Technical & Economic Feasibility of 20GBaud based 100Gb Transceivers

IEEE 802.3 Higher Speed Study Group

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Outline

- Applicable IEEE 802.3 Study Group Criteria
- Applicable HSSG Fiber Optic Ad Hoc study alternatives
- 5x21G Transceiver System Architectures with Gen1 10G I/O PCS IC
- 5x21G Transceiver System Architecture with Gen2 20G I/O PCS IC
- 10km 5x21G DWDM Transceiver: performance and relative cost
- 40km 5x21G DWDM Transceiver: performance and relative cost
- 2km 5x21G CWDM Transceiver: performance and relative cost
- Discussion

Applicable IEEE 802.3 Study Group Criteria

- Technical Feasibility
  - Demonstrated feasibility; reports - - working models
  - Proven technology, reasonable testing
  - Confidence in reliability

- Economic Feasibility
  - Cost factors known, reliable data
  - Reasonable cost for performance expected
  - Total installation costs considered

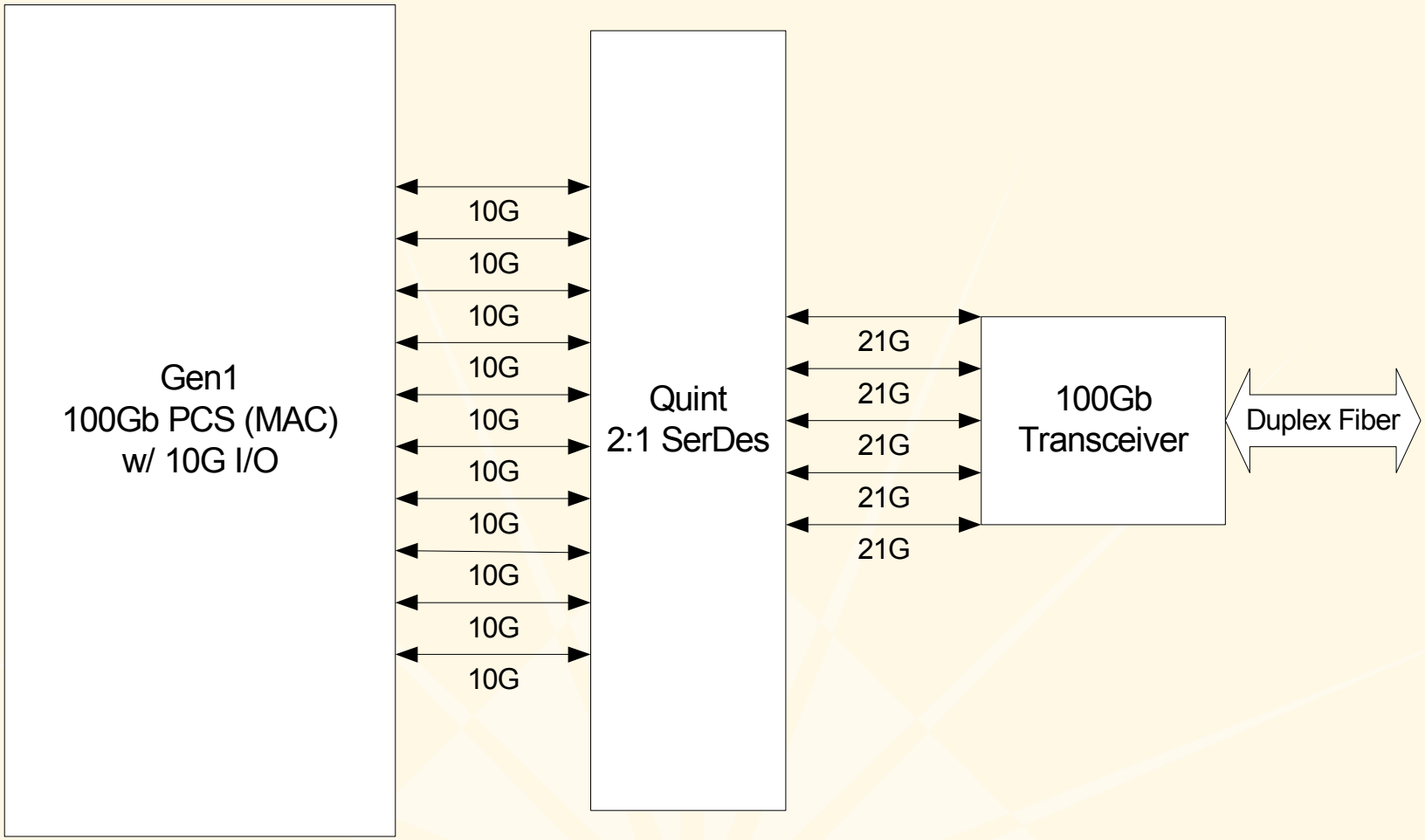
Official 802.3 SG critters

Alternate SG critters

Applicable Fiber Optic Ad Hoc study alternatives

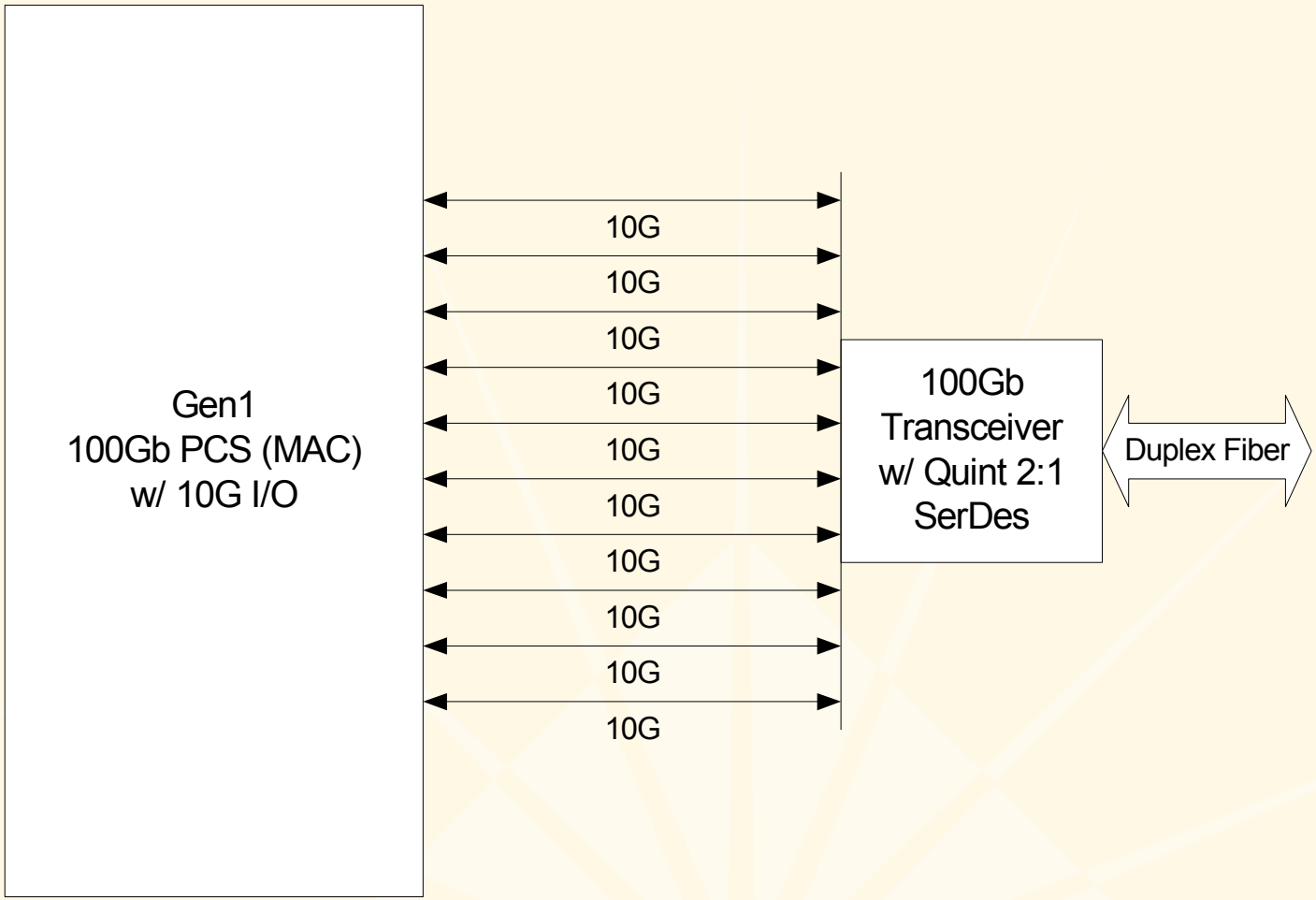
- Data rate alternatives
  1. *80Gb/s*
  2. **100Gb/s**
  3. *120Gb/s*
- Signal rate alternatives (corresponding number of channels)
  1. *10GB to 14GB (12, 10, 8)*
  2. **20GB to 28GB (6, 5, 4)**
  3. *40GB to 56GB (3, 2)*
- Reach alternatives (applications)
  1. **100m (data center)**
  2. **10km (metro)**
  3. **40km (extended metro)**
- Channel technology alternatives (implementation)
  1. **Wavelength multiplexing (CWDM, DWDM)**
  2. *Quadrature multiplexing (DQPSK)*
  3. *Multiple fibers (parallel optics)*

5x21G Transceiver System Architecture 1



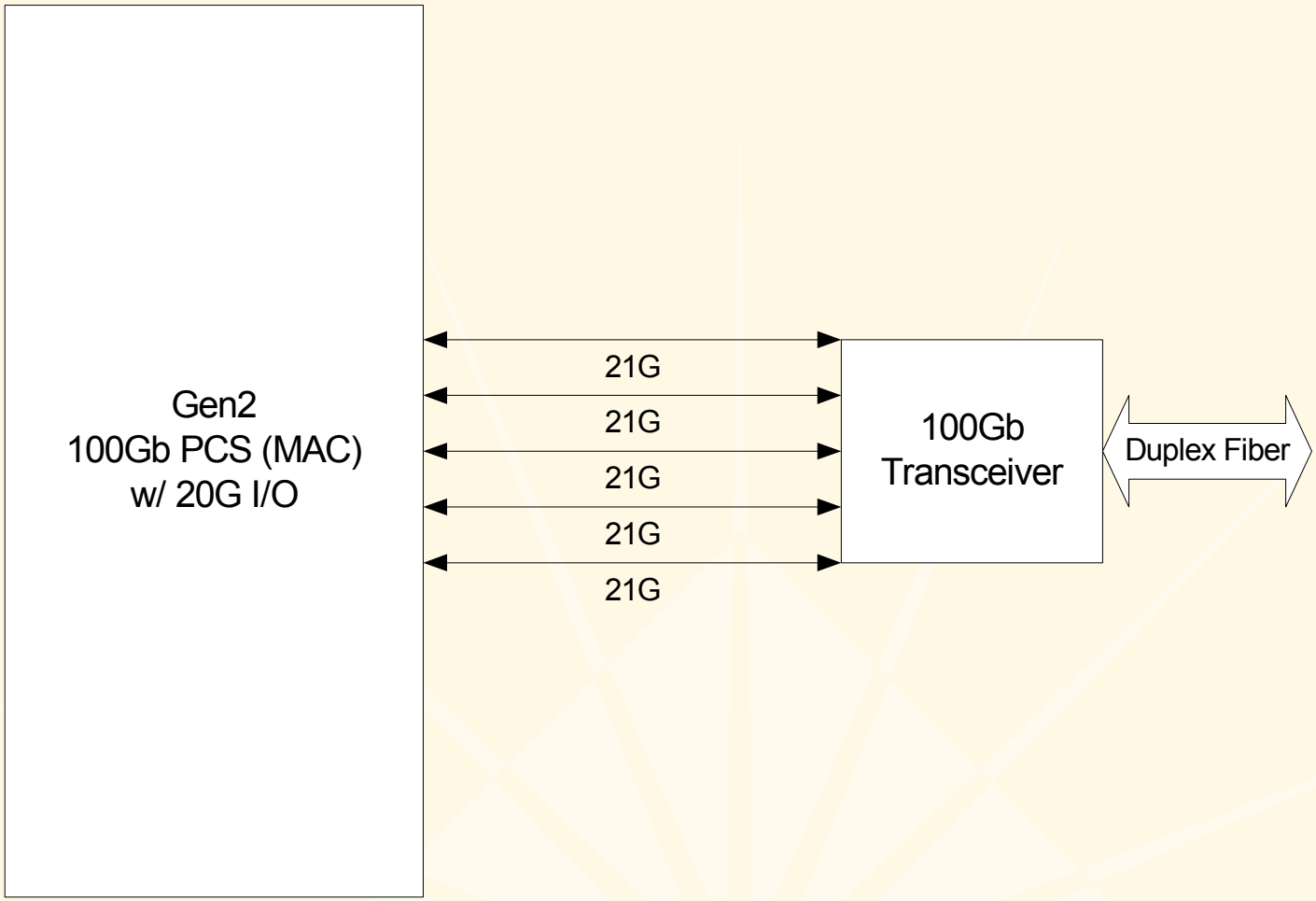
PCS IC performs skew alignment and lane re-ordering.

5x21G Transceiver System Architecture 2



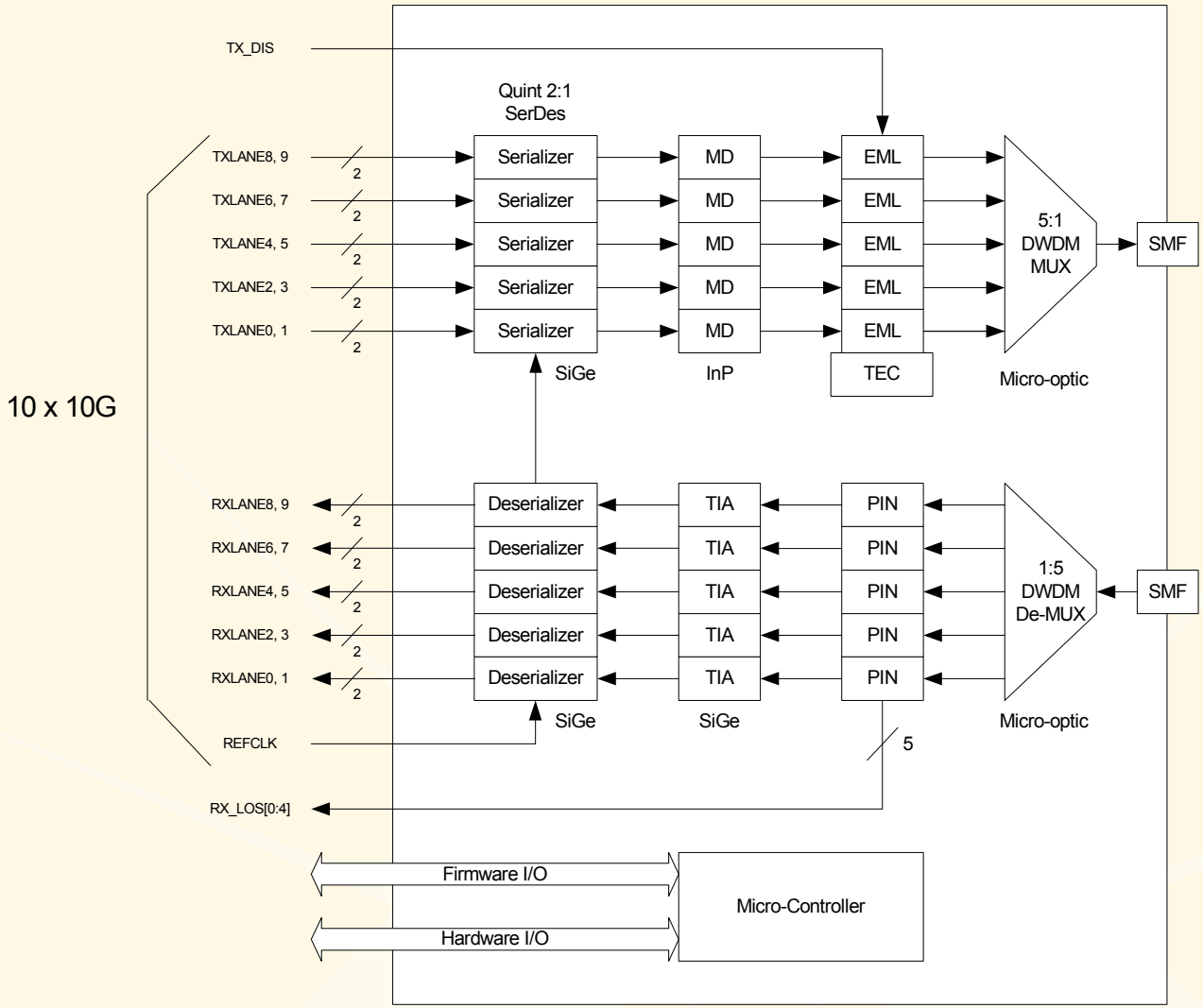
PCS IC performs skew alignment and lane re-ordering.

5x21G Transceiver System Architecture 3



PCS IC performs skew alignment.

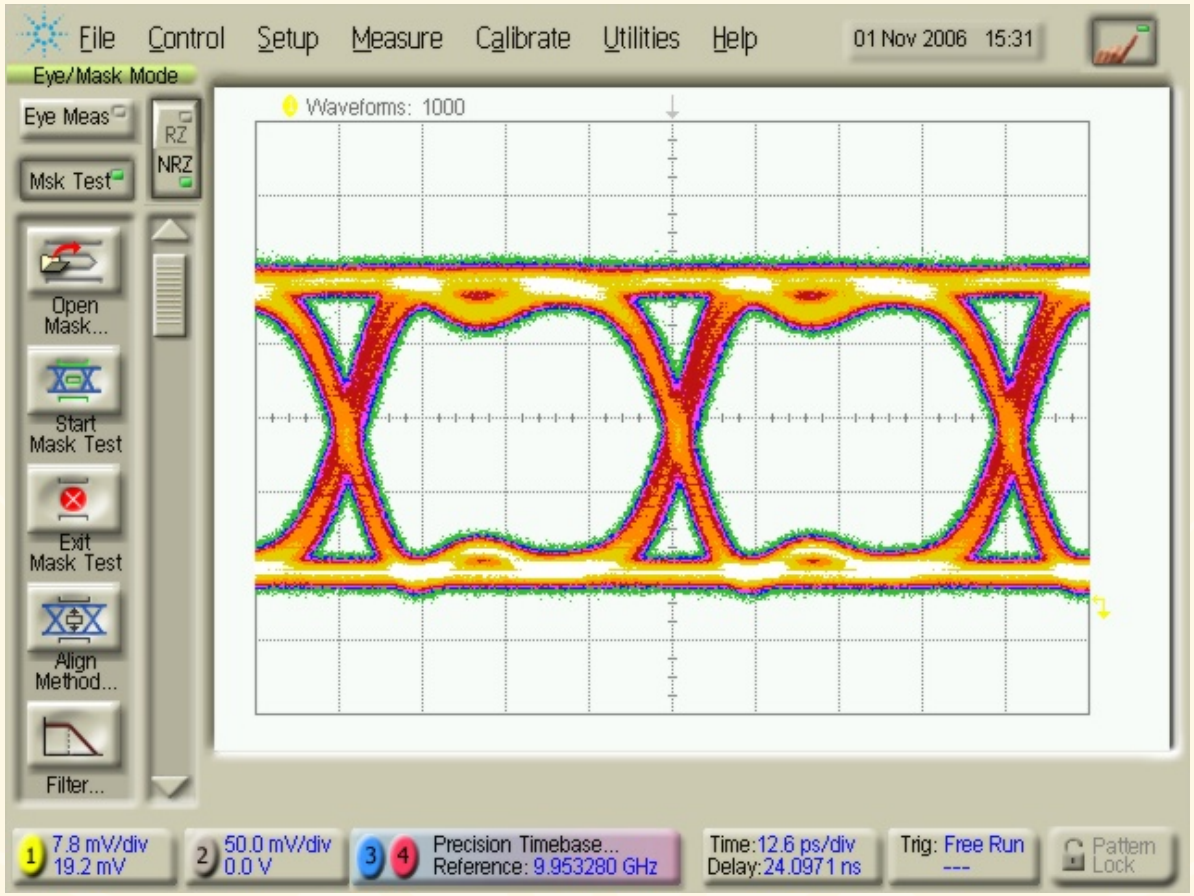
10km 1550nm DWDM 5x21G Transceiver



10km 1550nm 5x21G Transceiver Link vs. 10G Link

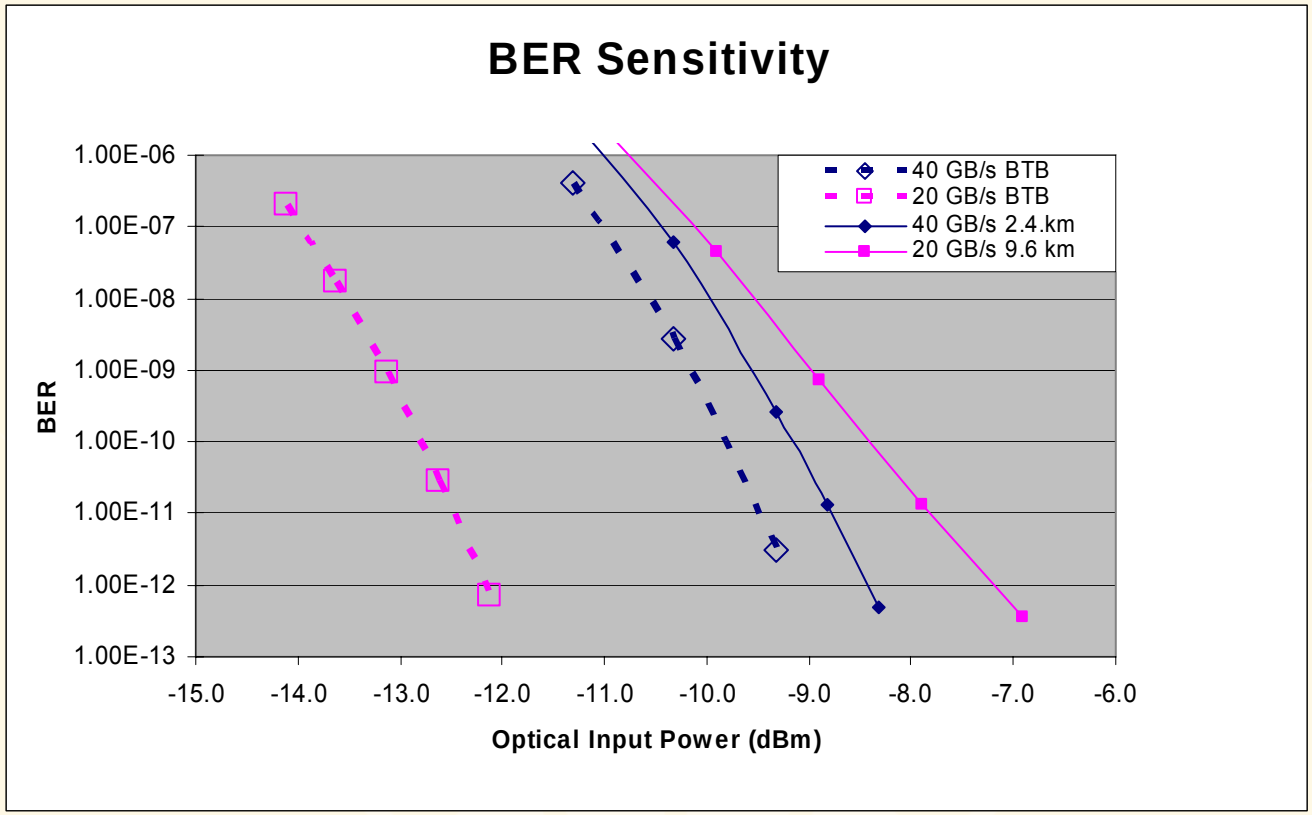
- 10GE-ER 40km TP2 to TP3 Link
  - 1530nm to 1565nm
  - Max dispersion coefficient < 20ps/nm-km
  - Max dispersion < 800ps/nm
  - Max loss coefficient = 0.2dB/km
  - Max loss = 11dB (8dB fiber + 3dB other loss)
- 5x21G DWDM 10km TP2 to TP3 Link
  - 1530.33, 1531.90, 1533.47, 1535.04, 1536.41 nm (200GHz) grid
  - Max dispersion coefficient < 20ps/nm-km
  - Max dispersion = 200ps/nm
  - Max dispersion x 4 = 800ps/nm ("10GE-ER Link equivalent")
  - Max loss coefficient = 0.2dB/km
  - Max loss = 5dB (2dB fiber + 3dB other loss)
  - Max loss + 3dB = 8dB ("10GE-ER Link equivalent")

20G Transmitter Performance



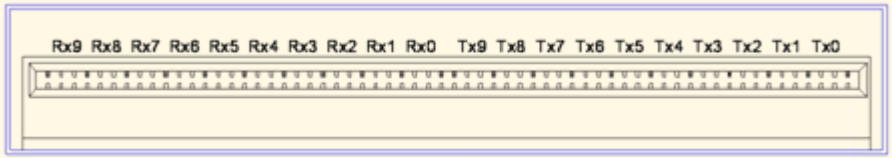
- 40G VSR 1550nm cooled EML TOSA
- 20G PRBS 2^31-1 data.

20G Receiver Performance

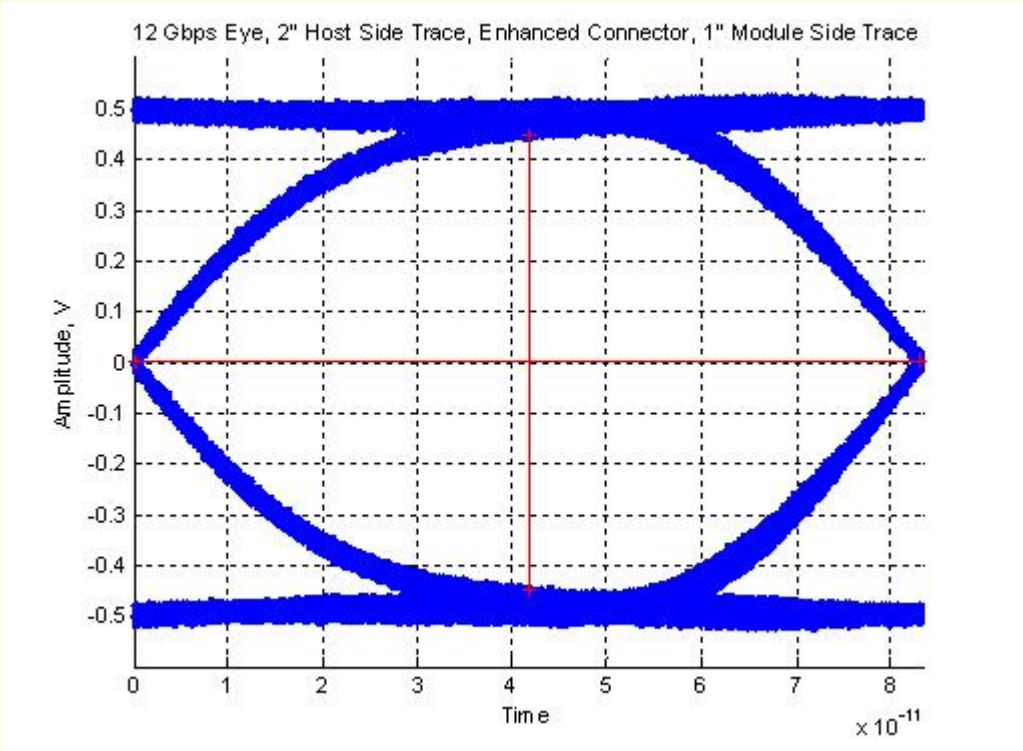


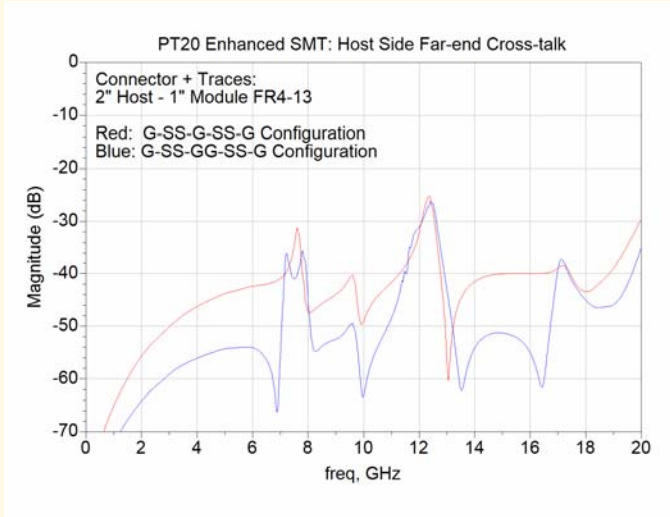
- 40G VSR 1550nm cooled EML TOSA → SMF-28 → 40G PIN ROSA (40°C)
- 40G BER sweep: 40G PRBS 2^31-1 data, 2.4km: 40ps/nm CD
- 20G BER sweep: 20G PRBS 2^31-1 data, 9.6km: 160ps/nm CD
  (Sub-optimal 20G sampling phase adds a 4dB link penalty.)

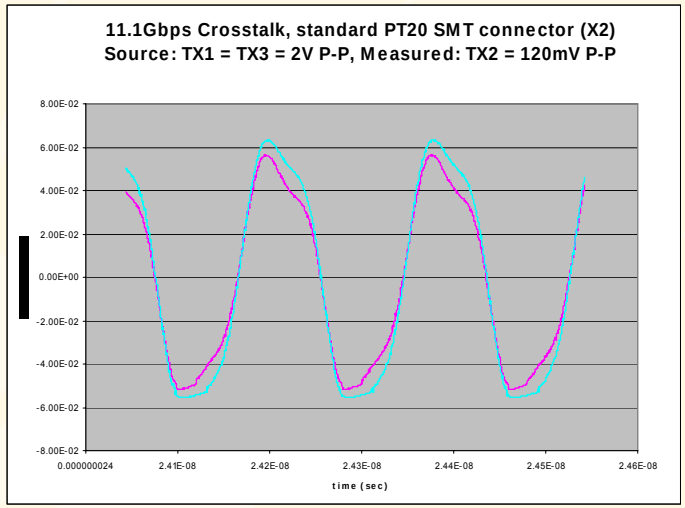
10x12G Gen1 Connector Technology



10x12Gbps, GSSGSSG.... approx 55mm





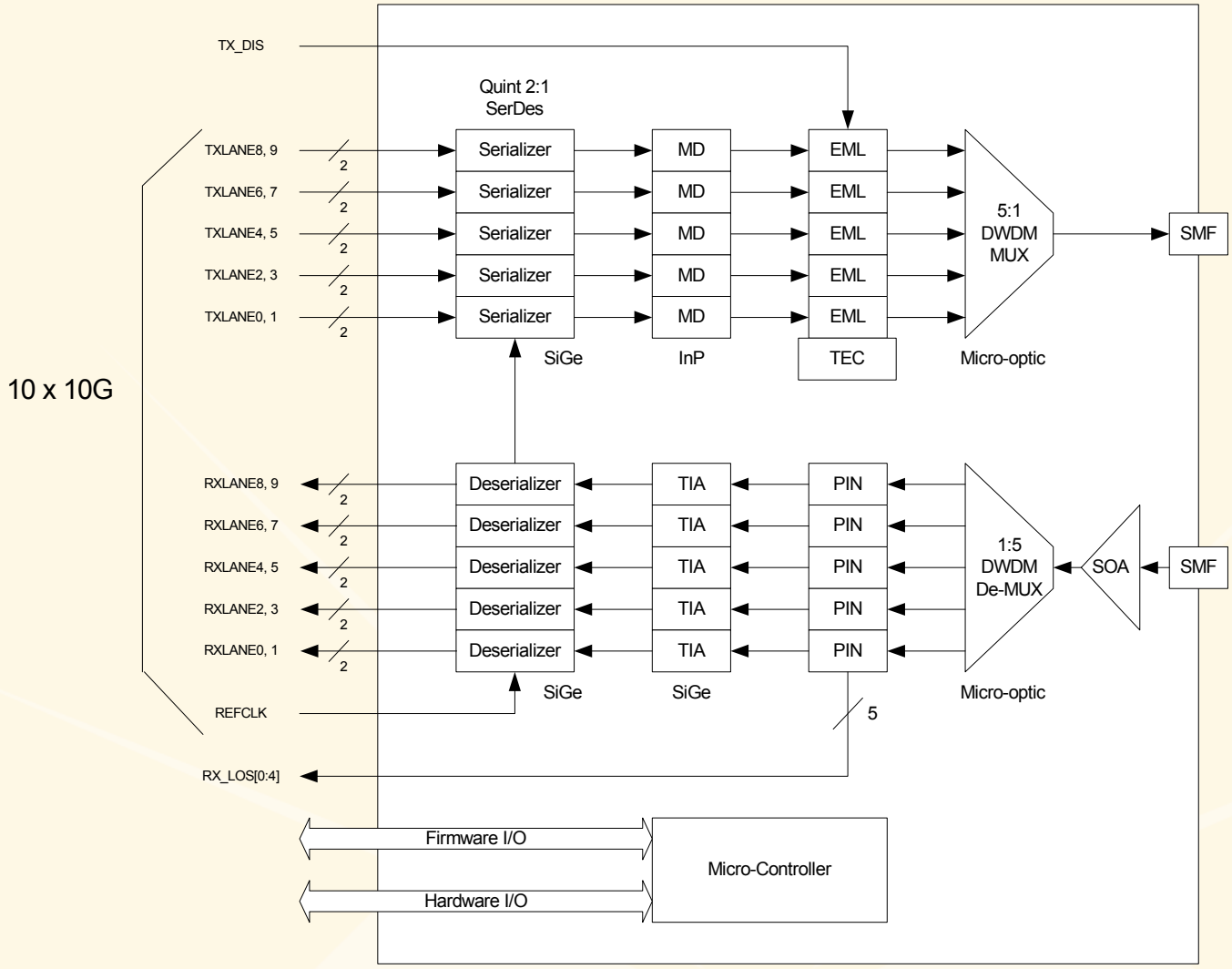


Enhanced PT20 SMT Connector, Michael Fogg, Tyco Electronics

10km 1550nm 5x21G Transceiver Relative Cost

Component	10GE-ER XENPAK	5x21G 10km Transceiver	Comments
SerDes	1x	3x	XAUI (SiGe) vs. Quint 2:1 SerDes (SiGe)
Mod Driver	1x	4x	Single MD (InP) vs. Quint MD (InP)
TOSA	1x	4x	Single EML TOSA vs. Quint EML, DWDM Mux (micro-optic)
ROSA	1x	5x	Single PIN, TIA ROSA vs. DWDM DeMux, Quint PIN, Quint TIA
PCBA & mechanical	1x	2x	FR4 PCBA, XENPAK parts vs. Nelco PCBA, new form factor parts
Test	1x	1x	Single channel testing vs. five channel parallel testing
TOTAL	**1x**	**4x**	**Weighted average of initial products at similar volumes**

40km 1310nm DWDM 5x21G Transceiver



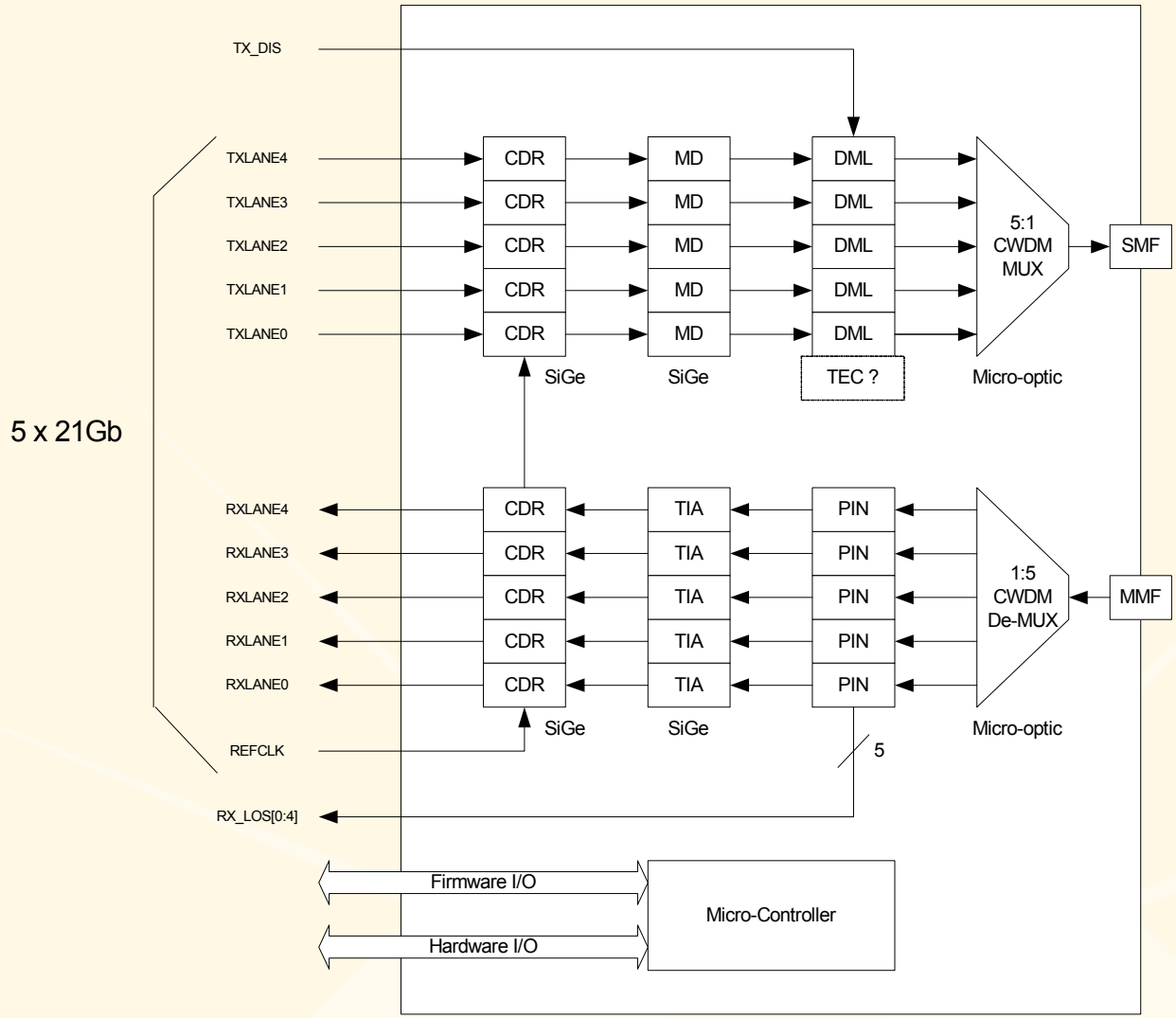
40km 1310nm 5x21G Transceiver Link vs. 10G Link

- 10GE-ER 40km TP2 to TP3 Link
  - 1530nm to 1565 operation
  - Max dispersion coefficient < 20ps/nm-km
  - Max dispersion < 800ps/nm
  - Max loss coefficient = 0.2dB/km
  - Max loss = 11dB (8dB fiber + 3dB other loss)
- 5x21G DWDM 40km TP2 to TP3 Link
  - 1310.28, 1311.43, 1312.58, 1313.73, 1314.89 nm (200GHz grid)
  - Max dispersion coefficient < 2ps/nm-km
  - Max dispersion = 80ps/nm
  - Max dispersion x 4 = 320ps/nm ("10GE-ER Link equivalent")
  - Max loss coefficient = 0.4dB/km
  - Max loss = 19dB (16dB fiber + 3dB other loss)
  - Max loss + 3dB = 22dB ("10GE-ER Link equivalent")
- (Note: 5x21G 10km TP2 to TP3 Link Max loss = 7dB)

40km 1310nm 5x21G Transceiver Relative Cost

Component	10GE-ER XENPAK	5x21G 40km Transceiver	Comments
SerDes	1x	3x	XAUI (SiGe) vs. Quint 2:1 SerDes (SiGe)
Mod Driver	1x	4x	Single MD (InP) vs. Quint MD (InP)
TOSA	1x	5x	Single EML TOSA vs. Quint EML, DWDM Mux (micro-optic)
ROSA	1x	7x	Single PIN, TIA ROSA vs. DWDM DeMux, Quint PIN, Quint TIA, SOA
PCBA & mechanical	1x	2x	FR4 PCBA, XENPAK parts vs. Nelco PCBA, new form factor parts
Test	1x	1x	Single channel testing vs. five channel parallel testing
TOTAL	**1x**	**5x**	**Weighted average of initial products at similar volumes**

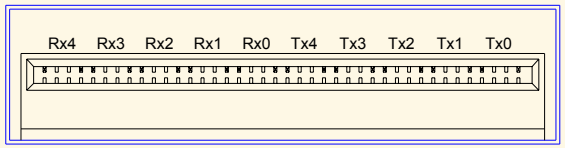
2km 1310nm CWDM 5x21G Transceiver



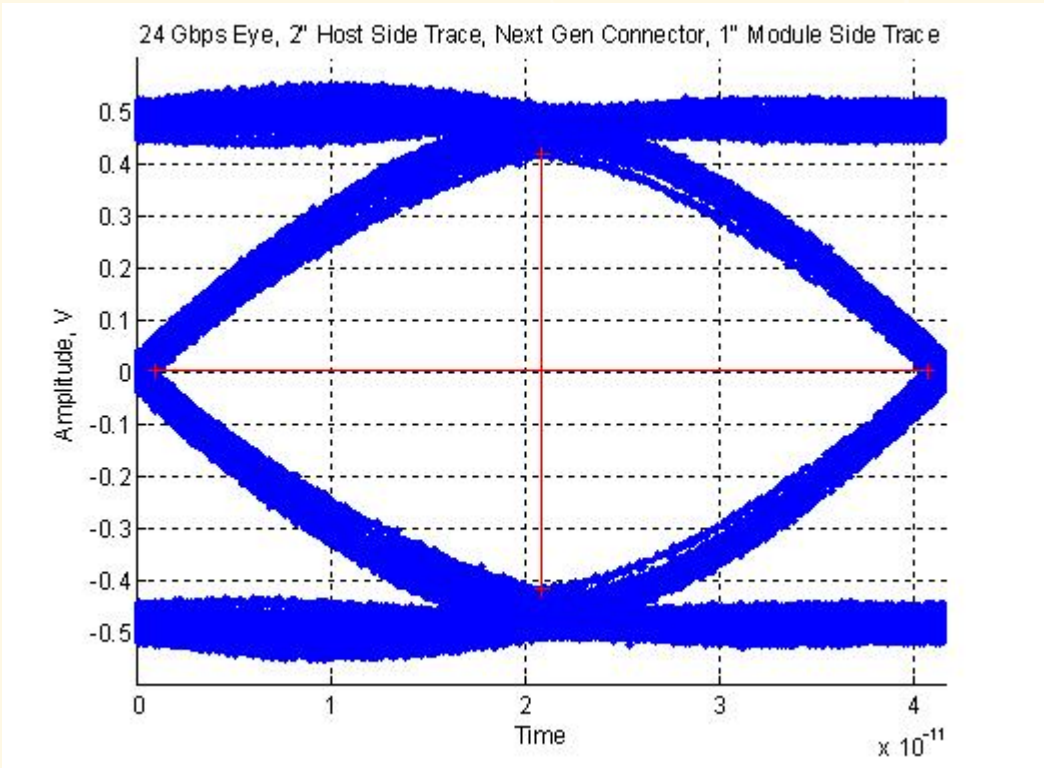
2km 1310nm 5x21G Transceiver Link vs. 10G Link

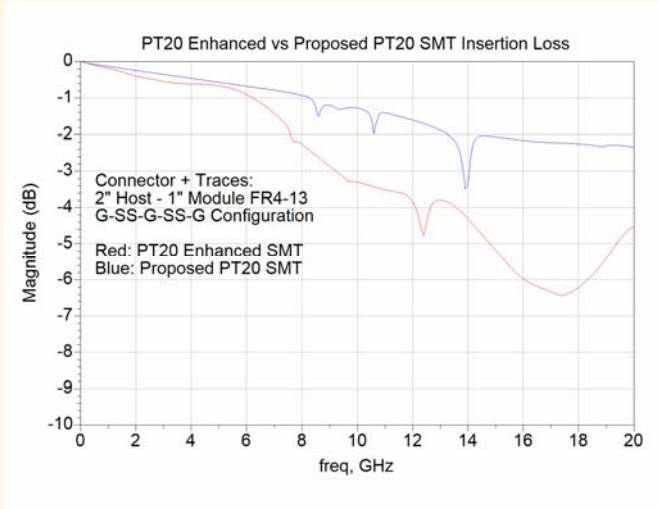
- 10GE-LR 10km TP2 to TP3 Link
  - 1260nm to 1355nm operation
  - Max dispersion coefficient < 7ps/nm-km
  - Max dispersion < 70ps/nm
  - Max loss coefficient = 0.4dB/km
  - Max loss = 6dB (4dB fiber + 2dB other loss)
- 5x21G CWDM 2km TP2 to TP3 Link
  - 1271, 1291, 1311, 1331, 1351 nm (20nm ITU grid, 13nm width)
  - Max dispersion coefficient < 6ps/nm-km
  - Max dispersion < 12ps/nm
  - Max dispersion x 4 < 48ps/nm ("10GE-LR Link equivalent")
  - Max loss coefficient = 0.4dB/km
  - Max loss = 3dB (1dB fiber + 2dB other loss)
  - Max loss + 3dB = 6dB ("10GE-LR Link equivalent")
- 5x21G CWDM 100m MMF TP2 to TP3 Link
  - OM3 BW = 2000MHz-km ("Probably OK for one 100m")

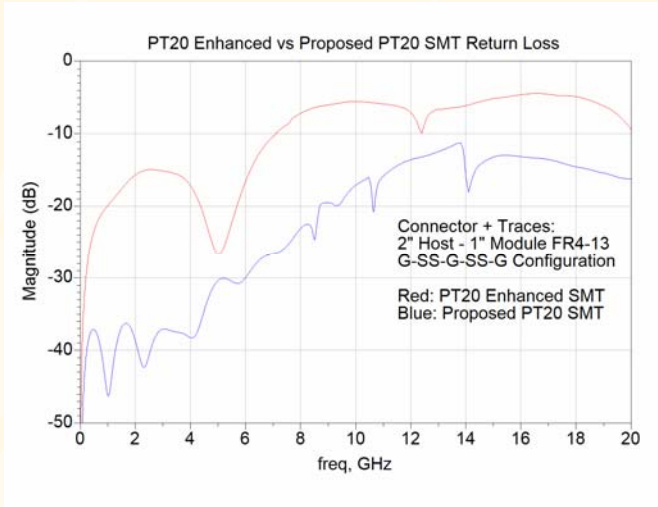
5x24G Gen2 Connector Technology



5x24Gbps, GSSGGSSGG.... approx 37mm







Proposed PT20 SMT Connector, Michael Fogg, Tyco Electronics

2km 1310nm 5x21G Transceiver Relative Cost

Component	10GE-LR XENPAK	5x21G 2km Transceiver	Comments
SerDes	1x	2x	XAUI (SiGe) vs. Quint CDR (SiGe)
Mod Driver	1x	4x	Single MD (SiGe) vs. Quint MD (SiGe)
TOSA	1x	5x	Single DFB TOSA vs. Quint DML, CWDM Mux (micro-optic)
ROSA	1x	6x	Single PIN, TIA ROSA vs. CWDM DeMux, Quint PIN, Quint TIA
PCBA & mechanical	1x	2x	FR4 PCBA, XENPAK parts vs. Nelco PCBA, new form factor parts
Test	1x	1x	Single channel testing vs. five channel parallel testing
TOTAL	**1x**	**5x**	**Weighted average of initial products at similar volumes**

Discussion

- This study focused on 20GBaud based Transceivers to enable detailed comparison to 10GBaud and 40GBaud based alternatives. It is a work in progress and results may change as the study continues.
- Cost
  - Optics drives the cost.
  - Component packaging cost is still variable.
  - Development and capital equipment costs are not factored in.
  - Further integration of electronics and optics will significantly reduce cost.
  - Cost is not price. It would be nice if Transceiver vendors can make money when 100Gb Transceivers are commercialized. ☺
- Transmit optics
  - 21G cooled EML TOSA requires a straightforward development effort.
  - 21G 1550nm and 1310nm cooled EMLs have different trade-offs between dispersion and loss, depending on reach/application. Ideally, the standard will specify one set of wavelengths. For example, 1310nm cooled 21G EML TOSA can be used for both 10km and 40km reach applications.
  - 21G cooled DML requires more development effort then 21G cooled EML.
  - 21G un-cooled DML (lowest cost) will require a larger development effort.

Discussion, cont.

- Receive optics
  - SMF 21G PIN ROSA requires a straightforward development effort.
  - MMF/SMF 21G PIN ROSA will require a larger development effort.
- Mux / DeMux
  - Micro-optic WDM components use existing technology.
- Gray and DWDM standards
  - 10GE-ER (and “10GE-ZR”) Gray optical interfaces can be turned into DWDM optical interfaces through rate adjustment and wavelength control.
  - All proposed 100GE Gray optical interfaces use multi-channel multiplexing (WDM or ribbon fiber,) which makes them incompatible with DWDM.
  - Standards for Gray and DWDM optical interfaces will likely be different.
- Possible 802.3 Higher Speed Ethernet standard set
  - 10x10G 850nm VCSEL array ribbon fiber (100m applications)
  - 5x21G CWDM 1310nm DML array (2km applications)
  - 5x21G DWDM 1310nm EML array (10km and 40km applications)
  - 2x56G DQPSK 1550nm IQ mod (>40km and DWDM applications)