

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

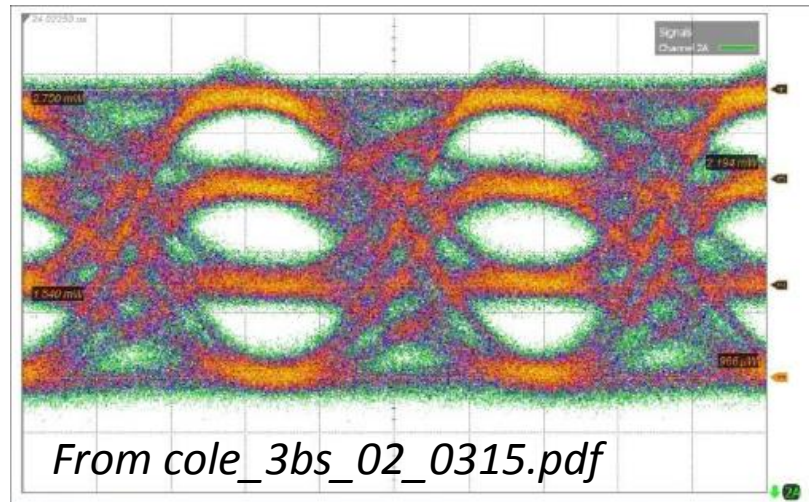
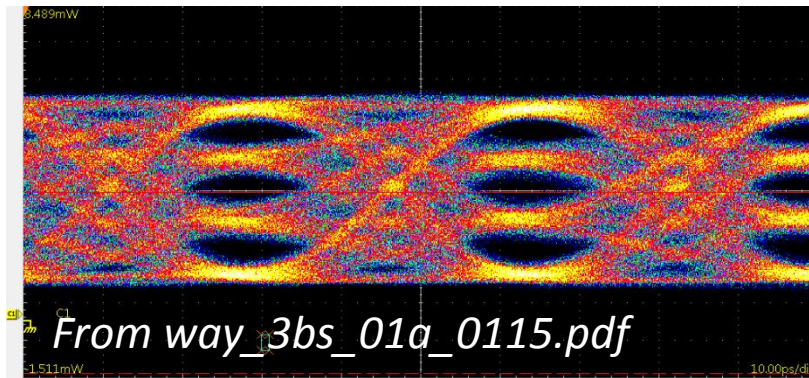
Technical Feasibility

Technical Feasibility

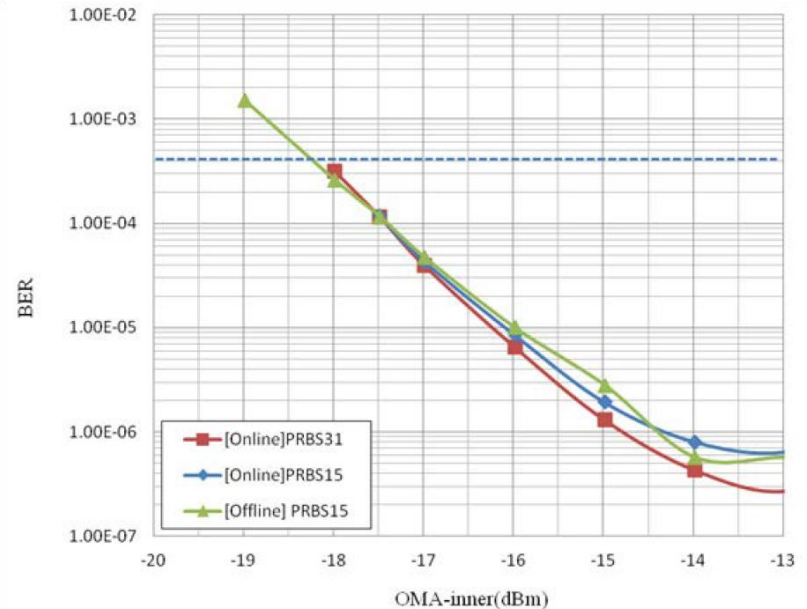
- Assuming a 26.5625 GBd-PAM4 modulation type per lane
 - Same per lane modulation type as adopted for 400G-FR8/LR8 baseline proposals
 - Same per lane modulation type as presented in support of 50GE 2km and 10km reach objectives
 - Same per lane modulation type as presented in support of 200GE 2km and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



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) \approx 2.9 – 3.5 W

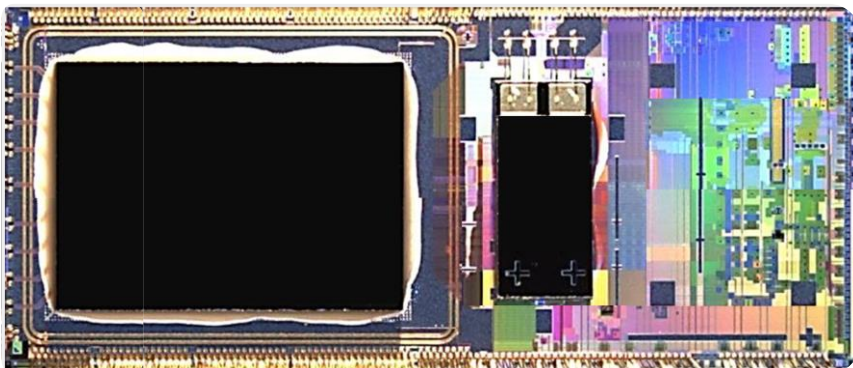
Economic Feasibility

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

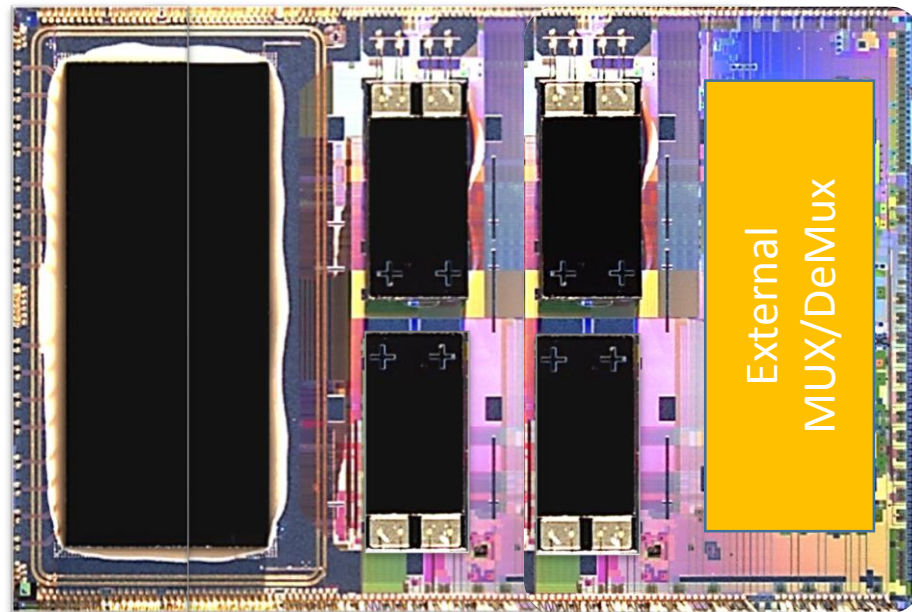
200G-PSM4/DR4



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 |

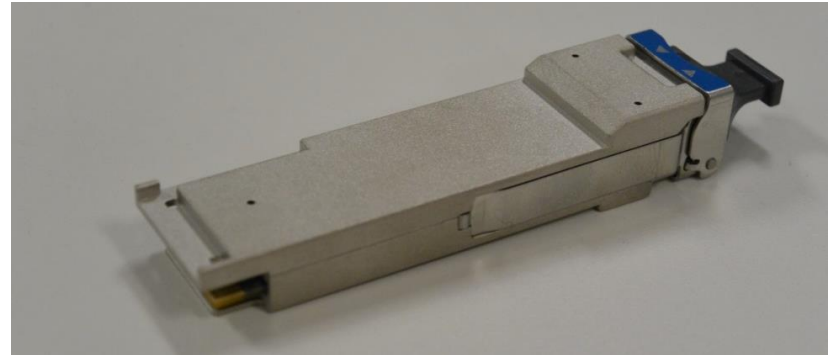
Module Comparisons

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

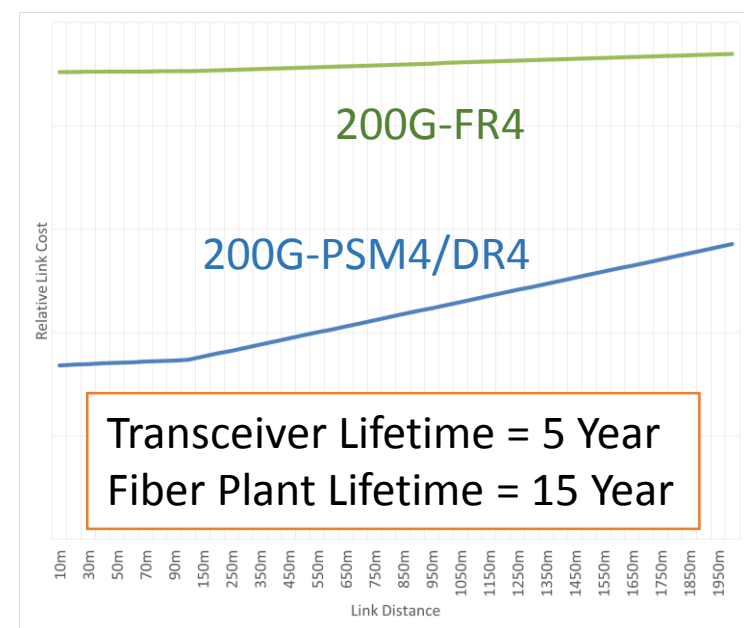
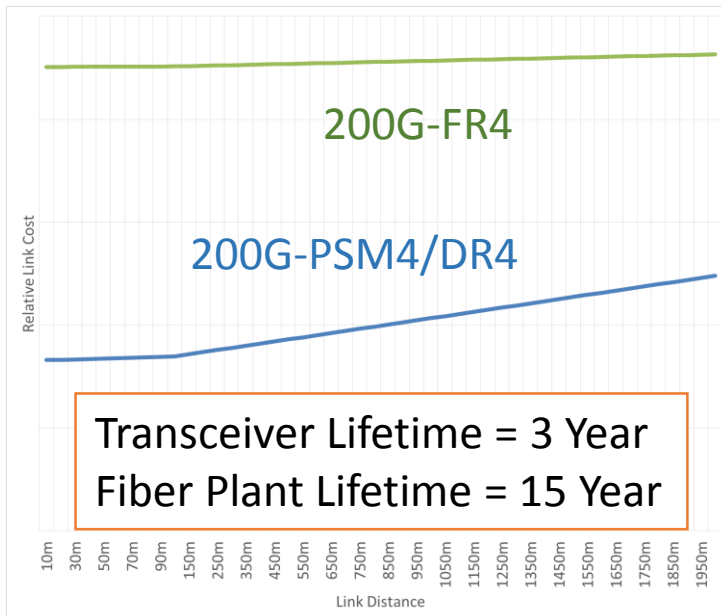
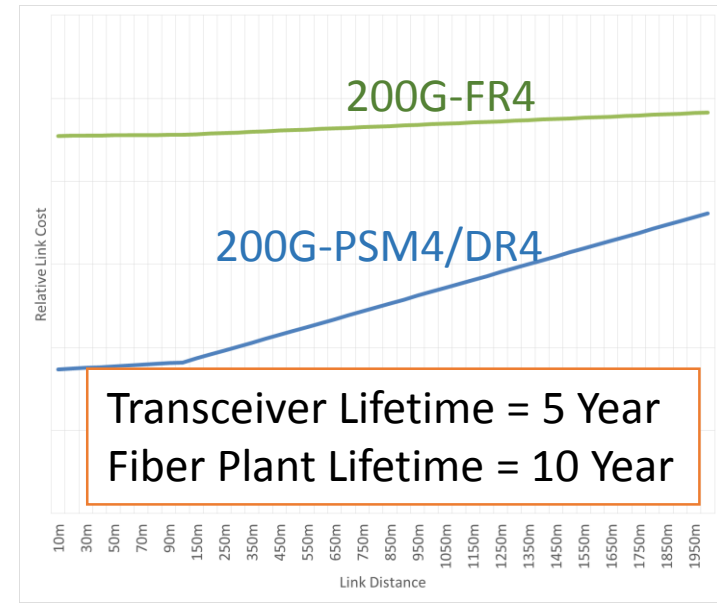
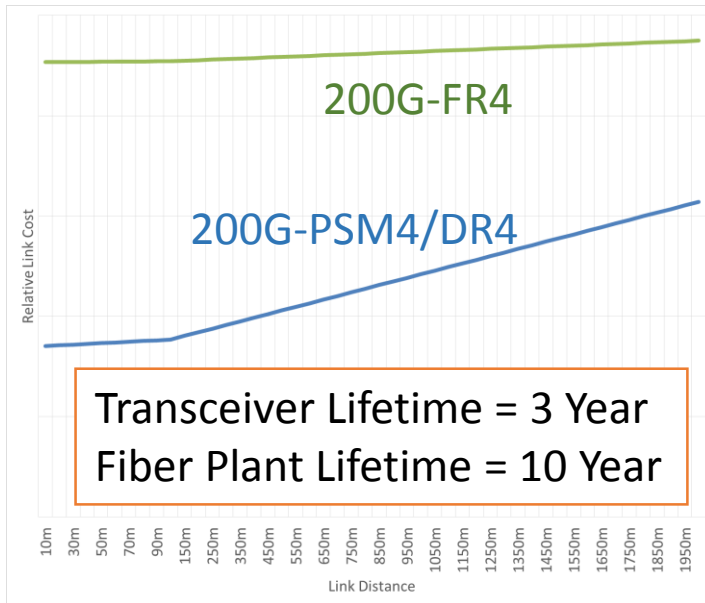


| CMOS | ~ 140mm ² |
|--------------------------|----------------------|
| Light Source(s) | 4 |
| Discrete MUX/DEMUX | 1 |
| Optical Attaches | 6 |
| Yield per Attach | 95% |
| Net Yield | 74% |
| Module COGS (Normalized) | 2.8 |

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



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

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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 |