40GBit/s and 100 GBit/s Transmission over OM3 Duplex Fiber

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Scope

→ Provide a solution for transmission on duplex OM3 fiber
  ▪ with 40 GBit/s (PART A)
  ▪ with 100 GBit/s (PART B)

to allow an upgrade of existing OM3 fiber networks

→ Approach: WDM on OM3 fiber

→ Define PMD for both data rates
<table>
<thead>
<tr>
<th>Distance</th>
<th>Fiber</th>
<th>40GBit/s</th>
<th>100GBit/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>100m</td>
<td>OM3 (0.85µm)</td>
<td>4 x 10GBit/s</td>
<td>10 x 10GBit/s</td>
</tr>
<tr>
<td>10km</td>
<td>SM (1.3µm)</td>
<td>4 x 10GBit/s</td>
<td>4 x 25GBit/s</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x 40GBit/s</td>
<td></td>
</tr>
<tr>
<td>40km</td>
<td>SM (1.3µm)</td>
<td></td>
<td>4 x 25GBit/s</td>
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</tbody>
</table>

There are only proposals with 4 x 25GBit/s for SM-fiber (WDM).
High speed Transmitter for 850nm

- Transmission with 17GBit/s at 850nm have been demonstrated at the OFC 2008
- Several manufacturers have such devices in the lab
- The next step of FC standardization for 17GBit/s transmission will start this year.
- 850nm transmission with up to 40GBit/s was proposed at the IEEE P802.3ba March 2008 Plenary Meeting
  kropp_01_0308.pdf

- 20 - 25GBit/s speed is feasible at 850nm.
Similar PMD for SR as for LR

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</tr>
<tr>
<td></td>
<td></td>
<td>2 x 20GBit/s</td>
<td>4 x 25GBit/s</td>
</tr>
<tr>
<td>10km</td>
<td>SM (1.3(\mu)m)</td>
<td>4 x 10GBit/s</td>
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<td>4 x 25GBit/s</td>
</tr>
</tbody>
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Define a 4 x 25GBit/s PMD for 100m on MMF as for the SM-fiber!
Define a 2 x 20GBit/s PMD for 100m on MMF.
PART A:
40 GBit/s Transmission over OM3 Duplex Fiber
Consider as part of the 40G MMF objective both a multi-fiber and a **duplex fiber**

Scenario
- Use of duplex OM3 fiber for 40GBit/sec transmission
- Parallel transmission with 2x 20 Gbit/s with NRZ
- as CWDM with 840nm and 860nm on one OM3

Upgrade of existing Duplex OM3 Fiber links is possible
- Adequate Bandwidth of 1800MHz*km over the slightly larger spectral window of about 833nm to 867nm is reached by the Standard OM3 fiber (Draka/Corning)
Channel Spacing for Uncooled Operation

→ Channel Spacing: 20nm

→ Total width of operating wavelength window: 13nm
  - Temperature drift of laser (0.07nm/°)
    operating temperature 0°-85°: 6nm
  - Manufacturing tolerance of wavelength 7nm

→ Channel separation between windows: 7nm
  - easy to reach with standard technology

→ Same channel separation as in 1300nm CWDM systems
2x20G: Simple WDM Filter

- Channel 1: window 833.5nm – 846.5nm
- Channel 2: window 853.5nm – 866.5nm
- One edge WDM filter only
- Moderate spectral edge characteristic is necessary
- Filter can be manufactured by standard Thin Film Technology
  (Reference: e.g. CubeOptics)
The MUX and DEMUX are simple one stage devices with low power and low cost manufactured based on CMOS or BiCMOS technology.
Scenario: 20 Gbit/s

→ Fiber: OM3 Fiber
  used with a restricted launch condition according to 10 GbE Standard
  used effective Modal Bandwidth: 1800 MHz·km because of extended spectral range of 833nm to 867nm

→ Transmitter: wavelength 833 nm - 867 nm, \( \Delta \lambda = 0.45 \text{ nm} \) (rms spectral width), \( T_r, T_f = 15 \text{ ps} \);
  OMA power min. = -3.8 dBm; ext. Ratio min. = 3.0 dB;
  det. jitter = 12.0 ps; RIN = -130 dB/Hz

→ Connectors: 1.5 dB loss by connectors

→ Receiver: Bandwidth = 15 GHz; sensitivity OMA = -11.1 dBm
20 Gbit/s Link Simulation

OM3 fiber with RML similar to 10 GbE

Total Power Budget 7.3 dB

Link length: 100 m

Power margin: 0.9 dB

100 m distance feasible with OM3 fiber
<table>
<thead>
<tr>
<th>Component</th>
<th>Relative Cost</th>
<th>2 x 20GBit/s WDM</th>
<th>Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x 10GBit/s parallel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x TIA</td>
<td>1</td>
<td>2x TIA + DEMUX</td>
<td>1,5</td>
</tr>
<tr>
<td>4x Driver</td>
<td>1</td>
<td>2x Driver + MUX</td>
<td>1,5</td>
</tr>
<tr>
<td>OSA assembly 4+4</td>
<td>1</td>
<td>OSA WDM assembly 2+2</td>
<td>2</td>
</tr>
<tr>
<td>4x Laser / 4x PD</td>
<td>1</td>
<td>2x Laser / 2x PD</td>
<td>0,7</td>
</tr>
<tr>
<td>electronic assembly</td>
<td>1</td>
<td>electronic assembly</td>
<td>1,3</td>
</tr>
<tr>
<td>PMD Package</td>
<td>1</td>
<td>PMD Package</td>
<td>1</td>
</tr>
<tr>
<td>Weighted average at similar volumes</td>
<td>1x</td>
<td></td>
<td>1,4x</td>
</tr>
</tbody>
</table>
Summary for 40Gbit/s on duplex OM3

→ PMD 100 m 40G over OM3 (2x20G) is feasible
→ 20 GBit/s transmission over FR4 using 90nm CMOS demonstrated (power consumption of 11.8 mW/Gb/s):
  peeters_01_1106.pdf
→ Only slightly higher cost and power than 4x10G parallel

but

→ standard OM3 duplex fibers can be used
→ possible upgrade of existing duplex OM3 fiber links
PART B:
100 GBit/s Transmission over OM3 Duplex Fiber
Advantage of similar PMDs

10 x 10G (e.g. XFI) TRX

- MUX 10:4
- DEMUX 4:10
- 4x driver
- 4x laser
- 4x amp
- 4x RX
- WDM MUX
- WDM DEMUX
- 4 x 25G

LR:
LAN-WDM 1300nm

SR:
LAN-WDM 850nm on OM3 Duplex

- Same electrical interface with same functions
- Most electronic components are the same
- Same form factor as for the SM-application
- Advantage of higher volume for both interfaces
WDM-Grid at 850nm

→ Wavelength channels: 840nm, 847nm, 854nm, 861nm

→ Channel Spacing: 7nm

→ Width of operating wavelength windows: 3.5nm

→ Channel separation between windows: 3.5nm

→ Similar concept as the LAN-WDM (even with somewhat larger spacing)

→ The wavelength window is nearly completely covered by the existing specification window of the OM3 fiber.
Link Simulation 25 Gbit/s

- Fiber: OM3 Fiber
  used with a restricted launch condition according to 10 GbE Standard
  used effective Modal Bandwidth: **1900 MHz·km only** because of slightly extended spectral range of 838nm to 863nm

- Transmitter: wavelength 838 nm - 863 nm,
  $\Delta \lambda = 0.45$ nm (rms spectral width), $T_r, T_f = 11$ ps;
  OMA power min. = -3.8 dBm; ext. Ratio min. = 3.0 dB;
  det. jitter = 8.0 ps; RIN = -130 dB/Hz

- Connectors: 1.5 dB loss by connectors

- Receiver: Bandwidth = 20 GHz; sensitivity OMA = -11.1 dBm
25 Gbit/s Link Simulation

OM3 fiber with RML similar to 10 GbE

Total Power Budget 7.3 dB

Link length: 100 m

Power margin: 0.6 dB

100 m distance feasible with OM3 fiber
100G Technical Approach

TOSA:
- Wavelength stabilization e.g. with temperature control
- 4 VCSEL cooled with one TEC device
- this active cooling adds about 0.5 Watts only

Transceiver:
- Same form-factor as for 1300nm LAN-WDM
- Same components for electronic interface
- Lower power for low current driver electronics for VCSEL
- Lower cost because of VCSEL laser and simpler WDM-TOSA design
Summary for 100 Gbit/s on duplex OM3

→ Transmission over OM3 Duplex fiber instead of ribbon cable
→ Same electronic components for SR and LR (no additional development effort)
→ Easier cable connections (less bulky, lower bend radius, reduced space consumption, …..)
→ Potential of higher reliability than the 10x10G approach due to less opto-electronic components

but

→ standard OM3 duplex fibers can be used
→ possible upgrade of existing duplex OM3 fiber links
Summary 40/100G on duplex OM3

➔ 40 Gbit/s and 100 Gbit/s transmission on OM3 duplex is technically feasible

➔ upgrade of existing OM3 fiber links is possible

➔ 2x20G OM3 duplex is competitive to 4x10G ribbon in cost and power consumption

➔ the proposed PMDs should be included in the standard in addition to the proposed ribbon fiber solutions
Thank You!