRZ	10 - 12.9	2.5 – 3.2

100 Gbps per lane solutions close to 1/3rd the cost of 50 Gbps per lane solutions

Power Modeling

Power Modeling

- Electrical Interface:
  - CDAUI-8 VSR Interconnect
- Optical Interface
  - Optical Transmitter
    - MZI with Integrated PAM4 Encoder
    - Light Source
  - Optical Receiver
    - TIA/AGC
    - PAM4 Decoder

Electrical Interface

- Advanced CAUI-4 electrical I/O (VSR type) consume around 5-8 mW/Gbps
  - 500 – 800 mW per 100G
- Assume CDAUI-8 interface is approximately the same power/bit
  - 2000 – 3200 mW per 400G
- Optical power consumption added to this to get module power consumption

Optical Interface

25 Gbaud

- Transmitter ~ 125 mW
  - High Speed Signal Path
  - Low Speed Control
  - About 15% power increase for PAM4 usage (145 mW)
  - Light source power function of OMA requirements
- Receiver ~ 75 mW
  - High Speed Signal Path
  - Low Speed Control
  - About 25% power increase for linear/AGC operation (95 mW)
- PAM4 decoder ~ 200 mW
- Assuming 28nm CMOS

50 Gbaud

- Transmitter ~ 175 mW
  - High Speed Signal Path
  - Low Speed Control
  - About 15% power increase for PAM4 usage (200 mW)
  - Light source power function of OMA requirements
- Receiver ~ 115 mW
  - High Speed Signal Path
  - Low Speed Control
  - About 25% power increase for linear/AGC operation (140 mW)
- PAM4 decoder ~ 300 mW
- Assuming 16nm CMOS

Power Consumption – 500m Solutions

	100G-PSM4: 1λx4x25GBD-NRZ	400G-PSM4: 1λx4x50GBD-PAM4	400G-PSM4: 2λx8x25GBD-PAM4	400G-PSM4: 2λx8x50GBD-NRZ
Electrical I/O	500-800	2000-3200	2000-3200	2000-3200
Optical Transmitters (#)	4	4	8	8
Optical Transmitters (mW)	500	860	1160	1480
Light Source (#)	1	1	2	2
Light Source (mW)	250	375	562	562
Receivers (#)	4	4	8	8
Receivers (mW)	260	500	640	800
PAM4 Decoder (#)	0	4	8	0
PAM4 Decoder (mW)	0	1200	1600	1200†
Auxilliary (mW)	75	150	150	150
Total (W)	**1.7 – 2.0**	**5.1 – 6.3**	**6.3 – 7.5**	**6.3 – 7.5**

† Designates a 50 Gbaud CDR for NRZ operation

Power Consumption – 2km Solutions

	400G-PSM4: 4λx1x50GBD-PAM4	400G-PSM4: 8λx1x25GBD-PAM4	400G-PSM4: 8λx1x50GBD-NRZ
Electrical I/O	2000-3200	2000-3200	2000-3200
Optical Transmitters (#)	4	8	8
Optical Transmitters (mW)	1000	1450	1750
Light Source (#)	1	2	2
Light Source (mW)	375	562	562
Receivers (#)	4	8	8
Receivers (mW)	500	640	800
PAM4 Decoder (#)	4	8	0
PAM4 Decoder (mW)	1200	1600	1200†
Auxilliary (mW)	150	150	150
Total (W)	**6 – 7.2**	**7.6 – 8.8**	**7.7 – 8.9**

† Designates a 50 Gbaud CDR for NRZ operation

Conclusions

- 100 Gbps/λ are cost and power advantaged when compared to 50 Gbps/λ solutions
  - 100 Gbps/λ close to 1/3rd the cost/Gbps of 50 Gbps/λ
  - 100 Gbps/λ about 20% lower power than 50 Gbps/λ
- 400G using 100 Gbps/λ compares favorably to contemporary 100G standards
  - About 60% lower cost/gbps
  - About 25% lower power/gbps
- 400G using 50 Gbps/λ solutions offer minimal benefits when compared to contemporary 100G standards
  - About 5% lower cost/gbps
  - About 5% lower power/gbps

Thank You

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