40GE 10km SMF PMD Alternatives
Historical Cost Comparison

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Introduction

- 40GE-CWDM (4x10G) and 40GE-Serial (1x40G) are two proposed alternatives to meet the 40GE 10km SMF PMD objective
- The alternatives are technically feasible
- Cost is the key deciding factor in selecting between the alternatives
- 40GE-Serial cost is much higher today then 40GE-CWDM cost
- 40GE-Serial cost is expected to cross-over 40GE-CWDM cost in the future
- Predicting the cross-over point is central to making a decision
- Presentation conclusions:
  - Based on technology and volume, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR.)
  - Today, 6 years after 802.3ae standard adoption, 10GE-ER has 60% higher cost than 10GE-LX4.
  - Based on historical cost data and reasonable component cost assumptions, aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013, with more likely cross-over after 2016.

All market cost data in this presentation is from Lightcounting, based on actual transceiver sales confidentially shared by 21 optics vendors with Lightcounting.
## 10GE PMD Technology

<table>
<thead>
<tr>
<th>ALL VALUES ARE APPROXIMATE</th>
<th>10GE-LR</th>
<th>10GE-ER</th>
<th>40GE-Serial</th>
<th>10GE-LX4</th>
<th>40GE-CWDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC Technology (typical)</td>
<td>4:1 XAUI</td>
<td>4:1 XAUI</td>
<td>4:1 Mux / DeMux</td>
<td>4:4 XAUI</td>
<td>4:4 CDR</td>
</tr>
<tr>
<td>TX Technology (typical)</td>
<td>Un-cooled DFB</td>
<td>Cooled EML</td>
<td>Cooled EML</td>
<td>Un-cooled DFB/MUX (7dB loss)</td>
<td>Un-cooled DFB/MUX (2dB loss)</td>
</tr>
<tr>
<td>RX Technology (typical)</td>
<td>PIN</td>
<td>PIN</td>
<td>PIN</td>
<td>DeMux/PIN (2dB loss)</td>
<td>DeMux/PIN (2dB loss)</td>
</tr>
<tr>
<td>Typical feasible TP2 OMA power (not spec)</td>
<td>3dBm</td>
<td>2dBm</td>
<td>3dBm</td>
<td>-4dBm</td>
<td>1dBm</td>
</tr>
<tr>
<td>Link Budget</td>
<td>9dB</td>
<td>15dB</td>
<td>9dB</td>
<td>8dB</td>
<td>9dB</td>
</tr>
<tr>
<td>Typical feasible TP3 OMA sens. (not spec)</td>
<td>-17dBm</td>
<td>-18dBm</td>
<td>-7dBm</td>
<td>-20dBm</td>
<td>-15dBm</td>
</tr>
<tr>
<td>Technology Margin: TP2 – Budget – TP3</td>
<td>11dB</td>
<td>5dB</td>
<td>1dB</td>
<td>8dB</td>
<td>7dB</td>
</tr>
</tbody>
</table>

Optics technology type and margin determines PMD manufacturing difficulty, which drives PMD cost.
10GE Technology and Margin Comparison

- 10GE-LX4 and 40GE-CWDM have same transmitter technology (un-cooled DFB/Mux) and similar technology margin, so are fair historical analogies.

- 10GE-ER and 40GE-Serial have same transmitter technology (cooled EML) and similar technology margin, so are fair historical analogies.

- 10GE-LR and 40GE-Serial have different transmitter technology (un-cooled DFB vs. cooled EML) and large difference in technology margin (~10dB), so are unfair historical analogies.

- Based on technology type and technology margin (i.e. manufacturing cost) comparison, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR).

- 40GE-CWDM has more technology margin (~6dB) than 40GE-Serial, which offsets manufacturing costs due to multiple optical channels.
10GE Volume Comparison

- 2008 unit count of all 10G 10km un-cooled DFB Modules: 380,537
  (all XAUI, XFP, SFP+, for LR and OC-192 SR-1)
- 2008 unit count of all LX4 Modules: 58,902
  (all XAUI for LX4)
- 2008 unit count of all 10G 40km cooled EML Modules: 95,222
  (all XAUI, XFP, SFP+, for ER and OC-192 IR-2)

- ER optics have similar volume to LX4 optics so are fair historical comparisons.
- LR optics are 6x volume of LX4 optics so are unfair historical comparisons.
- Based on volume comparison, the fair historical analogy for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR).

- 2008 unit count of all XAUI modules: 378,352
  (all XAUI, for ER, LR and SR)
- LR and ER use high volume XAUI IC which favors their cost versus LX4
10GE XAUI PMD Historical Relative Market Cost

- 10GE-LX4 is being supplanted by 10GE-LRM and therefore has limited cost reduction investment; cost curve is atypically flat for Ethernet optics.
- 6 years after 802.3ae standard adoption in 2002, 10GE-ER still has 60% higher cost than 10GE-LX4.
- 3 years after standard adoption 10GE-LR cost crossed over 10GE-LX4 cost.
- 6 years after standard adoption and despite 6x higher volume, 10GE-LR has only 30% lower cost than 10GE-LX4.
1GE, 2.5G, 10GE PMD Historical Relative Market Cost

- All curves on this graph and all other graphs normalized to 2008 LR XFP cost.
- The cost of Gigabit Ethernet has declined significantly during 10GE adoption (about 50% in 4 years.)
- A similar decline can be assumed for the cost of 10GE during 40GE adoption, which will benefit 40GE-CWDM cost decrease.
- Ratio of 10G PMD cost to 2.5G PMD (OC-48 IR-1 SFP) cost gives a historical basis for estimating ratio of 40G PMD cost to 10G PMD (LR XFP) cost.
40GE PMD cost multipliers from 2008 10GE costs

- Conservative cost multipliers based on comparison to 2.5G SFP (OC-48 IR-1)
  - 40GE-CWDM cost / 10GE-LR XFP $^1$
    $\approx$ 10GE-LX4 XAUI cost / 2.5G SFP cost (from p.6 and p.7)
    $\approx 8 \times$
  - 40GE-Serial cost / 10GE-LR XFP cost $^2$
    $\approx$ 10GE-ER XAUI cost / 2.5G SFP cost (from p.6 and p.7)
    $\approx 12 \times$

- Aggressive cost multipliers based on aggressive component costs
  - 40GE-CWDM cost / 10GE-LR XFP cost $^1$
    $\approx 4 \times$
  - 40GE-Serial cost / 10GE-LR XFP cost $^2$
    $\approx 6 \times$

$^1$ 40GE-CWDM PMD will use existing 10GE-LR technology so cost multipliers are immediately usable for predicting cost.

$^2$ 40GE-Serial PMD will use new 3rd Gen 40G ICs and Optics (based on PCB 40G I/O,) which is a major departure from existing 1st and 2nd Gen 40G ICs and Optics (based on GPPO 40G I/O.) A lengthy development period is required before cost multipliers are usable for predicting cost.
40G PMD Cost Projections

- Solid curves are actual 40G VSR cost, and LR XFP multiplier 40GE-CWDM cost.
- Dashed curves are solid curves exponentially trend lined to predict future cost.
- **Red line** shows 40G Serial technology going from 2008 40x cost to claimed 2010 4.6x 10GE LR cost. This is a 9x cost reduction in two years, which is an unprecedented departure from all historical cost decrease trends.
- Aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013, with more likely cross-over after 2016.
Conclusions

- The fair historical analogy, based on technology and volume, for 40GE-CWDM is 10GE-LX4, and for 40GE-Serial is 10GE-ER (not 10GE-LR.)
- Despite 10GE-LX4 cost curve being atypically flat compared to other Ethernet optics cost curves, today 10GE-ER has 60% higher cost than 10GE-LX4 (6 years after 802.3ae standard adoption.)
- Despite being an unfair historical analogy (different technology and 6x higher volume,) today 10GE-LR has only 30% lower cost than 10GE-LX4.
- The cost of 10GE during 40GE adoption is expected to decrease, continuing 40GE-CWDM cost reduction and lowering cross-over target for 40GE-Serial.
- Claimed 40GE-Serial cost cross-over in 2010 is unsupported by any historical cost data:
  - Requires aggressive 40G-Serial cost multiplier and conservative 40GE-CWDM cost multiplier,
  - Requires an unprecedented 9x optical PMD cost reduction in two years.
- Based on historical cost data and reasonable component cost assumptions, aggressive cross-over of 40GE-CWDM cost by 40GE-Serial cost is in 2013 (3 years after 40GE standard adoption,) with more likely cross-over after 2016 (6 years after 40GE standard adoption.)
Appendix 1: 40G PMD Cost Projection Worksheet

Same data as on page 9. Refer to legend on page 9 for exact definition of cost curves.