1x40 Gbit/s and 4x25 Gbit/s Transmission at 850 nm on Multimode Fiber

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1. Feasibility of components for 4x25G and 1x40G solutions for short reach interconnects:
   - novel type of modulated VCSEL
   - photodetectors
   - integrated circuit TIAs and drivers
   - fibers

2. First link performance simulation

3. Proposal
Maximum commercial single channel data rate increases 4-fold each 5 years

17G VCSELs and 17G Receivers are on the roadmaps
Novel Electro-Optic VCSEL Approach

Today’s VCSELs:
- direct modulation of gain medium

Novel EOM VCSEL:
- modulation of integrated “modulator section“
EOM VCSEL: Experimental Results

Presented:
Paraskevopoulos et al., OFC 2006, paper PDP22

For related work see also:
van Eisden et al., OFC 2008, paper JWA42

First generation monolithic electro-optically modulated EOM VCSEL

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Degradation Robustness of EOM VCSEL

→ Limitations of standard directly modulated VCSELs:
  – high speed typically requires high drive current densities
  – high current densities cause accelerated degradation
    (see e.g. tatum_01_1106.pdf)

→ EOM VCSEL reaches high-speed using a modulator medium
  – moderate drive current densities increase device reliability
  – near-zero current for modulator section
  – no accelerated degradation
Advantage of EOM VCSEL

- Laser is running CW with moderate current
- No chirp with modulation
- Small spectral line width (single mode emission is possible)
- Modulation characteristic is decoupled from laser current
- Very high speed switching
- Low cost because of standard single-step epitaxial growth and standard VCSEL processing

- High-speed EOM VCSEL was demonstrated and will be available
40 Gbit/s 850 nm Photodetectors

- Detectors for 40 Gbit/s at 850 nm are demonstrated
- Known technology
- Coupling to MM-fiber is possible
- Low cost packaging is possible

40 Gbit/s photodetectors for 850 nm are available
40 Gbit/s Integrated Circuits

f<sub>T</sub> up to 300 GHz has been demonstrated with SiGe; see for example:

- H. Rücker et al., *IEEE IEDM 2007*
- S. P. Voinigescu et al., *IEEE BC TM 2006*
- B. Heinemann et al., *IEEE IEDM 2004*

\[ \Rightarrow \text{>40 Gbit/s has been demonstrated i.e. with low cost SiGe VLSI technology} \]
Multimode Fibers

- **OM3** fiber with 2000 MHz·km is a standard product.

- Higher speed versions with a bandwidth parameter of up to 4700 MHz·km are available from several suppliers.
  - such a higher speed version of MMF is now in discussion as “**OM4**” fiber in a standardization proposal.

- Multimode fibers are available to support data rates of 25 Gbit/s and 40 Gbit/s.
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Consider two typical cases for performance evaluation:

Transmission on Multimode Fiber at 850 nm:

- **Scenario a)**
  - Serial transmission at 28 Gbit/s with NRZ coding according to the proposal of the OIF for the CEI-25 interface

- **Scenario b)**
  - Serial transmission at 40 Gbit/s with NRZ coding
Scenario a): 28 Gbit/s

→ Fiber: **OM3 Fiber**
  used with a restricted launch condition according to
  10 GbE Standard
  effective Modal Bandwidth: 2000 MHz·km

→ Transmitter: wavelength 840 nm - 860 nm,
  $\Delta \lambda = 0.20$ nm (rms spectral width), $T_r, T_f = 11$ ps;
  OMA power min. = -3.8 dBm; ext. Ratio min. = 3.0 dB;
  detector jitter = 6.0 ps; RIN = -130 dB/Hz

→ Connectors: 1.5 dB loss by connectors

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

OM3 fiber with RML similar to 10 GbE

Total Power Budget 7.3 dB

Link length: 100 m

Power margin: 0.7 dB

100 m distance feasible with OM3 fiber
Scenario b) : 40 Gbit/s

→ Fiber: “OM4” Fiber, Very High Grade MMF
used with restricted launch condition according to the
10GbE Standard
effective Modal Bandwidth: 4700 MHz·km

→ Transmitter: wavelength 840 nm - 860 nm;
\( \Delta \lambda = 0.20 \) nm (rms spectral width); \( T_r, T_f (20 - 80) = 8 \) ps;
OMA power min.= -3.8dBm; ext. Ratio min. = 3.0 dB;
detector jitter = 5.0 ps; RIN = -130 dB/Hz

→ Connectors: 1.5 dB loss by connectors

→ Receiver: Bandwidth = 30 GHz; sensitivity OMA = -10.0 dBm
40Gbit/s: First Link Simulation

- Fiber bandwidth 4700 MHz-km with RML similar to 10 GbE
- Total Power Budget 6.2 dB
- Link length: 100 m
- Power margin: 0.6 dB

→ 100 m feasible with “OM4” fiber
Advantages of 4x25G or 1x40G

- Smaller number of components – lower overall cost
- Only one duplex fiber or one 4+4 fiber bundle per transceiver
- Higher reliability
  - fewer components
  - fewer VCSELs, each requiring low-stress drive conditions
- One set of electronics because of one channel (1x40G)
- Reduced power consumption
- Fiber options:
  - 4x25G can be arranged as a 4-fiber solution
  - or WDM is possible with a single fiber
- Same set of management ICs for LR and SR
4x25 Gbit/s and 40 Gbit/s transmission at 850 nm on multimode fiber:

→ Components / solutions exist

→ Many advantages

→ Link over 100 m is feasible
1. Include a 4x25 Gbit/s solution for short reach interconnects on multimode fibers in the Standardization (with OM3)

2. Include a 40 Gbit/s serial solution for short reach interconnects on multimode fibers in the Standardization (with “OM4”)

3. Support the Standardization of the “OM4” fiber
Thank You!