# In Support of a 500m objective for 200G Ethernet: Part I

Technical and Economic Feasibility

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# Caveats and Disclaimers

- The materials presented within assume a 200G-DR4/PSM4 type solution for a 500m reach

# Technical Feasibility

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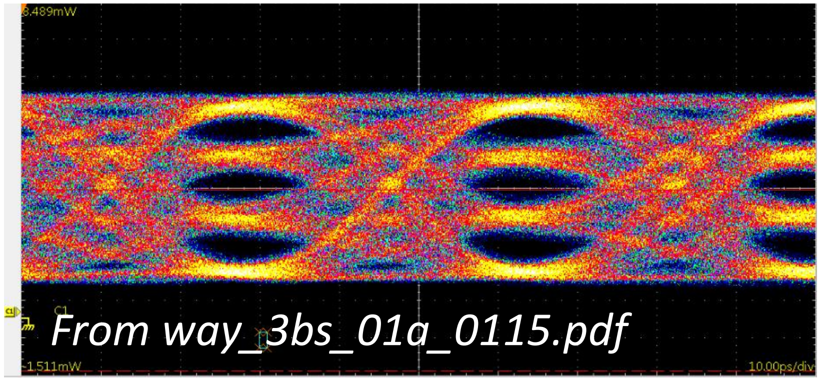
- Assuming a 26.5625 GBd-PAM4 modulation type per lane
  - Same per lane modulation type as adopted for 400G-FR8/LR8 baseline proposals
  - Same per lane modulation type as presented in support of 50GE 2km and 10km reach objectives
  - Same per lane modulation type as presented in support of 200GE 2km and 10km reach objectives
  - Same modulation type as adopted for per lane 50Gbps electrical interconnects as part of CDAUI-8 interface specifications

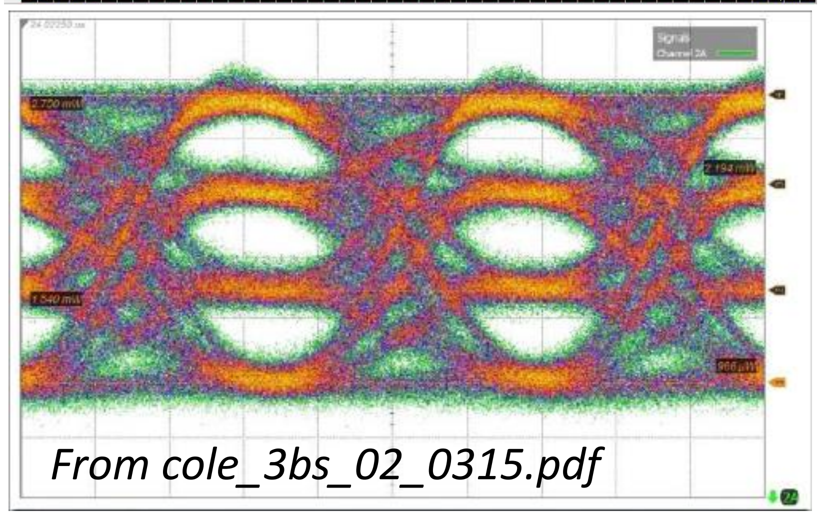
- Considerable presentation on 26.5625 GBD-PAM4 modulation type in 802.3bs project
  - Over 20 presentations through eight meeting cycles from May 2014 - July 2015
  - Additional presentations as part of the 50G/NGOATH study group

# Selected Demonstrations of 50G Optical Lanes

**Eye Diagrams**

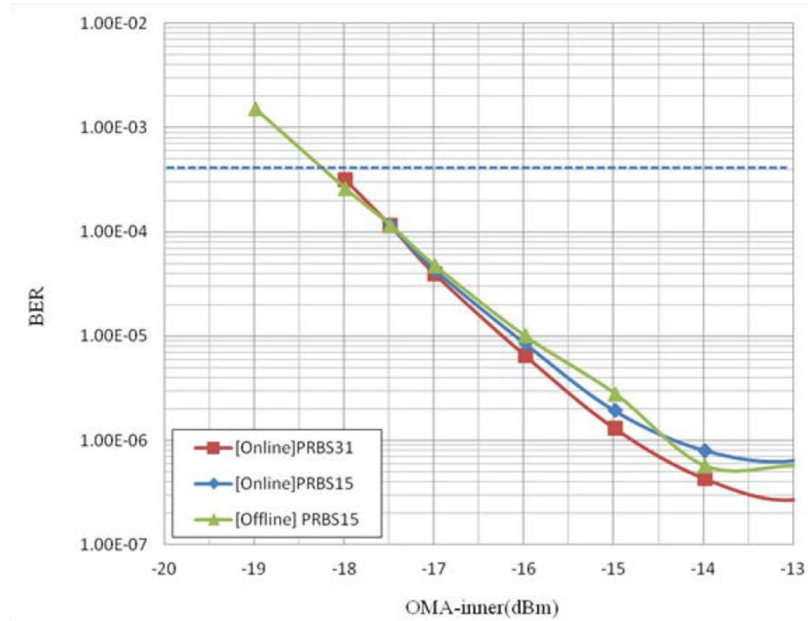



*From way_3bs_01a_0115.pdf*



*From cole_3bs_02_0315.pdf*

**BER vs. OMA**




*From stassar_3bs_01a_0315.pdf*

# Comparison of prospective specifications

| | 200G-PSM4/DR4† | 50G-FR | 200G-FR4 | 400G-FR8 |
|---|---|---|---|---|
| OMA – Pre Mux | **-2.5** | -2 | 0.8 | 3 |
| OMA | **-2.5** | -2 | -1.2 | 0 |
| RX Sensitivity | **-11.6** | -11.8 | -11 | -10 |
| RX Sensitivity – Post Mux | **-11.6** | -11.8 | -13.3 | -13.3 |

Prospective solution for 200G-PSM4/DR4 has relaxed OMA and RX sensitivity specs when compared to other 50G/lane optical specifications and proposals

- OMA (Pre Mux) 5.5 dB lower than 400G-FR8
- RX Sensitivity (Post Mux) 1.7 dB less stringent than 400G-FR8

† *from welch_50GE_NGOATH_01_0316.pdf*

# Power Consumption

**PMA**

- Assuming comparable power/throughput as CAUI-4
  - Advanced CAUI-4 PMA typically around 500-800mW (per 100G)
  - 5-8 mW/Gbps
- 200G electrical PMA expected to be around 1-1.6W

**PMD**

- 25GBD-PAM4 Optical Transmitter ~ 145 mW per lane
- 25GBD-PAM4 TIA/Receiver ~ 95 mW per lane
- PAM4 Decoder ~ 200mW per Lane
- 200G-PSM4/DR4 Total ~ 1.8 W

**Module Total = PMA + PMD + Overhead (~100mW) ≈ 2.9 – 3.5 W**

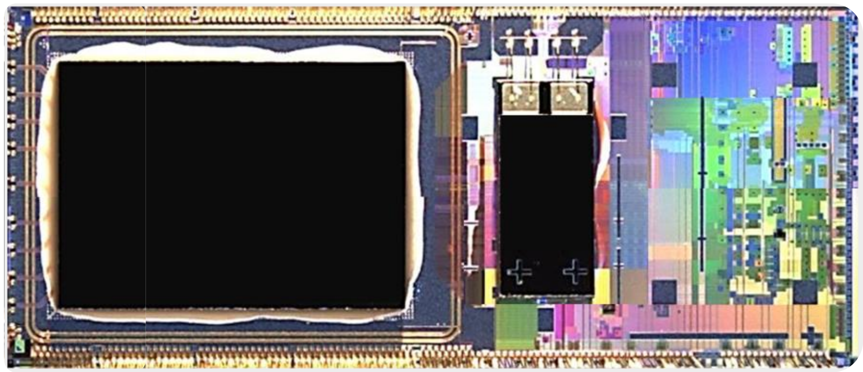
# Economic Feasibility

# Module Cost

- Comparison of a prospective 200G-PSM4/DR4 solution with a prospective 200G-FR4 solution
  - Assumes both done in a QSFP (or similar) form factor
- Cost modeling uses the methodology first employed in welch_01b_0113_opts.pdf
  - COGS build up from silicon photonics chipset
  - Compares amount of silicon area and light sources used
- Methodology does not consider parametric yield effects
  - Assembly yield is considered though
- Assumes both solutions manufactured in similar volumes
- Comparison done in a silicon photonics technology

# Chipset Comparisons

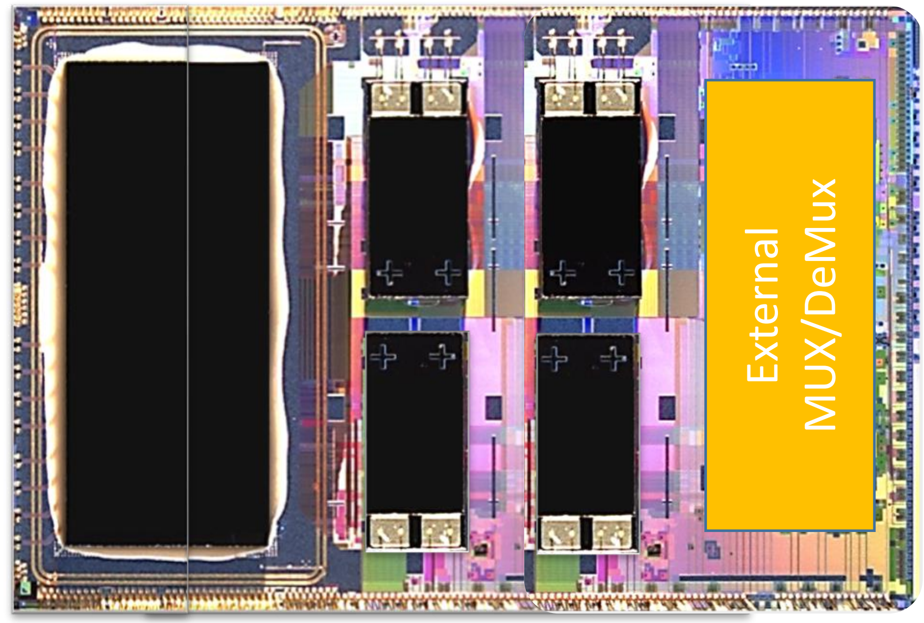
**200G-PSM4/DR4**



*Conceptual – Not an Actual Die Photo*

| | |
|---|---|
| Electronics IC | ~ 21 mm$^2$ |
| Photonics IC | ~ 80 mm$^2$ |
| Light Source(s) | 1 |

**200G-FR4**




*Conceptual – Not an Actual Die Photo*

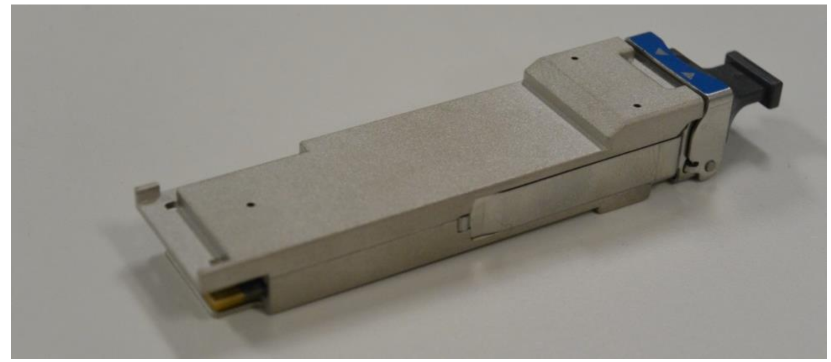
| | |
|---|---|
| Electronics IC | ~ 21 mm$^2$ |
| Photonics IC | ~ 120 mm$^2$ |
| Light Source(s) | 4 |

# Module Comparisons

## 200G-PSM4/DR4

| | |
|---|---|
| CMOS | ~ 100mm$^2$ |
| Light Source(s) | 1 |
| Discrete MUX/DEMUX | 0 |
| Optical Attaches | 2 |
| Yield per Attach | 95% |
| Net Yield | 90% |
| Module COGS (Normalized) | 1 |

## 200G-FR4

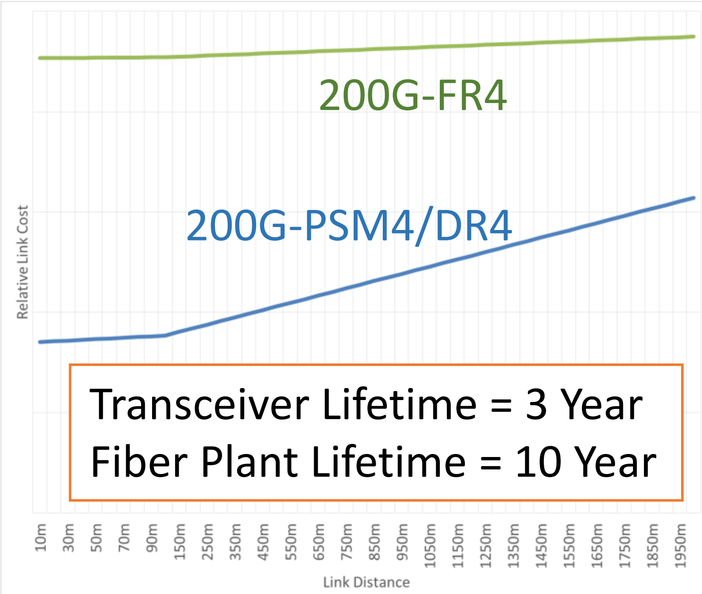


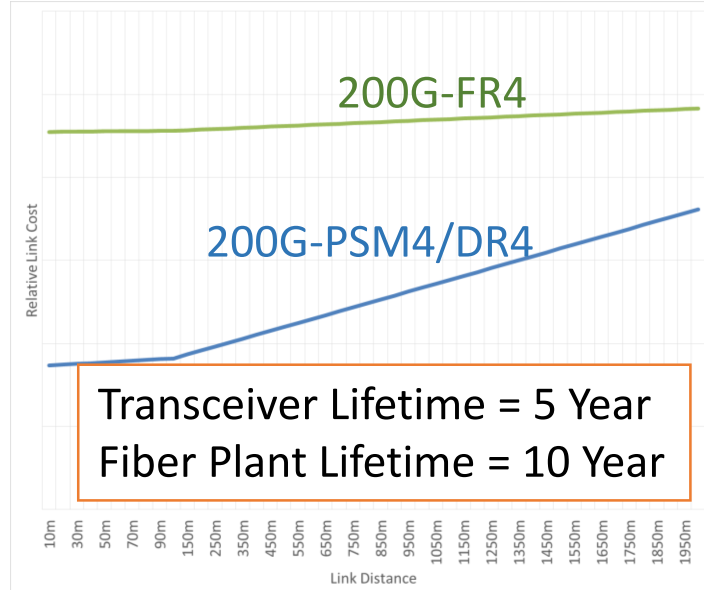
| | |
|---|---|
| CMOS | ~ 140mm$^2$ |
| Light Source(s) | 4 |
| Discrete MUX/DEMUX | 1 |
| Optical Attaches | 6 |
| Yield per Attach | 95% |
| Net Yield | 74% |
| Module COGS (Normalized) | 2.8 |

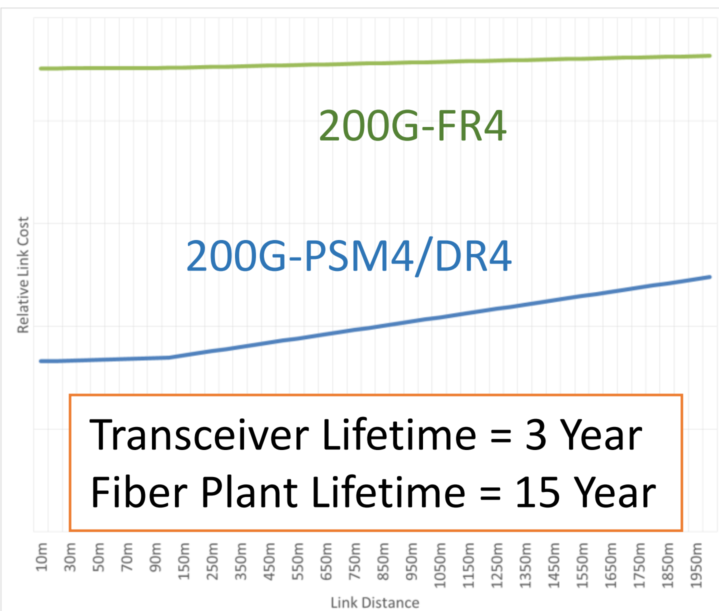
# Link Costs

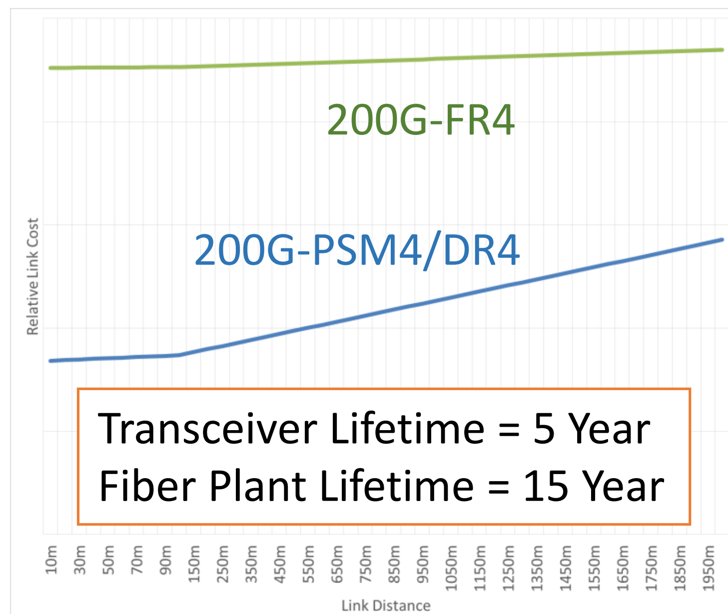
- Uses module costs previously calculated
- Uses depreciation model for fiber plant as first presented in welch_400_01_1113.pdf
  - Uses MACRs depreciation to model different fiber plant lifetimes
  - Modeling 10 and 15 year SMF fiber plant (depreciation) lifetimes
  - Modeling 3 and 5 years SMF transceiver lifetimes
- Uses double link fiber plant from kolesar_02_0313_optx.pdf
- Link cost vs. reach shown (up to 2 km)

# Link Costs


200G-FR4
200G-PSM4/DR4
Transceiver Lifetime = 3 Year
Fiber Plant Lifetime = 10 Year
Relative Link Cost
10m 30m 50m 70m 90m 150m 250m 350m 450m 550m 650m 750m 850m 950m 1050m 1150m 1250m 1350m 1450m 1550m 1650m 1750m 1850m 1950m
Link Distance


200G-FR4
200G-PSM4/DR4
Transceiver Lifetime = 5 Year
Fiber Plant Lifetime = 10 Year
Relative Link Cost
10m 30m 50m 70m 90m 150m 250m 350m 450m 550m 650m 750m 850m 950m 1050m 1150m 1250m 1350m 1450m 1550m 1650m 1750m 1850m 1950m
Link Distance


200G-FR4
200G-PSM4/DR4
Transceiver Lifetime = 3 Year
Fiber Plant Lifetime = 15 Year
Relative Link Cost
10m 30m 50m 70m 90m 150m 250m 350m 450m 550m 650m 750m 850m 950m 1050m 1150m 1250m 1350m 1450m 1550m 1650m 1750m 1850m 1950m
Link Distance


200G-FR4
200G-PSM4/DR4
Transceiver Lifetime = 5 Year
Fiber Plant Lifetime = 15 Year
Relative Link Cost
10m 30m 50m 70m 90m 150m 250m 350m 450m 550m 650m 750m 850m 950m 1050m 1150m 1250m 1350m 1450m 1550m 1650m 1750m 1850m 1950m
Link Distance

# Summary and Observations

- 50Gbps per lane signaling using 25GBD-PAM4 signaling is technically feasible
  - Broad consensus shown for that through it’s adoption in multiple other standards
- Solutions optimized for 500m likely to fit into QSFP (or similar) form factors
  - Not expected to have power/thermal limitations
- 200G-DR4/PSM4 type solutions for 500m are economically feasible
  - Lower transceiver and link cost expected than with duplex solutions

# In Support of a 500m objective for 200G Ethernet: Part I

Technical and Economic Feasibility

# Thank You

# Reference: MACRS Tables

| Recovery Year | 3 | 5 | 7 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|
| 0 | 0.333 | 0.200 | 0.143 | 0.100 | 0.050 | 0.038 |
| 1 | 0.445 | 0.320 | 0.245 | 0.180 | 0.095 | 0.072 |
| 2 | 0.148 | 0.192 | 0.175 | 0.144 | 0.086 | 0.067 |
| 3 | 0.074 | 0.115 | 0.125 | 0.115 | 0.077 | 0.062 |
| 4 | 0.000 | 0.115 | 0.089 | 0.092 | 0.069 | 0.057 |
| 5 | 0.000 | 0.058 | 0.089 | 0.074 | 0.062 | 0.053 |
| 6 | 0.000 | 0.000 | 0.089 | 0.066 | 0.059 | 0.049 |
| 7 | 0.000 | 0.000 | 0.045 | 0.066 | 0.059 | 0.045 |
| 8 | 0.000 | 0.000 | 0.000 | 0.066 | 0.059 | 0.045 |
| 9 | 0.000 | 0.000 | 0.000 | 0.066 | 0.059 | 0.045 |
| 10 | 0.000 | 0.000 | 0.000 | 0.033 | 0.059 | 0.045 |
| 11 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.045 |
| 12 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.045 |
| 13 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.045 |
| 14 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.045 |
| 15 | 0.000 | 0.000 | 0.000 | 0.000 | 0.030 | 0.045 |
| 16 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.045 |
| 17 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.045 |
| 18 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.045 |
| 19 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.045 |
| 20 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.022 |